Volume 5

AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS®

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PROCEEDINGS

2004 ANNUAL MEETING

MARCH 10 – 14

SAN FRANCISCO

CALIFORNIA

- Abstracts of Papers
- Abstracts of Posters
- Abstracts of Scientific Exhibits

American Academy of Orthopaedic Surgeons

71st Annual Meeting

PROCEEDINGS

Symposia Handouts

Abstracts of Podium Presentations, Poster Presentations, Scientific Exhibits

2004 ANNUAL MEETING
MARCH 10–14
SAN FRANCISCO, CALIFORNIA

American Acadamy of Orthopaedic Surgeons
6300 North River Road, Rosemont, Illinois 60018-4262
Phone: 847.823.7186 • 800.346.2267
Fax: 847.823.8031 • www.aaos.org

Dear Colleagues:

Welcome to the 71st AAOS Annual Meeting! A valuable tool and wonderful resource for future reference is in these pages. In a collaborative effort, the Central Program Committee and the Exhibits Committee have combined the abstracts from selected scientific portions of the meeting for you.

The Proceedings Book and CD-Rom are sorted by symposia handouts followed by podium and poster abstracts and scientific exhibit abstracts, all sorted by classification.

We have also included:

- a subspecialty guide to the Annual Meeting identifying presentations by classification
- an author index
- a key word index

All in all, this is an excellent review of some of the most exciting topics presented at the 2004 Annual Meeting. We hope that you find this book useful now and in the future.

Sincerely,

Jon J.P. Warner, MD
Chair, Program Committee

Frank A. Pettrone, MD
Chair, Exhibits Committee

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TABLE OF CONTENTS

Subspecialty Guide to the Annual Meeting vi

Introduction 1

Symposia Handouts. 6

Abstracts of Podium Presentations, Poster Presentations, Scientific Exhibits. 369

Author Index. 628

Key Word Index 649

Subspecialty Guide to Annual Meeting

WEDNESDAY, March 10								
	8:00-10:00 AM	**8:00-11:00 AM**	**10:30 AM-12:30 PM**	**1:30-3:30 PM**	**1:30-4:30 PM**	**4:00-6:00 PM**	**6:30-7:30 PM**	**6:30-8:30 PM**
ADULT RECONSTRUCTION HIP AND KNEE								
Instructional Courses	#101-3			#121-3	#185	#162-4		#192-3
Scientific Exhibits 7:00 AM-7:00 PM	SE003-SE023; SE027-SE045							
Scientific Papers			Adult Knee I: Outcomes Papers 1-10, Room 3002, West	Adult Hip I: Complications in THA Papers 31-40, Room 304				
Scientific Posters 7:00 AM-7:00 PM	Hip P001-P091, Knee P092-172							
Up Close and Personal							Choosing the Right Bearing for Each Patient, Room 3024, West	
Symposia	Hip Arthritis in the Young, Active Patient: Surgical Options Room 2005, West		Different Surgical Options for Monocompartmental Osteoarthritis of the Knee Unispacers, High Tibial, Gateway Ballroom AAOS/ORS The Role of Pharmacological Agents in Fracture Healing and Implant Fixation Room 304	Optimizing Outcomes Following Complications of Primary Total Knee Arthroplasty Room 3014, West				
BASIC RESEARCH								
Instructional Courses				#125				
Scientific Exhibits 7:00 AM-7:00 PM	SE047-SE052							
FOOT AND ANKLE								
Instructional Courses	#106			#126	#186	#166		#196
Scientific Exhibits 7:00 AM-7:00 PM	SE024							
Scientific Posters 7:00 AM-7:00 PM	P431-P448							
HAND AND WRIST								
Instructional Courses	#107			#127		#167		#197
Scientific Exhibits 7:00 AM-7:00 PM	SE025, SE026							
Scientific Papers				Hand and Wrist I Papers 41-50 Room 250				
Scientific Posters 7:00 AM-7:00 PM	P449-P466							
NONCLINICAL/PRACTICE MANAGEMENT								
Instructional Courses	#108	#183		#128, 133		#168, 175		
Scientific Exhibits 7:00 AM-7:00 PM	SE064, SE065							
Scientific Posters 7:00 AM-7:00 PM	P356-P368							
PEDIATRICS								
Instructional Courses	#112-3	#181		#132		#172		#195
Scientific Exhibits 7:00 AM-7:00 PM	SE066, SE067							
Scientific Papers			Pediatrics I: Lower Extremity Trauma Papers 21-30, Room 250					
Scientific Posters 7:00 AM-7:00 PM	P369-P378							
Symposia				Management of Pediatric Fractures in the Lower Extremity: An International Perspective, Room 3002, West				

REHABILITATION MEDICINE								
Scientific Posters 7:00 AM-7:00 PM	P195-P198							
SHOULDER AND ELBOW								
Instructional Courses	#109	#182		#129		#169		#191
Scientific Exhibits 7:00 AM-7:00 PM	SE053, SE054							
Scientific Posters 7:00 AM-7:00 PM	P252-P303							
Up Close and Personal							The Complex Shoulder, Room 2024	
Symposia			Difficult Elbow Fractures: Pearls and Pitfalls, Room 2005, West	Principles and Procedures for Glenohumeral Instability – An International Perspective Room 2005, West				
SPINE								
Instructional Courses	#110, 115			#130, 135		#170		
Scientific Exhibits 7:00 AM-7:00 PM	SE060, SE061							
Scientific Posters 7:00 AM-7:00 PM	P379-P430							
Up Close and Personal							Cerviral and Lumbar Degenerative Operative Spine Problem Room 3005, West	
Symposia	Innovative Intervention for the Thoracic and Lumbar Spine, Gateway Ballroom							
SPORTS MEDICINE/ARTHROSCOPY								
Instructional Courses	#111			#131	#184	#171		#198
Scientific Exhibits 7:00 AM-7:00 PM	SE068							
Scientific Papers			Sports Medicine/Arthroscopy I Papers 11-20, Room 3014, West					
Scientific Posters 7:00 AM-7:00 PM	P304-P355							
TRAUMA								
Instructional Courses	#104, 114			#124, 134		#161, 173, 174		#194
Scientific Exhibits 7:00 AM-7:00 PM	SE055-SE058							
Scientific Posters 7:00 AM-7:00 PM	P199-P251							
Up Close and Personal							Plates or Nails for Proximal and Distal Tibial Fractures, Room 3000, West	
Symposia	AAOS/ORS Tendon Repair and Regeneration: Challenges and Opportunities for Engineered Tissue Constructs, Room 304							
TUMOR/METABOLIC DISEASE								
Instructional Courses	#105					#165		
Scientific Exhibits 7:00 AM-7:00 PM	SE062, SE063							
Scientific Posters 7:00 AM-7:00 PM	P173-P193							

AAOS sessions will be held at The Moscone Center and the Argent Hotel.

All Scientific Exhibits and Poster Presentations will be held at The Moscone Center, Level I, West.

Subspecialty Guide to Annual Meeting

THURSDAY, March 11						
	8:00-10:00 AM	**8:00-11:00 AM**	**10:30 AM-12:30 PM**	**1:00-3:00 PM**	**1:30-4:30 PM**	**3:30-5:30 PM**
ADULT RECONSTRUCTION HIP AND KNEE						
Instructional Courses	#201-3	#282		#221-4	#284-5	#261-3
Scientific Exhibits 7:00 AM-5:30 PM	SE003-SE023; SE027-SE045					
Scientific Papers	Adult Knee II: Unicompartmental Disease Papers 51-60 Room 304		Adult Hip II: The Bearing Surface Papers 91-100, Room 304			
Scientific Posters 7:00 AM-5:30 PM	Hip P001-P091, Knee P092-172					
Symposia	Hot Topics and Controversies in Primary Total Hip Arthroplasty Room 2005, West			Techniques in Revision Total Hip Arthroplasty: Video Techniques Showing How to Do It Safely, Effectively, and Efficiently, Gateway Ballroom		
BASIC RESEARCH						
Instructional Courses				#225		
Scientific Exhibits 7:00 AM-5:30 PM	SE047-SE052					
FOOT AND ANKLE						
Instructional Courses	#206			#226		#266
Scientific Exhibits 7:00 AM-5:30 PM	SE024					
Scientific Papers			Foot and Ankle I Papers 111-120, Room 250			
Scientific Posters 7:00 AM-5:30 PM	P431-P448					
Symposia	Updates on Tendon Injuries of the Foot and Ankle, Gateway Ballroom					
HAND AND WRIST						
Instructional Courses	#207			#227, 233		#267, 273
Scientific Exhibits 7:00 AM-5:30 PM	SE025, SE026					
Scientific Posters 7:00 AM-5:30 PM	P449-P466					
Symposia						Current Concepts in the Management of Distal Radius Fractures, Room 304
NONCLINICAL/PRACTICE MANAGEMENT						
Instructional Courses	#208, 214, 298-9	#281		#228		#268, 275
Scientific Exhibits 7:00 AM-5:30 PM	SE064, SE065					
Scientific Papers						Practice Management/ Rehabilitation I Papers 151-160, Room 250
Scientific Posters 7:00 AM-5:30 PM	P356-P368					
Symposia				Surgical Techniques and Management during Operation Iraqi Freedom, Room 304		
PEDIATRICS						
Instructional Courses	#212-3			#232		#272, 274
Scientific Exhibits 7:00 AM-5:30 PM	SE066, SE067					
Scientific Papers				Pediatrics II Papers 131-140, Room 250		
Scientific Posters 7:00 AM-5:30 PM	P369-P378					
Symposia			Upper Extremity Pediatric Fractures: Operative Techniques - Avoiding Problems with Problem Fractures, Room 2005, West			

REHABILITATION MEDICINE						
Scientific Papers						Practice Management/ Rehabilitation I Papers 151-160, Room 250-262
Scientific Posters 7:00 AM-5:30 PM	P195-P198					
SHOULDER AND ELBOW						
Instructional Courses	#209, 215			#229		#269, 276
Scientific Exhibits 7:00 AM-5:30 PM	SE053, SE054					
Scientific Papers	Shoulder and Elbow I Papers 71-80, Room 3014, West					Shoulder and Elbow II Papers 141-150, Room 3002, West
Scientific Posters 7:00 AM-5:30 PM	P252-P303					
Symposia				Management of Rotator Cuff Disease: Science, Technique, and Technology, Room 2005, West		
SPINE						
Instructional Courses	#210	#283		#230, 236		#270
Scientific Exhibits 7:00 AM-5:30 PM	SE060, SE061					
Scientific Papers				Spine 1 Papers 121-130, Room 3014, West		
Scientific Posters 7:00 AM-5:30 PM	P379-P430					
Symposia						Modern Techniques in the Surgical Management of Cervical Spine Disorders, Room 3014, West
SPORTS MEDICINE/ARTHROSCOPY						
Instructional Courses	#211			#231		#271
Scientific Exhibits 7:00 AM-5:30 PM	SE068					
Scientific Papers			Sports Medicine/Arthroscopy II Papers 101-110, Room 3014, West			
Scientific Posters 7:00 AM-5:30 PM	P304-P355					
Symposia				Cell-Based Therapies in Bone and Cartilage Repair - Current Strategies for Clinical Practice, Room 3002, West		Can Knee Arthrosis be Prevented Following Sports Injury? Gateway Ballroom
TRAUMA						
Instructional Courses	#204			#234-5		#264
Scientific Exhibits 7:00 AM-5:30 PM	SE055-SE058					
Scientific Papers	Trauma I: Tibia Papers 61-70 Room 3002, West					
Scientific Posters 7:00 AM-5:30 PM	P199-P251					
Symposia						Limited Exposure Fracture Plating Techniques -- The Current Topic of Greatest Interest in Orthopaedic Trauma, Room 2005, West
TUMOR/METABOLIC DISEASE						
Instructional Courses	#205					#265
Scientific Exhibits 7:00 AM-5:30 PM	SE062, SE063					
Scientific Papers	Tumor I Papers 81-90, Room 250					
Scientific Posters 7:00 AM-5:30 PM	P173-P193					
Symposia			Commonly Used Enhancers of Bone Healing -- Do We Really Have Evidence of Efficacy: Live Mini-Debates, Room 3002, West			

Subspecialty Guide to Annual Meeting

FRIDAY, March 12					
	8:00-10:00 AM	**10:30 AM-12:30 PM**	**1:00-3:00 PM**	**1:30-4:30 PM**	**3:30-5:30 PM**
ADULT RECONSTRUCTION HIP AND KNEE					
Instructional Courses		#301-4	#321-3	#382	#361-4, 376
Scientific Exhibits 7:00 AM-5:30 PM	SE003-SE023; SE027-SE045				
Scientific Papers		Adult Knee III: Failure and Revision TKR Papers 171-180, Room 3002, West	Adult Hip III Papers 201-210 Room 3002, West		Adult Hip IV: Acetabular Revision Papers 241-250, Room 3002, West
Scientific Posters 7:00 AM-5:30 PM	Hip P001-P091, Knee P092-172				
Symposia			Controversial Issues and Hot Topics in Primary Total Knee Replacement, Room 2005, West		
BASIC RESEARCH					
Instructional Courses			#325		
Scientific Exhibits 7:00 AM-5:30 PM	SE047-SE052				
FOOT AND ANKLE					
Instructional Courses		#306	#326		
Scientific Exhibits 7:00 AM-5:30 PM	SE024				
Scientific Posters 7:00 AM-5:30 PM	P431-P448				
HAND AND WRIST					
Instructional Courses		#307	#327		#367, 373
Scientific Exhibits 7:00 AM-5:30 PM	SE025, SE026				
Scientific Posters 7:00 AM-5:30 PM	P449-P466				
NONCLINICAL/PRACTICE MANAGEMENT					
Instructional Courses		#398-9	#328, 333		#368
Scientific Exhibits 7:00 AM-5:30 PM	SE064, SE065				
Scientific Posters 7:00 AM-5:30 PM	P356-P368				
Symposia		Outcomes and Incomes: Clinical Application of Evidence-Based Practice, Room 3014, West	Tort Reform, Gateway Ballroom		
PEDIATRICS					
Instructional Courses		#312-3	#332		#372
Scientific Exhibits 7:00 AM-5:30 PM	SE066, SE067				
Scientific Papers					Pediatrics III Papers 261-270, Room 250
Scientific Posters 7:00 AM-5:30 PM	P369-P378				
Symposia					Current Concepts in the Treatment of Pediatric Foot Disorders, Gateway Ballroom
REHABILITATION MEDICINE					
Scientific Posters 7:00 AM-5:30 PM	P195-P198				

SHOULDER AND ELBOW					
Instructional Courses		#309, 316, 318	#329, 334, 336		#366, 369, 375
Scientific Exhibits 7:00 AM-5:30 PM	SE053, SE054				
Scientific Papers			Shoulder and Elbow III: Rotator Cuff Papers 211-220, Room 3014, West		
Scientific Posters 7:00 AM-5:30 PM	P252-P303				
SPINE					
Instructional Courses		#310, 315	#330		#370
Scientific Exhibits 7:00 AM-5:30 PM	SE060, SE061				
Scientific Papers		Spine II Papers 181-190 Room 250			Spine III Papers 251-260 Room 3014, West
Scientific Posters 7:00 AM-5:30 PM	P379-P430				
SPORTS MEDICINE/ARTHROSCOPY					
Instructional Courses		#311, 317	#331	#381	#371
Scientific Exhibits 7:00 AM-5:30 PM	SE068				
Scientific Papers					Sports Medicine/ Arthroscopy III Papers 231-240, Room 304
Scientific Posters 7:00 AM-5:30 PM	P304-P355				
TRAUMA					
Instructional Courses		#305, 308, 314	#324		#374
Scientific Exhibits 7:00 AM-5:30 PM	SE055-SE058				
Scientific Papers		Trauma II Papers 161-170 Room 304	Trauma III Papers 191-200 Room 304		
Scientific Posters 7:00 AM-5:30 PM	P199-P251				
Symposia					Controversies in Upper Extremity Operative Fracture Management – Debatable Topics Room 2005, West
TUMOR/METABOLIC DISEASE					
Instructional Courses			#335		#365
Scientific Exhibits 7:00 AM-5:30 PM	SE062, SE063				
Scientific Papers			Tumor II Papers 221-230 Room 250		
Scientific Posters 7:00 AM-5:30 PM	P173-P193				
Symposia		Oncologic Pitfalls and Solutions for the General Orthopaedist Room 2005, West			

Subspecialty Guide to Annual Meeting

SATURDAY, March 13		
	8:00-10:00 AM	**8:00 AM - 5:00 PM**
ADULT RECONSTRUCTION HIP AND KNEE		
		Hip Society, TMC, Gateway Ballroom 104 Knee Society, TMC, Gateway Ballroom 103 Limb Lengthening and Reconstruction Society TMC, Room 307
Scientific Exhibits 7:00 AM-5:30 PM	SE003-SE023; SE027-SE045	
Scientific Posters 7:00 AM-5:30 PM	Hip P001-P091, Knee P092-P172	
BASIC RESEARCH		
Scientific Exhibits 7:00 AM-5:30 PM	SE047-SE052	
FOOT AND ANKLE		
		American Orthopaedic Foot and Ankle Society TMC, Room 304, 306, 308
Scientific Exhibits 7:00 AM-5:30 PM	SE024	
Scientific Posters 7:00 AM-5:30 PM	P431-P448	
HAND AND WRIST		
		American Society for Surgery of the Hand TMC, 3002, 3004, 3006, 3008, West
Scientific Exhibits 7:00 AM-5:30 PM	SE025, SE026	
Scientific Posters 7:00 AM-5:30 PM	P449-P466	
NONCLINICAL/PRACTICE MANAGEMENT		
Scientific Exhibits 7:00 AM-5:30 PM	SE064, SE065	
Scientific Posters 7:00 AM-5:30 PM	P356-P368	
PEDIATRICS		
		Pediatric Society of North America TMC, Room 3001, 3003, West
Scientific Exhibits 7:00 AM-5:30 PM	SE066, SE067	
Scientific Posters 7:00 AM-5:30 PM	P369-P378	
REHABILITATION MEDICINE		
		Orthopaedic Rehabilitation Association, TMC, Room 3010, 3012
Scientific Posters 7:00 AM-5:30 PM	P195-P198	

SHOULDER AND ELBOW		
		American Shoulder and Elbow Society TMC, Room 2005, 2007, 2009, 2011, West
Scientific Exhibits 7:00 AM-5:30 PM	SE053, SE054	
Scientific Posters 7:00 AM-5:30 PM	P252-P303	
SPINE		
		Federation of Spine Associations TMC, Room 3014, 3016, 3018, West
Scientific Exhibits 7:00 AM-5:30 PM	SE060, SE061	
Scientific Posters 7:00 AM-5:30 PM	P379-P430	
SPORTS MEDICINE/ARTHROSCOPY		
		American Orthopaedic Society for Sports Medicine, San Francisco Hilton, Continental Ballroom 4-9 Arthroscopy Association of North America San Francisco Hilton, Grand Ballroom B
Scientific Exhibits 7:00 AM-5:30 PM	SE068	
Scientific Posters 7:00 AM-5:30 PM	P304-P355	
TRAUMA		
		Orthopaedic Trauma Association TMC, Room 303, 305
Scientific Exhibits 7:00 AM-5:30 PM	SE055-SE058	
Scientific Posters 7:00 AM-5:30 PM	P199-P251	
TUMOR/METABOLIC DISEASE		
		Musculoskeletal Tumor Society TMC, Room 3009, 3011, West
Scientific Exhibits 7:00 AM-5:30 PM	SE062, SE063	
Scientific Posters 7:00 AM-5:30 PM	P173-P193	
TMC – The Moscone Center	Visit the Poster Presentations, TMC, Level I, West	Visit the Scientific Exhibits, TMC, Level I, West

Subspecialty Guide to Annual Meeting

SUNDAY, March 14			
	8:00-10:00 AM	**8:00-11:00 AM**	**10:30 AM-12:30 PM**
ADULT RECONSTRUCTION HIP AND KNEE			
Instructional Courses	#402-3		#421-2
Scientific Exhibits 7:30 AM-12:30 PM	SE003-SE023; SE027-SE045		
Scientific Papers	Adult Hip V Papers 271-280, Room 304 Adult Knee IV Papers 281-290, Room 250		
Scientific Posters 7:30 AM-12:30 PM	Hip P001-P091, Knee P092-P172		
Symposia	Computer Navigation in Adult Reconstructive Surgery: The International Experience Room Gateway 103		Thromboembolism After Total Hip and Knee Arthroplasty: What's Best for My Patient, Room 250-262 Future Directions in THR and TKR – Lessons Learned from Joint Replacement Registries, Room Gateway 103
BASIC RESEARCH			
Scientific Exhibits 7:30 AM-12:30 PM	SE047-SE052		
FOOT AND ANKLE			
Instructional Courses	#406		
Scientific Exhibits 7:30 AM-12:30 PM	SE024		
Scientific Posters 7:30 AM-12:30 PM	P431-P448		
HAND AND WRIST			
Instructional Courses	#407		#427
Scientific Exhibits 7:30 AM-12:30 PM	SE025, SE026		
Scientific Posters 7:30 AM-12:30 PM	P449-P466		
NONCLINICAL/PRACTICE MANAGEMENT			
Instructional Courses	#404		#426
Scientific Exhibits 7:30 AM-12:30 PM	SE064, SE065		
Scientific Posters 7:30 AM-12:30 PM	P356-P368		
PEDIATRICS			
Instructional Courses	#401		
Scientific Exhibits 7:30 AM-12:30 PM	SE066, SE067		
Scientific Posters 7:30 AM-12:30 PM	P369-P378		
REHABILITATION MEDICINE			
Scientific Posters 7:30 AM-12:30 PM	P195-P198		

SHOULDER AND ELBOW			
Instructional Courses	#405		#425
Scientific Exhibits 7:30 AM-12:30 PM	SE053-, SE054		
Scientific Posters 7:30 AM-12:30 PM	P252-P303		
Symposia			Complex and Revision Problems in Shoulder Arthroplasty Gateway Ballroom 104
SPINE			
Instructional Courses			#423
Scientific Exhibits 7:30 AM-12:30 PM	SE060, SE061		
Scientific Posters 7:30 AM-12:30 PM	P379-P430		
SPORTS MEDICINE/ARTHROSCOPY			
Instructional Courses		#481	
Scientific Exhibits 7:30 AM-12:30 PM	SE068		
Scientific Posters 7:30 AM-12:30 PM	P304-P355		
Symposia			The ACL Injury Revisited: Understanding the Injury, Outcomes of Treatment, Issues in Rehabilitation, and Preventative Strategies, Room 304
TRAUMA			
Instructional Courses		#482	#424
Scientific Exhibits 7:30 AM-12:30 PM	SE055-SE058		
Scientific Posters 7:30 AM-12:30 PM	P199-P251		
Symposia	Optimizing Operative Treatment of Intertrochanteric Hip Fractures: How to Maximize Success and Avoid Failure in 2004 Gateway Ballroom 104		
TUMOR/METABOLIC DISEASE			
Scientific Exhibits 7:30 AM-12:30 PM	SE062, SE063		
Scientific Posters 7:30 AM-12:30 PM	P173-P193		

Call for Abstracts

Applications to submit a poster presentation, podium presentation, scientific exhibit or multimedia education presentation are available on-line at

www.aaos.org

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2005 Annual Meeting

February 23 – 27 • Washington, DC

Submission deadline is May 3, 2004

American Academy of Orthopaedic Surgeons®

71st Annual Meeting
March 10-14, 2004
San Francisco, California

American Academy of Orthopaedic Surgeons

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There will not be any on-site delivery of products.

Adult Reconstruction

- ❒ 261 Bone Graft Substitutes: The State of the Art
- ❒ 285 Magnetic Resonance Imaging of the Knee and Shoulder
- ❒ 301 Diagnosis and Management of Acute and Chronic Pain in an Orthopaedic Practice
- ❒ 304 Surgical Navigation in Adult Reconstruction Surgery
- ❒ 321 Soft Tissue Balancing of the Hip - A Concept Which Has Come of Age
- ❒ 364 Infected Total Joint Arthroplasty
- ❒ 376 Less and Minimally Invasive Joint Replacement: Fact and Fiction
- ❒ 382 Common Patellofemoral Problems: What to Do and Why?

Adult Reconstruction Track available on MP3 Disc - $199.00 for complete track

Adult Reconstruction/Hip

- ❒ 6 Hot Topics and Controversies in Primary Total Hip Arthroplasty
- ❒ 9 Techniques in Revision Total Hip Arthroplasty: Video Techniques Showing How to Do It Safely, Effectively, and Efficiently
- ❒ 19 Optimizing Operative Treatment of Intertrochanteric Hip Fractures: How to Maximize Success and Avoid Failure in 2004
- ❒ 102 Periprosthetic Hip and Knee Replacement Fractures
- ❒ 122 Managing Bone Loss in Revision THR
- ❒ 164 Complications in Primary THA: Avoidance and Management
- ❒ 202 Hip Arthroscopy
- ❒ 221 Technology 2004: Alternatives Bearing Surfaces: The Good, the Bad and the Indifferent
- ❒ 262 How to Perform Difficult Primary THR
- ❒ 302 Revision in Total Hip Arthroplasty: Understanding and Management of Osteolysis
- ❒ 322 Achieving Stability and Leg Length Equality in Total Hip Arthroplasty
- ❒ 362 Osteonecrosis of the Hip: Management in the 21st Century
- ❒ 402 Surgical Strategies to Improve Total Hip Arthroplasty for the New Millennium I: Primary Total Hip Arthroplasty
- ❒ 422 Surgical Strategies to Improve Total Hip Arthroplasty for the New Millennium II: Revision Total Hip Arthroplasty

Adult Reconstruction/Hip Track available on MP3 Disc - $199.00 for complete track

Adult Reconstruction/Knee

- ❒ 4 Optimizing Outcomes Following Complications of Primary Total Knee Arthroplasty
- ❒ 15 Controversial Issues and Hot Topics in Primary Total Knee Replacement
- ❒ 20 Future Directions in Total Hip Replacement and Total Knee Replacement -- Lessons Learned from Joint Replacement Registries
- ❒ 103 Prevention and Management of Instability with Primary and Revision Hip and Knee Arthroplasty
- ❒ 185 Revision Total Knee Arthroplasty: Planning, Management and Controversies
- ❒ 203 Complications After Total Knee Arthroplasty: Prevention and Management
- ❒ 223 The Surgical Treatment of Articular Cartilage Defects of the Knee
- ❒ 263 Total Knee Replacement in the Young Patient
- ❒ 284 Primary Total Knee Arthroplasty: Surgical Technique and Principles
- ❒ 403 Surgical Options in the Middle Aged Arthritic Knee

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Basic Research

- ❒ 325 Gene Therapy and Tissue Engineering in Orthopaedic Surgery

Foot and Ankle

- ❒ 10 Updates on Tendon Injuries of the Foot and Ankle
- ❒ 106 Updates in Common Foot and Ankle Problems
- ❒ 206 Techniques for Arthrodesis of the Foot and Ankle
- ❒ 306 The Achilles Tendon: Injury and Repair
- ❒ 326 Sports Injuries of the Foot and Ankle: Surgical Techniques to Speed Return-to-Play
- ❒ 406 Surgical Technique in the Management of the Adult Flatfoot

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Hand and Wrist

- ❒ 12 Current Concepts in the Management of Distal Radius Fractures
- ❒ 107 Update on the Management of Traumatic and Reconstructive Problems of the Scaphoid
- ❒ 167 Intra-Articular Fractures of the Distal Radius and Ulna
- ❒ 207 Athletic Hand Injuries-Diagnosis and Treatment
- ❒ 233 Flexor Tendon Injury and Reconstruction: State of the Art
- ❒ 307 Arthritic Wrist
- ❒ 367 Changing Concepts: Fractures and Ligamentous Injuries About the Wrist-Scaphoid and Distal Radius Fractures, and Carpal Instability
- ❒ 427 Injuries of the Distal Radioulnar Joint

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Pediatrics

- ❒ 3 Management of Pediatric Fractures in the Lower Extremity: An International Perspective
- ❒ 7 Pediatric Upper Extremity Fractures:Operative Techniques - Avoiding Problems with Problem Fractures
- ❒ 16 Current Concepts in the Treatment of Pediatric Foot Disorders
- ❒ 132 Lower Extremity Fractures in Children- Case Based Discussion
- ❒ 172 The Difficult Pediatric Supracondylar Humerus Fracture: Tips and Tricks to Avoid Complications
- ❒ 181 Staying Out of Trouble With Your Pediatric Patients
- ❒ 212 Pediatric Musculoskeletal Infections: Recent Advancements and Basic Treatment Principles
- ❒ 232 The Operative Management of Pediatric Fractures
- ❒ 332 Pediatric Sports Medicine Operative Challenges and Solutions: A Case Based Approach

Pediatrics Track available on MP3 Disc - $199.00 for complete track

Practice Management

- ❒ 168 Mastering Digital Media for the Orthopaedist in Daily Practice
- ❒ 214 The Uses and Abuses of CAM (Complementary and Alternative Medicine) Therapies in Orthopaedics
- ❒ 228 Orthopaedic Surgery in the Developing World
- ❒ 275 Orthopaedic Information: How to Find It Fast on the Internet
- ❒ 281 The Electronic Medical Office-Optimal Solutions
- ❒ 333 Coding and Documentation: Fraud and Abuse
- ❒ 426 Digital X-Ray for the Orthopaedic Surgeon

Practice Management Track available on MP3 Disc - $199.00 for complete track

Shoulder and Elbow

- ❒ 18 Complex and Revision Problems in Shoulder Arthroplasty
- ❒ 109 Shoulder Arthroplasty: Current Techniques
- ❒ 129 Athletic Injuries of the Elbow
- ❒ 169 Shoulder Impingement Revisted: Advanced Concepts of Pathomechanics and Treatment
- ❒ 182 Arthroscopic Evaluation and Treatment of Shoulder Instability
- ❒ 191 Examining the Shoulder: What's New, What Works and a Critical Analysis
- ❒ 209 Elbow Arthroscopy: Beginners to Advanced
- ❒ 215 Arthroscopic Acromioplasty Update: Philosophy, Technique, Results, Complications
- ❒ 229 Open and Arthroscopic Instability Repairs
- ❒ 269 Operative Management of Rotator Cuff Tears
- ❒ 309 Decision Making in Contemporary Shoulder Arthroplasty
- ❒ 316 Massive Rotator Cuff Tears-The Surgeons Dilemma
- ❒ 329 Proximal Humeral Fractures I: Alternatives to Arthroplasty
- ❒ 336 Should You Transition to Arthroscopic Repair?: A Comparison of Mini-Open and Arthroscopic Repair Techniques
- ❒ 366 The Unstable Elbow - Anatomy, Biomechanics, and Treatment
- ❒ 369 Proximal Humeral Fractures II: Arthroplasty and Management of Complications
- ❒ 375 Arthroscopic Rotator Cuff Repair: Indication and Technique
- ❒ 425 Arthroscopic Management of the Arthritic Elbow

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Spine

- ❒ 2 Innovative Intervention for the Thoracic and Lumbar Spine
- ❒ 13 Modern Techniques in the Surgical Management of Cervical Spine Disorders**(2 Tapes)**
- ❒ 115 Lumbar Spine: The Herniated Disc
- ❒ 135 Whiplash - The Distinction Between Disc Decay and Traumatic Disc Injury: How to Tell the Difference and the Importance to Treatment and Legal Inquiries
- ❒ 170 Cervical Spine Trauma
- ❒ 210 Cervical Spine: Neck Pain, Radiculopathy and Myelopathy
- ❒ 310 Lumbar Disc Degeneration - Treatment Options
- ❒ 370 Thoracolumbar Fractures

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Sports Medicine/Arthroscopy

- ❒ 11 Can Knee Arthrosis be Prevented Following Sports Injury?
- ❒ 131 Arthroscopic Management of Glenohumeral Instability: Indications and Techniques
- ❒ 171 Arthroscopic Meniscus Repair
- ❒ 231 Arthroscopy of the Ankle and Subtalar Joints
- ❒ 271 Tendinopathy-Assessment, Management and Science for the Orthopaedist
- ❒ 317 Anterior Cruciate Ligament Graft Selection in 2004
- ❒ 381 Anterior Cruciate Ligament Injury: Pathophysiology and Current Therapeutic Principles
- ❒ 481 Articular Cartilage Injury in the Athlete: Treatment Options in 2004

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Trauma

- ❒ 1 Tendon Repair and Regeneration: Challenges and Opportunities for Engineered Tissue Constructs
- ❒ 17 Controversies in Upper Extremity Operative Fracture Management -- Debatable Topics
- ❒ 124 Damage Control Orthopaedics: New Approaches in Orthopaedic Traumatology to the Isolated Extremity Injury and Polytrauma
- ❒ 134 High Energy Proximal Tibia Fractures: Options and Decision Making
- ❒ 174 Minimally Invasive Plate Osteosynthesis of Lower Extremity Fractures
- ❒ 234 Minimally Invasive Traumatology: New Techniques and Technology
- ❒ 264 Surgical Controversies in the Management of Subtrochanteric and Intertrochanteric Fractures of the Femur
- ❒ 308 Pelvis Instructional Course

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- ❒ 265 Osteoporosis: A Case Based Advanced Treatment Update for the Orthopaedic Surgeon

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The members of the Central Program Committee would like to thank the Program Sub-Committee members for all of their hard work in developing the 2004 Scientific Program. Their assistance in grading abstracts has made it possible to present an excellent scientific program.

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SCIENTIFIC PROGRAM

This Proceedings Book is divided into two sections, Symposia handouts and then Podium Presentations, Poster Exhibits, and Scientific Exhibits by classification.

SYMPOSIA PRESENTATION

Thirty-three symposia presentations will take place at the 2004 Annual Meeting. Topics range from Adult Hip Reconstruction to Spine to Practice Management. These symposia were chosen from many excellent applications submitted to the Program Committee.

PODIUM PRESENTATIONS

The Scientific Program features 290 podium presentations. All podium presentations are six minutes followed by an open floor discussion moderated by chosen Academy members. The Scientific Program takes place at The Moscone Center at various times and locations, please see the final program for the schedule.

POSTER EXHIBITS

Four hundred and ninety one Poster Exhibits will be presented during the Annual Meeting. All Poster Exhibits will be displayed the entire five days of the meeting. Included in these are COMSS posters. The COMSS posters will be indicated by their Society's name or the name of their presentation. We hope that you spend time visiting these poster exhibits and discussing the information with the presenters who will be at their display for 12:00 Noon until 1:00 PM Wednesday through Friday.

The Scientific Program Committee is very appreciative of the effort extended by all the presenters and wishes to congratulate them on the high quality of the abstracts that were submitted for evaluation.

Poster awards will be presented on Thursday morning, March 11 beginning at 7:00 AM. Awards will be given to the highest rated poster in each of the 12 classifications and from them one overall winner will be chosen.

Hip	P001 – P091
Knee	P092 – P172
Foot and Ankle	P431 – P448
Hand and Wrist	P449 – P466
Pediatrics	P369 – P378
Practice/Nonclinical	P356 – P368
Rehabilitation	P194 – P198
Shoulder and Elbow	P252 – P303
Spine	P379 – P430
Sports Med/Arthroscopy	P304 – P355
Trauma	P199 – P251
Tumor/Metabolic Disease	P173 – P193
ORS	P467 – P476
Allied Health	P477-P487, P489, P491

SCIENTIFIC EXHIBITS

The authors of the exhibits are requested to be present daily between 10:00 AM and 12:00 noon to discuss their ideas and presentation. The names of the authors presenting the Scientific Exhibits are printed in boldface.

Scientific Exhibits have been grouped in the following categories:

Adult Reconstruction Hip	SE003-SE023
Adult Reconstruction Knee	SE027-SE045
Basic Research	SE047-SE052
Foot/Ankle	SE024
Hand/Wrist	SE025-SE026
Practice Management	SE064-SE065
Shoulder/Elbow	SE053-SE054
Spine	SE060-SE061
Sports Medicine/Arthroscopy	SE068
Trauma	SE055-SE058
Tumor	SE062-SE063
COMSS	SE070-SE080
AAOS Committees	SE081-SE091

POSTER AND SCIENTIFIC EXHIBIT HOURS

Wednesday, March 10	7:00 AM – 7:00 PM
Thursday, March 11 – Saturday, March 13	7:00 AM – 5:30 PM
Sunday, March 14	7:00 AM – 12:30 PM

Poster and Scientific Exhibits are located in The Moscone Center, Level I, West.

ADULT RECONSTRUCTION HIP

B Hip Arthritis in the Young, Active Patient: Surgical Options 6
Robert T. Trousdale, MD, Rochester, MN - Moderator
Lawrence D. Dorr, MD, Inglewood, CA
William J. Hozack, MD, Philadelphia, PA
Joseph C. McCarthy, MD, Boston, MA
Michael A. Mont, MD, Baltimore, MD
Richard F. Santore, MD, San Diego, CA
Thomas P. Schmalzried, MD, Los Angeles, CA

AAOS/ ORS2 The Role of Pharmacological Agents in Fracture Healing and Implant Fixation 25
David B. Burr, PhD, Indianapolis, IN – Co-Moderator
Randy N. Rosier, MD, PhD, Rochester, NY – Co-Moderator
Louis C. Gerstenfeld, PhD, Boston, MA
Kevin Healy, University of California, CA
Joseph M. Lane, MD, New York, NY
Regis J. O'Keefe, MD, Rochester, NY
Rick Sumner, PhD, Oak Park, IL

I Hot Topics and Controversies in Primary Total Hip Arthroplasty 32
Daniel J. Berry, MD, Rochester, MN - Moderator
Lester S. Borden, MD, Cleveland, OH
Miguel E. Cabanela, MD, Rochester, MN
William J. Hozack, MD, Philadelphia, PA
Paul F. Lachiewicz, MD, Chapel Hill, NC
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Thomas P. Schmalzried, MD, Los Angeles, CA
Thomas P. Sculco, MD, New York, NY
Thomas S. Thornhill, MD, Boston, MA

L Techniques in Revision Total Hip Arthroplasty: Video Techniques Showing How to Do It Safely, Effectively, and Efficiently 45
David G. Lewallen, MD, Rochester, MN - Moderator
Daniel J. Berry, MD, Rochester, MN
Miguel E Cabanela, MD, Rochester, MN
John J. Callaghan, MD, Iowa City, IA
Michael J. Christie, MD, Nashville, TN
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Allan E. Gross, MD, Toronto, ON, Canada
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William A. Jiranek, MD, Richmond, VA
William J. Maloney MD, St. Louis, MO
Wayne G. Paprosky, MD, Winfield, IL
Harry E. Rubash, MD, Boston, MA

AA Computer Navigation in Adult Reconstructive Surgery: The International Experience 69
James B. Stiehl, MD, Milwaukee, WI - Moderator
William L. Bargar, MD, Sacramento, CA
Anthony M. DiGioia III, MD, Pittsburgh, PA
Andree Ellerman, MD, Mannheim, Germany
Rolf Georg Haaker, MD, Brakel, Germany
Joachim Hassenpflug, MD, Kiel, Germany
Werner Konermann, MD, Altrip, Germany
Eric Stindel, MD, Brest, France
S. David Stulberg, MD, Chicago, IL

EE Thromboembolism After Total Hip and Knee Arthroplasty: What's Best for My Patient 95
Paul F. Lachiewicz, MD, Chapel Hill, NC - Moderator
Clifford W. Colwell Jr, MD, La Jolla, CA
Richard J. Friedman, MD, Charleston, SC
Jay R. Lieberman, MD, Los Angeles, CA
Eduardo A. Salvati, MD, New York, NY

ADULT RECONSTRUCTION KNEE

C Different Surgical Options for Monocompartmental Osteoarthritis of the Knee — Unispacers, High Tibial Osteotomy vs. Unicondylar Knee Arthroplasty vs. Total Knee Arthroplasty: Indications, Techniques, Results and Controversies 100
Michael A. Mont, MD, Baltimore, MD - Moderator
Peter M. Bonutti, MD, Effingham, IL
Marc W. Hungerford, MD, Baltimore, MD
Dror Paley, MD, Baltimore, MD
Peter F. Sharkey, MD, Philadelphia, PA
Steven A. Stuchin, MD, New York, NY
Alfred J. Tria Jr., MD, Princeton, NJ

G Optimizing Outcomes Following Complications of Primary Total Knee Arthroplasty 108
Arlen D. Hanssen, MD, Rochester, MN - Moderator
John J. Callaghan, MD, Iowa City, IA
Douglas A. Dennis, MD, Denver, CO
Paul A. Lotke, MD, Philadelphia, PA
Mark W. Pagnano, MD, Rochester, MN

W Controversial Issues and Hot Topics in Primary Total Knee Replacement 115
William J. Maloney MD, St. Louis, MO - Moderator
Daniel J. Berry, MD, Rochester, MN
J. David Blaha, MD, Ann Arbor, MI
Robert Emrey Booth Jr, MD, Philadelphia, PA
John J. Callaghan, MD, Iowa City, IA
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Paul F. Lachiewicz, MD, Chapel Hill, NC
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Luke M. Vaughan, MD, Del Mar, CA
Leo A. Whiteside, MD, St. Louis, MO

DD Future Directions in Total Hip Replacement and Total Knee Replacement — Lessons Learned from Joint Replacement Registries 132
Robert B. Bourne, MD, London, ON Canada
Jeffrey N. Katz, MD, Boston, MA
Henrik Malchau, MD, Göteborg. Sweden
William J. Maloney MD, St. Louis, MO
Otto Robertsson, MD, Lund, Sweden

FOOT AND ANKLE

H Updates on Tendon Injuries of the Foot and Ankle 139
Glenn B. Pfeffer, MD, San Francisco, CA – Moderator
Stephen F. Conti, MD, Pittsburgh, PA
Jeffrey E. Johnson, MD, St. Louis, MO
James A. Nunley II, MD, Durham, NC
Lew C. Schon, MD, Baltimore, MD

HAND AND WRIST

Q Current Concepts in the Management of Distal Radius Fractures 158
David S. Ruch, MD, Winston-Salem, NC - Moderator
Mark S. Cohen, MD, Chicago, IL
William B. Geissler, MD, Jackson, MS
Jesse B. Jupiter, MD, Weston, MA
Andrew J. Weiland, MD, New York, NY
Scott W. Wolfe, MD, New York, NY

SYMPOSIA

PEDIATRICS

F Management of Pediatric Fractures in the Lower Extremity: An International Perspective 166
Kamal N. Ibrahim, MD, Oakbrook Terrace, IL - Moderator
Michael Bell, MD, Sheffield, United Kingdom
Julio de Pablos F, MD, Pamplona, Spain
Peter Engelhardt, MD, Berlin, Germany
Carol-Claus Hasler, MD, Basel, Switzerland
Klaus Parsch, MD, Stuttgart, Germany
Bertil Romanus, MD, Goeteborg, Sweden

J Upper Extremity Pediatric Fractures: Operative Techniques - Avoiding Problems with Problem Fractures 174
James H. Beaty, MD, Memphis, TN - Moderator
R. Jay Cummings Jr., MD, Jacksonville, FL
John M. Flynn, MD, Philadelphia, PA
James R. Kasser, MD, Boston, MA
Charles T. Price, MD, Orlando, FL
Vernon T. Tolo, MD, Los Angeles, CA

X Current Concepts in the Treatment of Pediatric Foot Disorders 185
Norman Y. Otsuka, MD, Los Angeles, CA - Moderator
Henri Bensahel, MD, Saint-Mande, France
Richard E. Bowen, MD, Los Angeles, CA
Robert M. Kay, MD, Los Angeles, CA
Wallace B. Lehman, MD, New York, NY
James G. Wright, MD, Toronto, ON, Canada

PRACTICE MANAGEMENT / NONCLINICAL

M Military Orthopaedics in Support of Operation Iraqi Freedom and Operation Enduring Freedom 196
Mark R. Bagg, MD, Ft. Sam Houston, TX - Moderator
Edward D. Arrington, MD, University Place, WA
David B. Carmack, MD, Baltimore, MD
William C. Doukas, MD, Bethesda, MD
Robert R. Granville, MD, San Antonio, TX
Richard B. Islinger, MD, Silver Spring, MD
Michael J. Phipps, MD, Bethesda, MD
Richard Pope, MD, Adelaide, Australia
Clark P. Searle, MD, Clarksville, TN
Joachim Tenuta, MD, New York, NY

U Outcomes and Incomes: Clinical Application of Evidence-Based Practice 200
Michael J. Goldberg, MD, Boston, MA - Moderator
William A. Abdu, MD, Lebanon, NH
Robert B. Bourne, MD, London, ON, Canada
Michael P. Dohm, MD, Grand Junction, CO
Khaled J. Saleh, MD, Minneapolis, MN
James G. Wright, MD, Toronto, ON, Canada

V Tort Reform 207
Stuart L. Weinstein, MD, Iowa City, IA - Moderator
Donald J. Palmisano, MD, JD, Chicago, IL
Victor E. Schwartz, Washington DC
David D. Teuscher, MD, Beaumont, TX

SHOULDER AND ELBOW

D Difficult Elbow Fractures: Pearls and Pitfalls 208
Shawn W O'Driscoll, MD, Rochester, MN - Moderator
Mark S Cohen, MD, Chicago, IL
Jesse B Jupiter, MD, Weston, MA
Michael D McKee, MD, Toronto, ON, Canada
David Ring, MD, Boston, MA

E Principles and Procedures for Anterior Glenohumeral Instability — An International Perspective 218
Frederick A Matsen III, MD, Seattle, WA - Moderator
Christian Gerber, MD, Zürich, Switzerland
Eiji Itoi, MD, Akita, Japan
Gilles Walch, MD, Lyon, France

N Management of Rotator Cuff Disease: Science, Technique, and Technology 228
Jon J. P. Warner, MD, Boston, MA - Moderator
Christian Gerber, MD, Zurich, Switzerland
Ralph Hertel, MD, Bern, Switzerland
Laurent Lafosse, MD, Annecy, France
Daniel Mole, MD, Nancy, France
Gilles Walch, MD, Lyon, France

BB Complex and Revision Problems in Shoulder Arthroplasty 238
David M. Dines, MD, Great Neck, NY - Moderator
Robert H. Cofield, MD, Rochester, MN
Evan L. Flatow, MD, New York, NY
Christian Gerber, MD, Zurich, Switzerland
Joseph P. Iannotti, MD, Cleveland, OH
Jon J. P. Warner, MD, Boston, MA

SPINE

A Innovative Intervention for the Thoracic and Lumbar Spine 251
Frank J. Eismont, MD, Miami, FL – Co-Moderator
Harry N. Herkowitz, MD, Royal Oak, MI – Co-Moderator
Gunnar B. J. Andersson, MD, Chicago, IL
Scott D. Boden, MD, Decatur, GA
Eugene Carragee, MD, Stanford, CA
Edward N. Hanley Jr., MD, Charlotte, NC
Paul C. McAfee, MD, Towson, MD
Peter O. Newton, MD, San Diego, CA
Frank M. Phillips, MD, Chicago, IL
Harry L. Shufflebarger, MD, Miami, FL

S Modern Techniques in the Surgical Management of Cervical Spine Disorders 263
K Daniel Riew, MD, St. Louis, MO - Moderator
Alan S. Hilibrand, MD, Philadelphia, PA
John J. M. Rhee, MD, Decatur, GA
Rick C. Sasso, MD, Indianapolis, IN
Alexander Vaccaro, MD, Philadelphia, PA
Jeffrey C Wang, MD, Los Angeles, CA

SPORTS MEDICINE/ARTHROSCOPY

O Cell-Based Therapies for Bone and Cartilage Repair - Current Strategies for Clinical Practice 275
George F. Muschler, MD, Cleveland, OH - Moderator
Farshid Guilak, PhD, Durham, NC
Randy N. Rosier, MD, Rochester, NY
Sean P. Scully, MD, Rochester, MN
J. Tracy Watson, MD, St. Louis, MO

P Can Knee Arthrosis Be Prevented Following Sports Injury? 282
Scott F. Dye, MD, San Francisco, CA
Steven P. Arnoczky, DVM, East Lansing, MI
Robert J. Johnson, MD, Burlington, VT
Edward M. Wojtys, MD, Ann Arbor, MI

CC The ACL Injury Revisited: Understanding the Injury, Outcomes of Treatment, Issues in Rehabilitation, and Preventative Strategies 290
Annunziato Amendola, MD, Iowa City, IA - Moderator
Elizabeth A. Arendt, MD, Minneapolis, MN
Peter J. Fowler, MD, London, ON, Canada
William A. Grana, MD, Tucson, AZ
Glenn N. Williams, PT ATC, Iowa City, IA

TRAUMA

AAOS/ORS Tendon Repair and Regeneration: Challenges and Opportunities for Engineered Tissue Constructs 299
Joseph P. Iannotti, MD, Cleveland, OH - Moderator
Steve Badylak, MD, Pittsburgh, PA
Albert J. Banes, PhD, Chapel Hill, NC
David L. Butler, PhD, Cincinnati, OH
David Kaplan, PhD, Medford, MA

R Limited Exposure Fracture Plating Techniques — The Current Topic of Greatest Interest in Orthopaedic Trauma 325
Marc F. Swiontkowski, MD, Minneapolis, MN - Moderator
Michael J. Bosse, MD, Charlotte, NC
Peter A. Cole, MD, Saint Paul, MN
Philip J. Kregor, MD, Nashville, TN
Sean E. Nork, MD, Seattle, WA
Emil H. Schemitsch, MD, Toronto, ON, Canada

Y Controversies in Upper Extremity Operative Fracture Management — Debatable Topics 326
Jesse B. Jupiter, MD, Weston, MA - Moderator
Ralph Hertel, MD, Bern, Switzerland
Michael D. McKee, MD, Toronto, ON, Canada
Margaret M. McQueen, MD, Edinburgh, United Kingdom
David Ring, MD, Boston, MA
Norbert Sudkamp, MD, Freiberg, Germany

Z Optimizing Operative Treatment of Intertrochanteric Hip Fractures: How to Maximize Success and Avoid Failure in 2004 336
George J. Haidukewych, MD, Tampa, FL - Moderator
Kenneth J. Koval, MD, Lebanon, NH
Richard F. Kyle, MD, Minneapolis, MN
Rajit Saluja, MD, Greenfield, WI
Roy W. Sanders, MD, Tampa, FL

TUMORS / METABOLIC DISEASE

K Commonly Used Enhancers of Bone Healing — Do We Really Have Evidence of Efficacy: Live Mini-Debates 342
Scott D. Boden, MD, Decatur, GA - Moderator
Joseph Benevenia, MD, Newark, NJ
Thomas A. Einhorn, MD, Boston, MA
Joseph M. Lane, MD, New York, NY
Cato T. Laurencin, MD, PhD, Earlysville, VA
Jay R. Lieberman, MD, Los Angeles, CA
William M. Parrish, MD, Hershey, PA
Randy N. Rosier, MD, PhD, Rochester, NY
Harvinder S. Sandhu, MD, New York, NY
Jeffrey C. Wang, MD, Los Angeles, CA
J. Tracy Watson, MD, St. Louis, MO

T Oncologic Pitfalls and Solutions for the General Orthopaedist 360
Scott D. Weiner, MD, Akron, OH - Moderator
Timothy A. Damron, MD, Syracuse, NY
Patrick J. Getty, MD, Cleveland, OH
Eric Gibbs, Orlando, FL
Terrance D. Peabody, MD, Chicago, IL
Mark T. Scarborough, MD, Gainesville, FL

HIP ARTHRITIS IN THE YOUNG, ACTIVE PATIENT: SURGICAL OPTIONS (B)

Moderator: Robert T. Trousdale, MD, Rochester, MN (n)

Young, active patients develop disabling hip arthritis and require surgical intervention. Their expectations are a return to a normal lifestyle, devoid of restrictions and limitations. What is the best surgical option for these demanding patients? This symposium will explore the surgical options – arthroscopy, debridement, osteotomy, hemiarthroplasty, surface replacement, and THA with three bearing surfaces (ceramic, metal, crosslinked polyethylene).

I. Arthroscopy for Hip Arthritis
Joseph C. McCarthy, MD (a – Arthrex, Innomed)

II. Impingement Surgery for Hip Arthritis
Robert T. Trousdale, MD, Rochester, MN (n)

III. Osteotomy for Hip Arthritis
Richard F. Santore, MD, San Diego, CA (*)

IV. The Role of Hemiresurfacing and Total Resurfacing
Michael A. Mont, MD, Baltimore, MD (a – Wright Medical Technology)

V. THA Using Crosslinked Poly
Thomas P. Schmalzried, MD, Los Angeles, CA (a, c – DePuy, Wright Medical)

VI. THA Using Ceramic Bearings
William J. Hozack, MD, Philadelphia, PA (e – Stryker)

VII. THA Using Metal on Metal Bearings
Lawrence D. Dorr, MD, Ingelwood, CA (c – Zimmer)

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx. If noted, the author indicates something of value received. The codes are identified as: a-research or institutional support; b-miscellaneous funding; c-royalties; d-stock options, e-consultant or employee, n-no conflicts disclosed, and * disclosure not available at the time of printing. For full information, refer to page iv.

HIP ARTHROSCOPY: EVALUATION AND TREATMENT AT DIFFERENT STAGES OF HIP DISEASE

Joseph C. McCarthy, MD

Clinical Presentation
- Mild to moderate joint space narrowing with mechanical symptoms of persistent clicking, catching, locking, or giving way
- Mild ache with strenuous activity but sharp pain with pivoting, twisting or movements that cause mechanical symptoms

Radiologic Evaluation
- Plain radiographs poor diagnostic yield for intra-articular abnormalities (loose bodies, labral tears, chondral defects)
- MRI poor diagnostic yield with intractable hip pain: Contrast agents in CT and MRI increase diagnostic yield of intra-articular hip abnormalities
- Gadolinium enhanced MR arthrography increases sensitivity and specificity in detecting labral tears and loose bodies

Indications for Arthroscopic Intervention in DJD
- Loose Bodies
- Labral Tears
- Chondral Lesions of the Acetabulum or Femoral Head
- Osteonecrosis
- Dysplasia
- Synovial & Crystalline Diseases
- Trauma
- Early stages osteooarthritis
- Intractable Hip Pain

Contraindications

Absolute
- joint conditions amenable to medical management, such as the arthralgias associated with hepatitis or colitis.
- pain referred from other sources such as compression fracture of L1.
- Peri articular conditions such as stress fractures of the femoral neck, insufficiency fractures of the pubis ischium and transient osteoporosis
- Grade III or IV heterotopic bone
- osteonecrosis without mechanical symptoms
- synovitis without mechanical symptoms
- Acute skin lesions or ulceration
- sepsis with accompanying osteomyelitis or abscess formation
- joint ankylosis, dense heterotopic bone formation, or significant protrusio
- advanced osteoarthritis

Relative
- Morbid obesity
- Pyarthrosis
- Moderate Dysplasia
- Chronic pain without mechanical symptoms or MR findings

Complications
- anatomical proximity of vital neurovascular structures
- femoral vascular injury
- femoral or sciatic nerve neuropraxia
- Transient neuropraxia to pudendal or sciatic nerves
- Pressure necrosis of the foot, scrotum, or perineum
- scuffing of the articular surfaces and breakage of arthroscopic instrumentation
- Avoidance of these complications
- surgical expertise with dedicated instruments for use in the hip
- improveed distraction techniques
- close attention is paid to the force and duration of traction
- well padded perineal post
- all arthroscopic instrumentation should be passed through sturdy metallic sheaths
- appropriate portal placement with thorough knowledge of anatomical relationships
- reproducible symptoms and physical findings that are functionally limiting
- failed trial of conservative treatment if negative MR findings

Summary
- Acetabular labral tears do occur
- Most frequently anterior associated with sudden twisting or pivoting motions
- Labral tears contribute or occur in association with articular cartilage lesions
- No radiographic study, including high contrast gadolinium-enhanced arthro – MRI scanning, is entirely sensitive nor specific to diagnose a labral tear
- The watershed lesion – labral tear occurs at the watershed zone may destabilize adjacent acetabular cartilage.
- **Results directly dependent on stage of articular surface involvement**

REFERENCES:

1. Holgersson S, Brattstrom H, Mogensen B, Lidgren L. Arthroscopy of the hip in juvenile chronic arthritis. J Pediatr Orthop 1981; 1:273-8.
2. Dvorak M, Duncan CP, Day B. Arthroscopic anatomy of the hip. Arthroscopy 1990; 6:264-73.
3. Fitzgerald RH, Jr. Acetabular labrum tears. Diagnosis and treatment. Clin Orthop 1995:60-8.
4. Hawkins RB. Arthroscopy of the hip. Clin Orthop 1989:44-7.
5. McCarthy JC, Busconi B. The role of hip arthroscopy in the diagnosis and treatment of hip disease. Orthopedics 1995; 18:753-6.
6. Okada Y, Awaya G, Ikeda T, Tada H, Kamisato S, Futami T. Arthroscopic surgery for synovial chondromatosis of the hip. J Bone Joint Surg [Br] 1989; 71:198-9.
7. Villar R. Arthroscopic debridement of the hip: A minimally invasive approach to osteoarthritis. J Bone Joint Surg (Br) 1991; 73:170-171.
8. McCarthy J, Day B, Busconi B. Hip Arthroscopy: Applications and Technique. J Am Acad Orthop Surg 1995; 3:115-122.
9. McCarthy, J.C. and J.A. Lee, Acetabular dysplasia: a paradigm of arthroscopic examination of chondral injuries. Clin Orthop, 2002(405): p. 122-8.
10. McCarthy, J.C., et al., Acetabular and Labral Pathology, in Early Hip Disorders: Advances in Detection and Minimally Invasive Treatment, J.C. MCCarthy, Editor. 2003, Springer-Verlag: New York. p. 113-134.
11. McCarthy, J.C., et al., The Otto E. Aufranc Award: The role of labral lesions to development of early degenerative hip disease. Clin Orthop, 2001(393): p. 25-37.
12. Epstein HC, Wiss DA, Cozen L. Posterior fracture dislocation of the hip with fractures of the femoral head. Clin Orthop 1985:9-17.
13. Glick JM. Hip arthroscopy using the lateral approach. Instr Course Lect 1988; 37:223-31.
14. Villar RN. Hip arthroscopy. Br J Hosp Med 1992; 47:763-6.
15. Byrd JW, Pappas JN, Pedley MJ. Hip arthroscopy: an anatomic study of portal placement and relationship to the extra-articular structures [see comments]. Arthroscopy 1995; 11:418-23.

IMPINGEMENT SURGERY FOR HIP ARTHRITIS

Robert T. Trousdale, MD

I. Introduction

A. Most hip arthritis is secondary to mechanical abnormalities ranging from instability (DDH) to impingement.

Instability	Normal	Impingement
←		→
DDH	Hip	SCFE Poor head-neck offset Torsional acetabular abnormalities Perthes, Malunions, Coxa profunda, Etc.

B. Concept of impingement recently popularized by the group from Berne. Initially seen after poor positioning of acetabular fragment after acetabular reorientation for classic DDH. Some patients had ▼ hip ROM and pain with flexion, adduction, and internal rotation.

C. Implications
- DDH leads to OA by mechanical overload (▼ hip surface area leads to ▲ contact pressures)
- Impingement leads to OA by damages to the acetabular labrum and adjacent cartilage

II. Diagnosis

A. History
- Patients with impingement commonly complain of activity-related groin pain
- Pain ≠ in positions of impingement (typically flexion, internal rotation, adduction)
- Occasional mechanical symptoms will be present in those with associated labral-cartilage problems

B. Diagnosis
1. Plain radiographs should include an orthograde AP pelvis, AP hip, cross-table lateral
2. Things to note:
   - Version of socket
   - Presence of deep acetabulum
   - Shape of femoral head
   - "Herniation pits" at head-neck junction secondary to impingement
   - Head-neck offset ratio on lateral radiograph
   - Rim lesions secondary to impingement
3. MRI with gadolinium - things to note:
   - Labral changes
   - Changes at femoral head-neck junction
   - Status of acetabular cartilage at site of impingement and opposite location (posterior-inferior acetabulum)
4. Lesions associated with impingement
   - Inner surface by labrum is ruptured
   - Adjacent cartilage delaminated
   - Reactive bone changes on femoral neck and/or rim of acetabulum

III. Different Mechanism of Impingement as Described by Ganz

A. "Cam" type
- Caused by femoral abnormalities where insufficient head-neck offsets cause damage as an increasing radius is "jammed" into the acetabulum with flexion-internal rotation
- This leads to damage to cartilage and an outside-in labral avulsion
- Damage is typically at anterior-superior rim
- Conditions associated with "cam" impingement:
  - SCFE
  - poor head-neck offset
  - out of round femoral head
  - Perthes
  - retroverted femoral neck (i.e. after femoral neck fracture)

B. "Pincer" type
- Caused by acetabular abnormalities which lead to acetabular over-coverage
- This leads to different damage than above. Labrum is first to fail and acetabular cartilage damage is a result of direct impact and proceeds at a slower rate than cam type.
- Conditions associated:
  - coxa profunda
  - retroverted acetabulum
  - protrusio acetabula

IV. Treatment
- In situations of endstage secondary DJD, THA is most reliable choice.
- Young patients with some viable cartilage, joint salvage is indicated.
- Treatments should be directed toward removing the pathologic elements that are creating the impingement.
- Femoral abnormalities corrected by osteotomy or ▲ head-neck offset by chondro-osteoplasty creating a satisfactory had-neck offset. This can safely be done via anterior surgical dislocation. The acetabular-labral lesions can be debrided and/or repaired.
- Acetabular abnormalities should be corrected by "reverse" PAO in those with acetabular retroversion or anterior acetabular debridement in those with satisfactory posterior coverage and a damaged anterior rim.
- Occasionally combinations of the above are indicated.

V. Conclusions
- In young patients with hip pain ± labral-rim lesions, look for structural problems ➔ instability (DDH) ⟷ impingement
- If viable articular cartilage remains, attempt to solve the structural problem to as near normal as possible.
  - DDH ➔ optimize hip mechanics with osteotomy
  - Impingement ➔ relieve impingement by improving structural problem that is present

BIBLIOGRAPHY

1. Eijer H, Leunig M, Mahomed N, Ganz R: Cross-tale lateral radiographs for screening of anterior femoral head-neck offset in patients with femoroacetabular impingement. Hip International 11:37-41, 2001.
2. Eijer H, Myers SR, Ganz R: Anterior femoroacetabular impingement after femoral neck fractures. J Orthop Trauma 15:475-481, 2001.
3. Ganz K, Krügel N: Die arteria circumflexa femoris medialis topographischer verlauf, anastomosen. Synos Inaugural Dissertation, 1997.
4. Ganz R, Beck M, Gill TJ, Leunig M, Notzli HP, Siebenrock KA: Femoroacetabular impingement as a frequent initiator for osteoarthritis of the dysplastic hip. In manuscript, pending publication.
5. Ganz R: Femoral-acetabular impingement: A cause of hip pain. Presented in Current Concepts on Joint Replacement, Winter 2001, Dec 12-15.
6. Ganz, Gill TJ, Gautier E, Kanz K, Krugel N, Berlemann U: Surgical dislocation of the adult hip: A technique with full access to the femoral head and acetabulum without the risk of avascular necrosis. J Bone Joint Surg 83B:119-1124, 2001.

7. Gautier E, Ganz K, Krügel N, Gill TJ, Ganz R: Anatomy of the femoral circumflex artery and its surgical implications. J Bone Joint Surg 82A:679-683, 2000.
8. Leunig M, Beck M, Kim Y, Nñtzli H, Werlen S, Ganz R: Herniation pits: Radiographic sign of the femoral neck associated with femoroacetabular impingement. J Bone Joint Surg (Awaiting publication).
9. Leunig M, Casillas M, hamlet M, hersche O, Notzli H, Slongo T, Ganz R: Slipped capital femoral epiphysis: Early mechanical damage to the acetabular cartilage by a prominent femoral metaphysis. Acta Orthop Scand 71:370-375, 2000.
10. Murphy SB, Ganz R, Müller M: The prognosis of untreated acetabular dysplasia: Factors predicting outcome. J Bone Joint Surg 77A:985-989, 1995.
11. Myers SR, Eijer H, Ganz R: Anterior femoroacetabular impingement after periacetabular osteotomy. Clin Orthop 363:93-99, 1999.
12. Wedge JH, Wasylenki MD, Houston CS: Minor anatomic abnormalities of the hip joint persisting from childhood and their possible relationship to idiopathic osteoarthrosis. Clin Orthop 264:122-128, 1991.

ROLE OF HIP OSTEOTOMY

Richard F. Santore, MD

Hip Disease in the Young Adult: Role of Hip Osteotomy

AAOS Symposium B
March 10, 2004

Richard F. Santore, M.D.
Clinical Professor,
University of California San Diego
Co-Director of San Diego Adult
Reconstruction Fellowship
rsantore@ucsd.edu

Basic Indications for PAO:

- Painful dysplasia
- Congruent joint
- Young Patient
- Good hip mobility
- Realistic expectations

Hip Disease in the Young Adult: Role of Hip Osteotomy

Role for Osteotomy of Pelvis and or Femur:

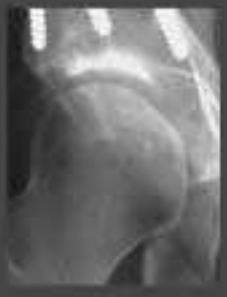
- Dysplasia
- Post-traumatic conditions
- Perthes
- Osteonecrosis
- SCFE
- Leg length inequality

Exclusions:

- Fixed Subluxation
- Significant Arthritis
- Osteoporosis
- Asymptomatic patient

Bernese Periacetabular Osteotomy (PAO)

- Developed 1983
- Published 1988
- Early Results 1995
- More Results 1999



Periacetabular Osteotomy Results

Authors	N	F/U	Complications	THR	Results
Ganz, et al	75	11.3yr	24%	13/71(18%)	73% Good
Murphy, Millis	130	3.9yr	N/R	5/130	N/R
Crockarell, et al	21	3.2 yr	66%*	1/21	N/R 86% Good*
Trumble, et al	123	4.3 yr	17%	7/123	83% Good
Matta, et al	58	4.0 yr	38%	5/58	76% Good

*_ mostly minor; *_ estimated

Periacetabular Osteotomy Results

Results in patients with established arthritis:

N = 42 f/u 2-8 yrs (avg. 4)

Age 11 – 56 (avg. 37)

Arthritis Pre-op		G/E Results	HHS
Tönnis Grade I	15	15 **(100%)**	58 → 94 (86-100)
Tönnis Grade II	18	17 **(94%)**	67 → 89 (42 –95)
Tönnis Grade III	9	8 **(11%)**	59 → 67 (48 –68)

Conclusion: No indication for PAO in advanced arthritis

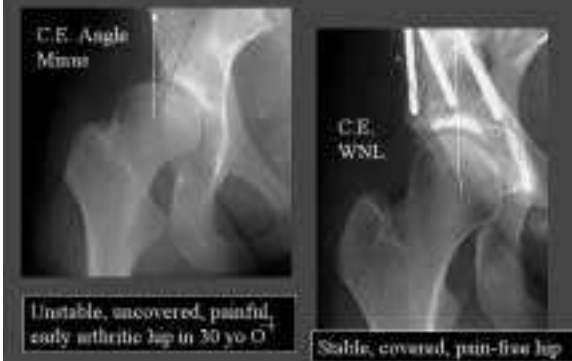
PAO Principles and Indications

Plain X-rays to assess suitability for PAO

PAO Principles and Indications

Case Presentation of X-Ray analysis and appropriate indication

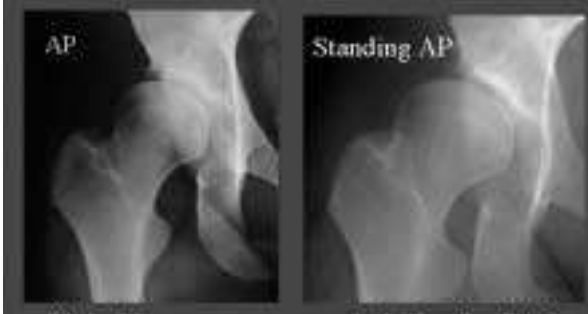
PAO Principles and Indications



Unstable, uncovered, painful, early arthritic hip in 30 yo ♂

Stable, covered, pain-free hip

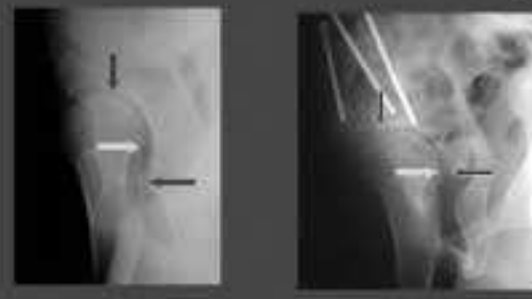
PAO Principles and Indications



Plain X-rays to assess suitability for PAO

PAO Principles and Indications

False Profile Views Before and After Surgery



DDH: *The Osteotomy Alternative*

False Profile View

- Standing position
- Foot parallel to cassette
- Opp. hip 20-25° posterior
- Beam over index hip (R)

Osteotomy Indications

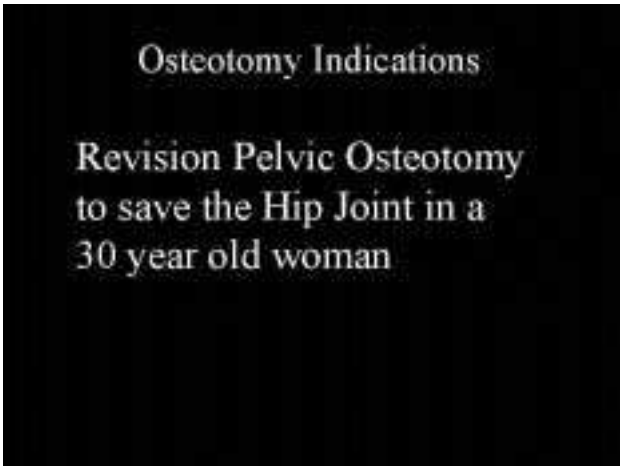
Basic Indications for Chiari:

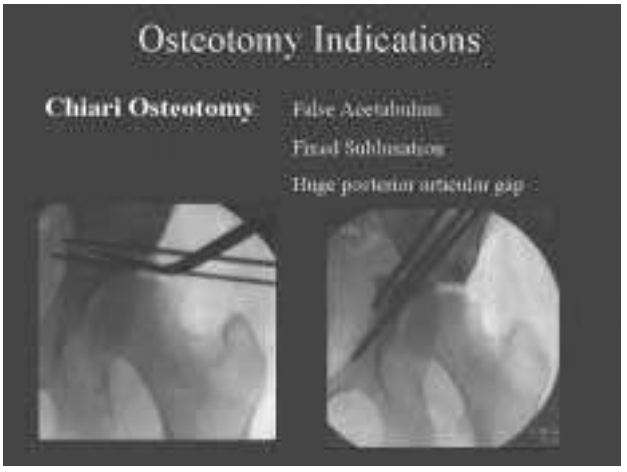
- fixed lateral subluxation
- incongruent joint OK
- combinable with valgus ITO
- same approach as PAO


Osteotomy Indications


Osteotomy Indications
One year
post op

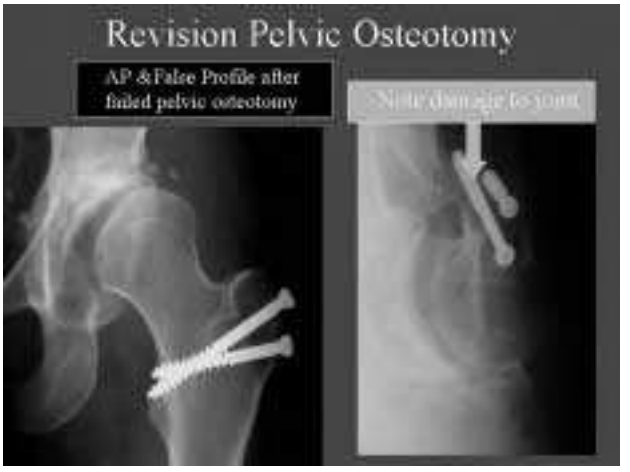

Osteotomy Indications
Standing AP
AP in ABD / IR
False Profile


Osteotomy Indications
Revision Pelvic Osteotomy
to save the Hip Joint in a
30 year old woman

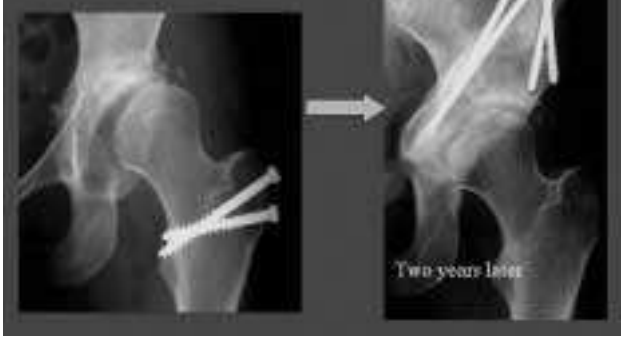

Osteotomy Indications
Chiari Osteotomy
False Acetabulum
Fixed Subluxation
Huge posterior articular gap


Revision Pelvic Osteotomy
30 y/o
woman
AP before failed
pelvic osteotomy
Failed osteotomy,
joint damage,
subluxation


Osteotomy Indications
One year
post op


Revision Pelvic Osteotomy
AP &False Profile after
failed pelvic osteotomy

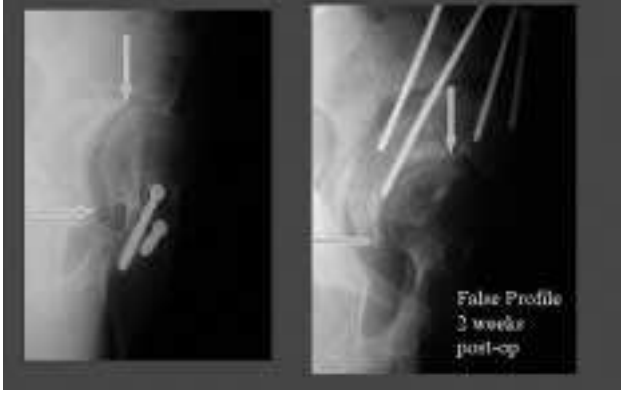
Revision Pelvic Osteotomy



Unique Capabilities of Femoral Osteotomy

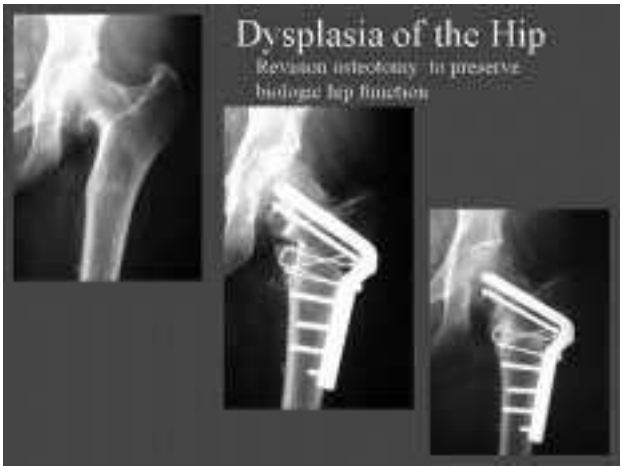
- Correct post-traumatic deformities
- Adjust (lengthen or shorten) leg length
- De-rotation
- Adjust Varus/Valgus & Flexion/Extension
- Exploit Osteophytes in Position of Comfort
- Purposeful deformity: i.e. valgus for femoral neck non-union

Revision Pelvic Osteotomy

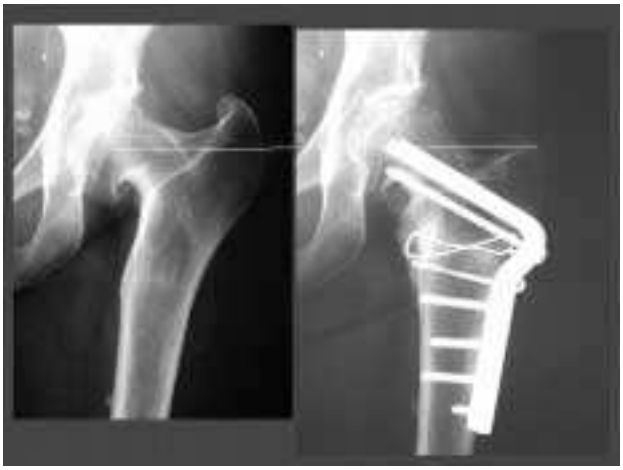


Dysplasia of the Hip

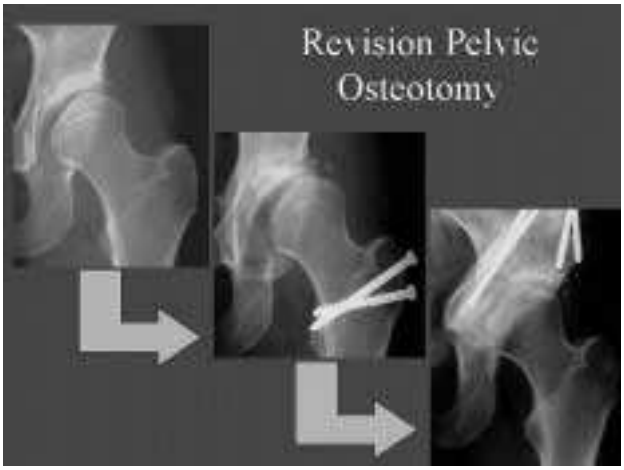
Revision osteotomy to preserve biologic hip function



Revision Pelvic Osteotomy



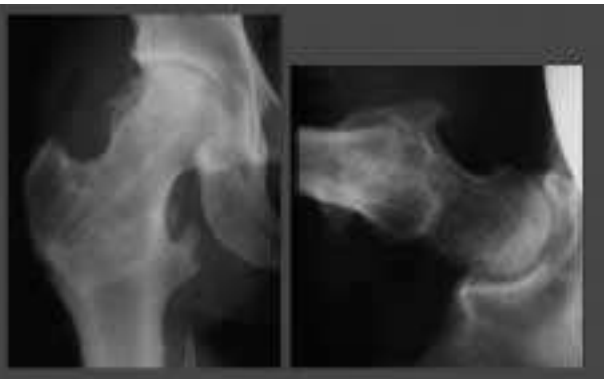
Revision Pelvic Osteotomy



Dysplasia of the Hip

Osteotomy for Osteonecrosis

Size of the lesion is the key factor in patient selection. Large lesions have low probability of success



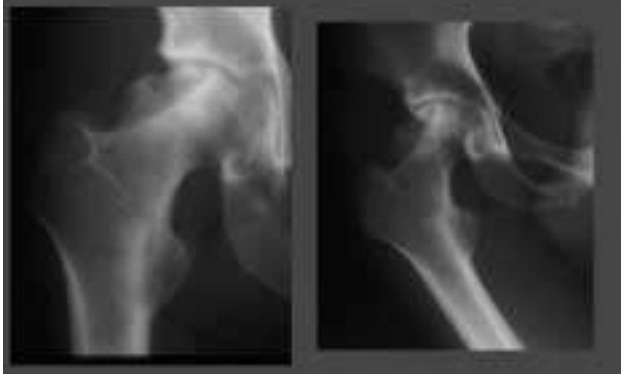
Radiographs ten years after osteotomy

Flexion Osteotomy

Osteotomy for Osteonecrosis

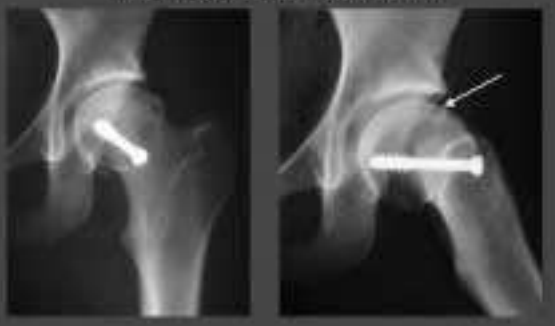
Summary:

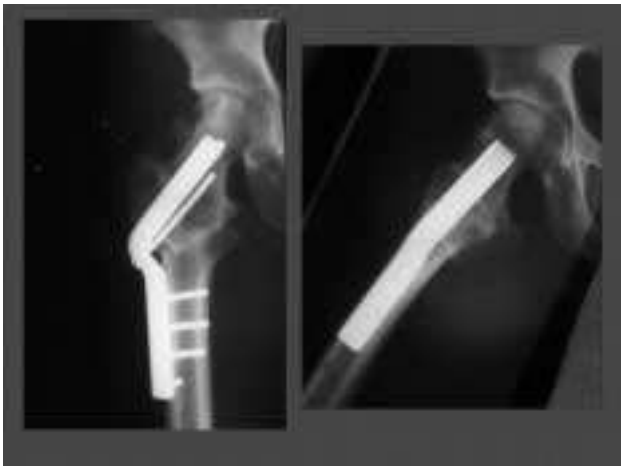
- Size is critical
- Few patients qualify
- No anterior wedge
- Anticipate THR



Intertrochanteric Osteotomy Techniques

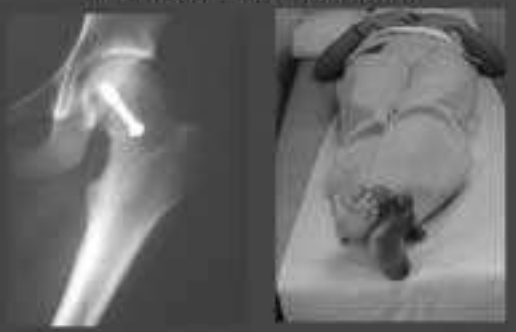
Tri-plane osteotomy for SCFE





Intertrochanteric Osteotomy Techniques

Tri-plane osteotomy for SCFE



Tri-plane Osteotomy for SCFE

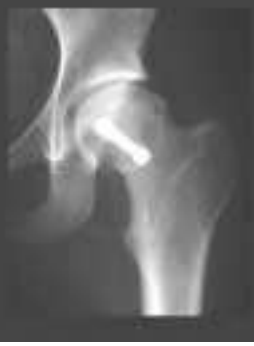
Pre-op external rotation, shortening 20mm, comfortable in adduction

Intertrochanteric Osteotomy Techniques

Tri-plane osteotomy for SCFE

Intertrochanteric Osteotomy Techniques

Tri-plane osteotomy for SCFE



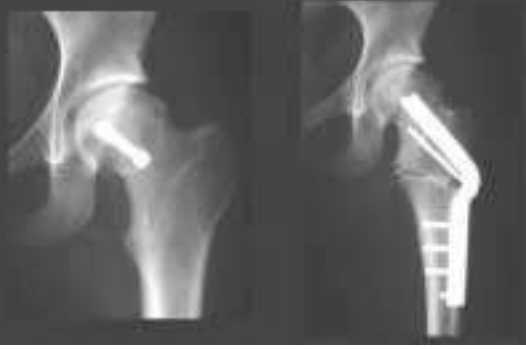
- Flexion in sagittal plane
- Valgus in frontal plane
- Derotation
- Limb lengthening strategy

Valgus ITO for post-traumatic mal-union, short limb, no dysplasia

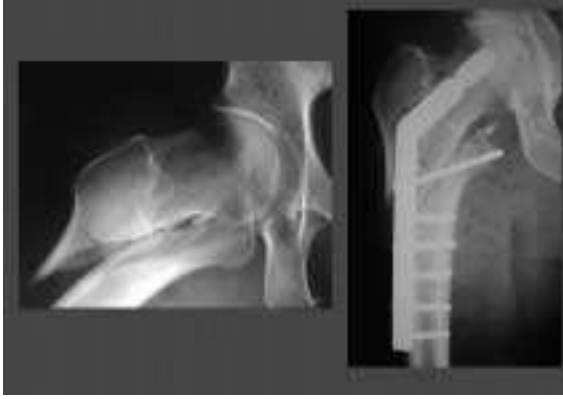
Note the normal hip joint

Intertrochanteric Osteotomy Techniques

Tri-plane osteotomy for SCFE

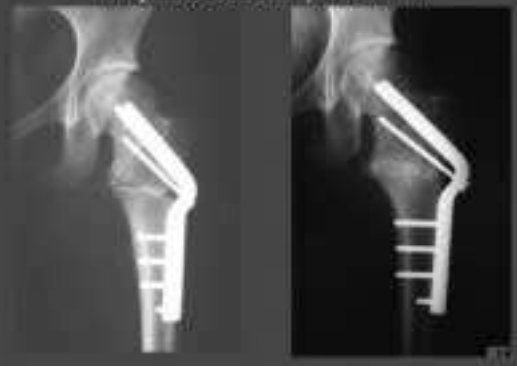


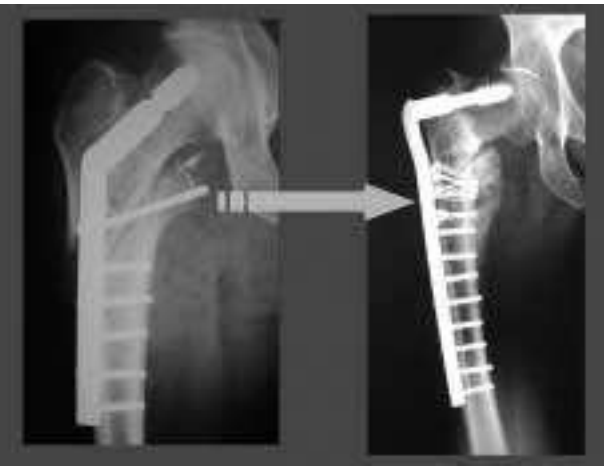
Bombelli Symposium

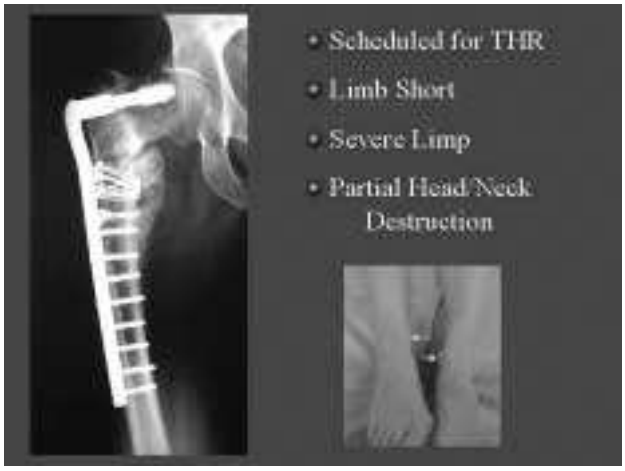


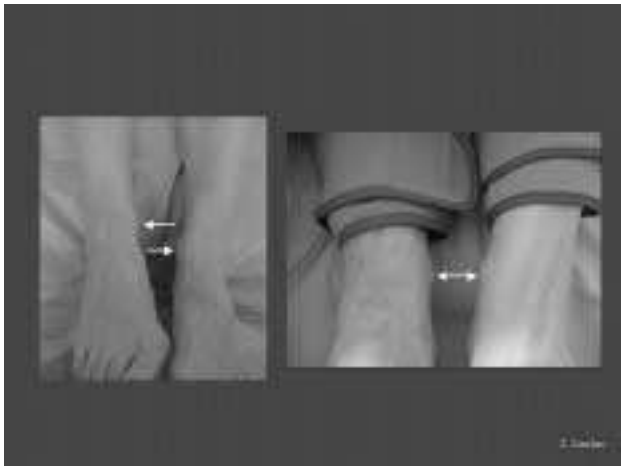
Intertrochanteric Osteotomy Techniques

Tri-plane osteotomy for SCFE

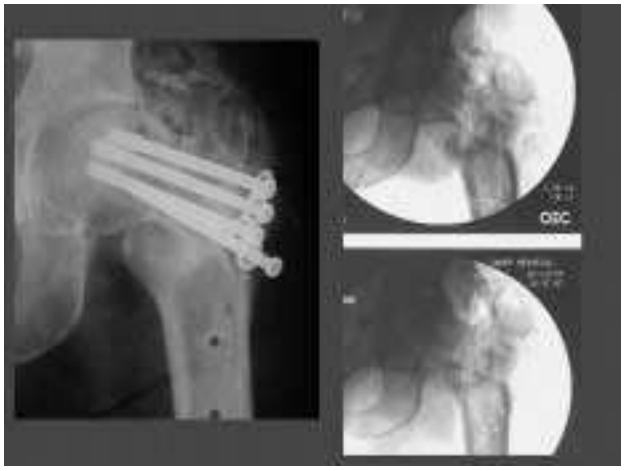


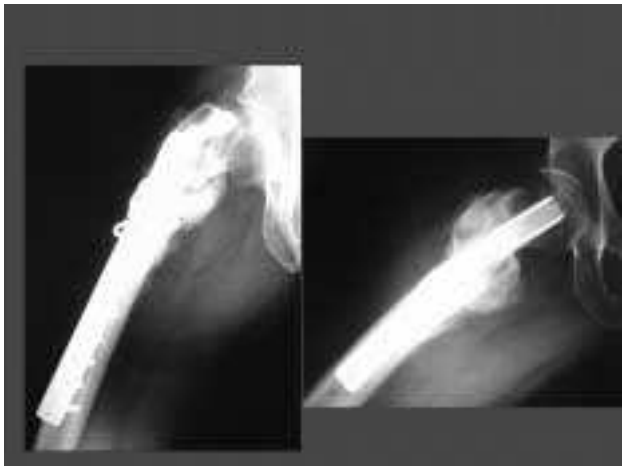


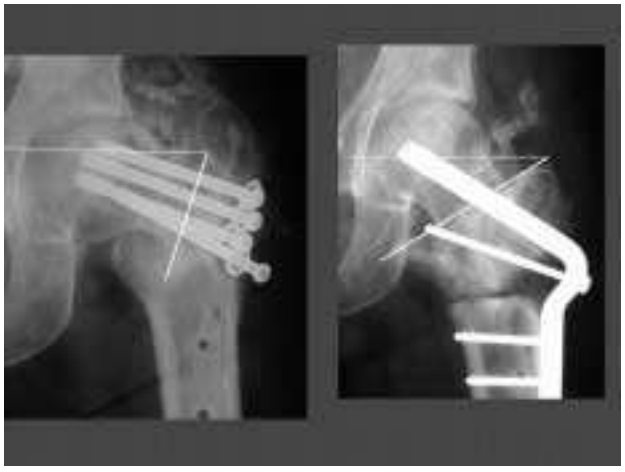

• Scheduled for THR
• Limb Short
• Severe Limp
• Partial Head/Neck Destruction

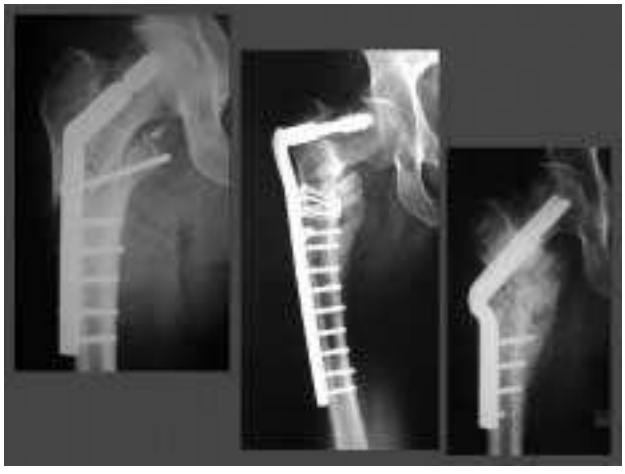


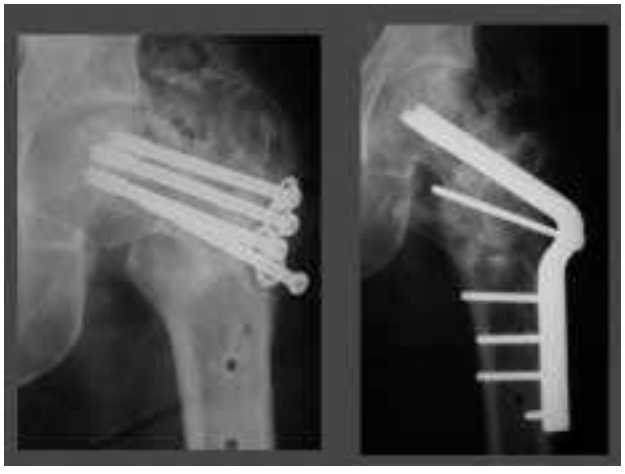

• Equal leg lengths
• Pain free
• Resumed skiing 12 months post osteotomy





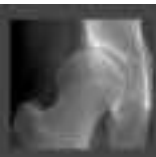




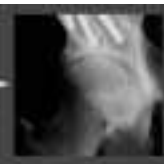


Hip Preserving Procedures

17 y/o girl with post-traumatic, unilateral osteonecrosis/arthritis of the right hip, pain, disability marked, crutch dependent.

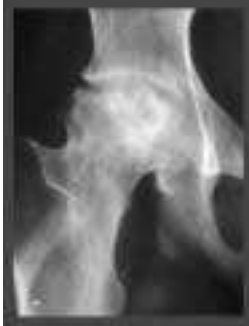


Final comment



A reconstructive surgeon.... is more than a "Total Joint" surgeon. We must train young surgeons to understand the indications & techniques for osteotomy and arthrodesis, as well as primary and revision arthroplasty.

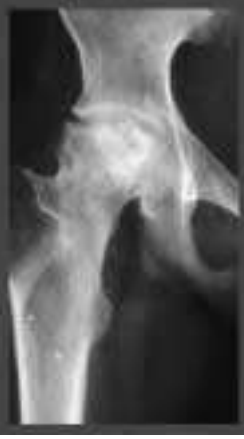
Hip Preserving Procedures: Arthrodesis



IC 102
Case presentation

- No position of comfort
- Poor range of motion
- No passive adduction
- Motion painful / crepitus

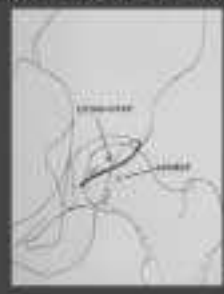
Had two children after fusion. Enjoys active, pain-free life 5 yrs post-op.

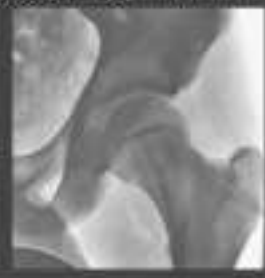


Arthrodesis remains the treatment of choice for unilateral, severe, post-traumatic arthritis of the hip in the very young patient.

Pelvic Osteotomy Principles and Indications

Retroversion of human socket (dysplasia variant)



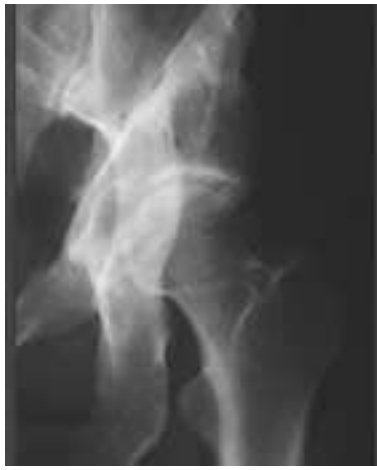


Siebenrock & Gerber, 2002 AAOS Poster exhibit

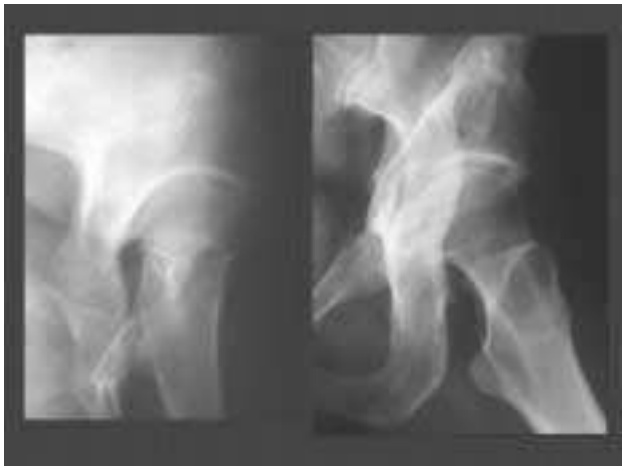
Pelvic Osteotomy Principles and Indications

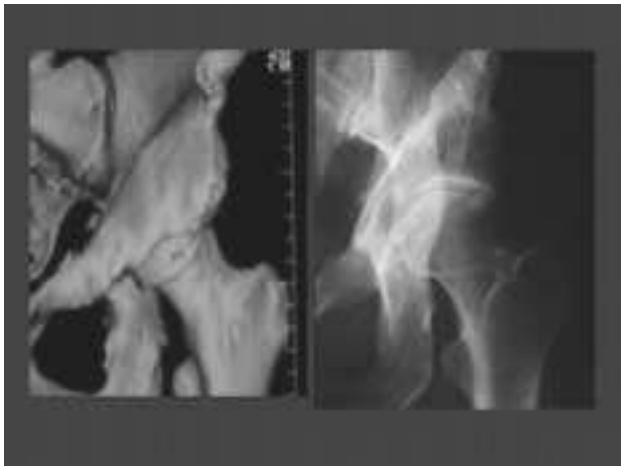
Retroversion of human socket (dysplasia variant)

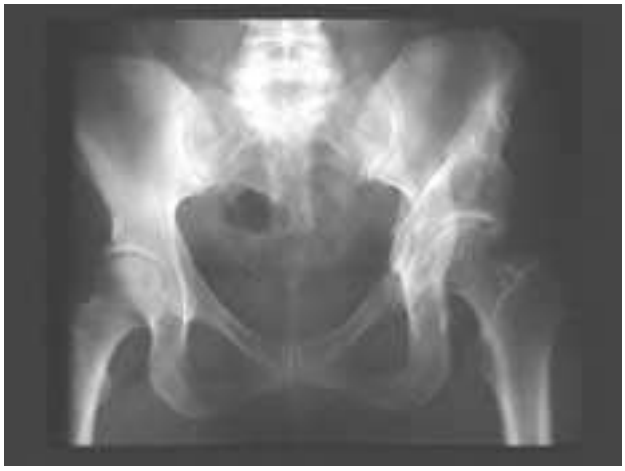
Siebenrock & Gerber, 2002 AAOS Poster exhibit

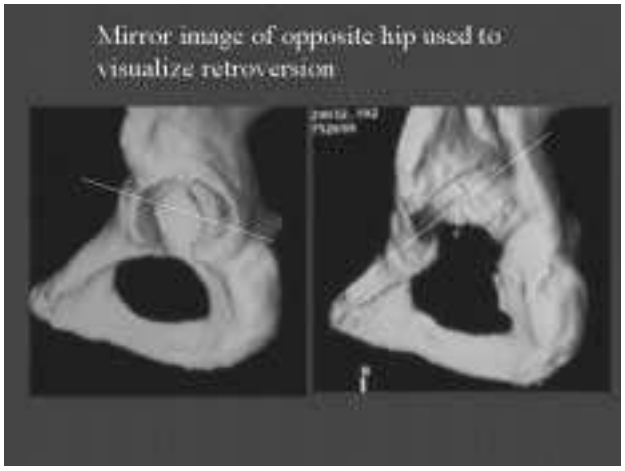


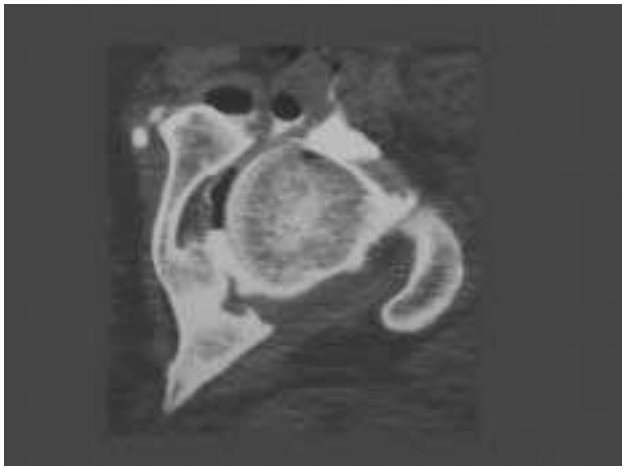
- 37 y/o
- 2 prior PAO's
- Stiff hip
- LFCN, Obturat. Palsies
- Cannot sit or stand without pain

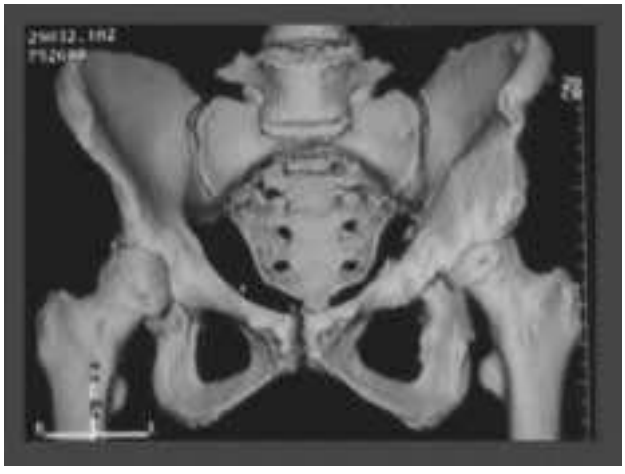


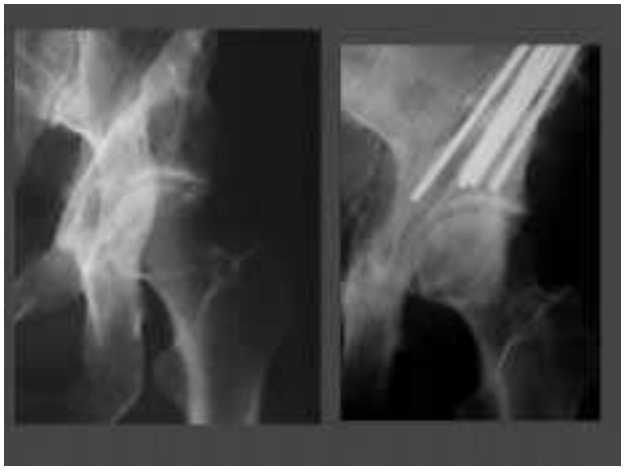





Mirror image of opposite hip used to visualize retroversion







HEMIARTHROPLASTY AND SURFACE REPLACEMENT FOR THE YOUNG PATIENT WITH HIP ARTHRITIS

Michael A. Mont, MD

Introduction:

Limited resurfacing arthroplasty (femoral head only) is only indicated for patients with osteonecrosis of the femoral head. Total resurfacing (femoral head and acetabulum) can be used in many patients with osteoarthritis. Its indications/contraindications will be discussed with a focus on results. Special circumstances where its use may be more advantageous than standard total hip replacement will be emphasized.

Problem:

- Because of the young patient population and long life expectancy of patients affected by osteonecrosis, total hip replacement should be a last resort

Solution:

- Important aims of treatment are:
  1. to preserve the proximal femoral bone stock
  2. avoid multiple procedures in the patient's lifetime
- Limited femoral resurfacing can accomplish these goals

Principles:

Limited Femoral Resurfacing

- articular congruity
- provides a smooth articulating surface for the femoral head
- provides stable structure and shape to a previously collapsed femoral head

Metal-on-Metal Total Joint Resurfacing

- survivorship of conventional constructs increases the likelihood that the young patient to multiple revisions in their lifetime
- metal-on-metal bearings have reduced volumetric wear providing a potentially permanent prosthetic reconstruction of the hip
- large diameter of the femoral head allows more anatomic location of the center of rotation and superior biomechanics to standard hip arthroplasty
- there is preservation of proximal bone stock allowing simple conversion to standard hip replacement if necessary

Indications and Prerequisites:

Limited femoral resurfacing

- Medium to large collapsed lesions (Ficat stage III and early stage IV)
- Large lesions not amenable to:
  - Osteotomy
  - Bone grafting
    - Vascularized
    - Non-vascularized
- Head depression >2 mm
- Intact and undamaged acetabular cartilage

Total Joint Resurfacing

- Advanced degenerative joint disease of the hip with acetabular involvement
- Special circumstances - discussed below

Technical Tips:

Limited Femoral Resurfacing

- Anterolateral approach
- Limited capsulotomy
- Keep dissection to a minimum to try to preserve the blood supply to the remainder of the femoral head from the lateral and posterior retinacular vessels
- Surgeons must remember to inspect and palpate the acetabular cartilage intra-operatively
- Post-operatively, early range of motion exercises are begun on the first or second day, 50 percent weight bearing on the third day, and full weight bearing at six
- Can be converted to total resurfacing by placement of an acetabular component

Total Joint Resurfacing

- A standard lateral or anterolateral approach is used
- An anterior hip arthrotomy is performed
- Difficult acetabular exposure because the femoral head and neck are not amputated
- Avoid notching (potential stress-riser) when reaming the femoral neck
- Post-operative management includes 20% weight bearing advanced to 50% at six weeks and weight-bearing as tolerated at twelve weeks post-operative
- Contraindications include large femoral neck sizes and large cysts of the femoral head/neck region

Special Considerations:

- Extra-articular deformities of the proximal femur. (malunion, bowing deformity, etc.)
- Hardware present in proximal femur (IM rod, cannulated screws, plates)
- Extraordinary post-operative range of motion necessary (patients with upper extremity malformation/limitations)

Conclusion:

- Limited femoral resurfacing is preferred when the femoral head cartilage is damaged.
- Metal on metal total joint resurfacing provides a potentially permanent solution for young patients with late-stage hip disease while preserving bone stock.
- It must be remembered that osteonecrosis is a continuum of disease. One should not utilize only one procedure for all patients with this disease, but rather stratify treatment options based on clinical, radiographic and imaging analysis.

Bibliography

1. Amstutz HC, Campbell P, McKellop H, Schmalzreid TP, Gillespie WJ, Howie D, Jacobs J, Medley J, Merritt K: Metal on metal total hip replacement workshop consensus document. Clin Orthop. 1996; 329 (Suppl): S297-303.
2. Amstutz HC, Dorey F, O'Carroll PF: Tharies resurfacing arthroplasty: Evolution and long-term results. Clin Orthop. 1986; 213: 92-114.
3. Amstutz HC, Grigoris P, Safran MR, Grecula MJ, Campbell PA, Schmalzried TP: Precision-fit surface hemiarthroplasty for femoral head osteonecrosis: Long-term result. J Bone Joint Surg Br 1994;76:423-427.
4. Beaule PE, Schmalzried TP, Campbell PA, Dorey F, Amstutz HC: Duration of symptoms and outcome of hemiresurfacing for osteonecrosis of the hip. Clin Orthop 001;385:104.117.
5. Bierbaum BE, Sweet R. Complications of resurfacing arthroplasty. Orthop Clin North Am. 1982; 13: 761-775.

6. Charnley J, Halley DK: Rate of wear in total hip replacement. Clin Orthop. 1975; 112:170-179.

7. Cohn BT, Fromison A, Brahms MA, Greenwald AS: Total articular replacement arthroplasty. Presented at the 55th Annual Meeting of the American Academy of Orthopaedic Surgeons, 1987.

8. Gerard Y: Traitement des necroses idiopathiques de la tete femorale par cupule ajustee a appui cylindrique. Acta Orthop Bel 1981;47:309-316.

9. Hungerford MW, Mont MA, Scott RD, Fiore C, Hungerford DS, Krackow KA: Surface replacement hemi-arthroplasty for the treatment of osteonecrosis of the femoral head. J Bone Joint Surg Am 1998;80:1656-1664.

10. Krackow KA, Mont MA, Maar DC: Limited femoral endoprosthesis for avascular necrosis of the femoral head. Orthop Rev 1993;12:457-463.

11. Mallory TH, Ballas S, Van Atta G: Total articular replacement arthroplasty. Clin Orthop 1984;185:131-136.

12. Mckellop H, Clarke I, Markolf K, Amstutz H: Friction and wear properties of polymer, metal and ceramic prosthetic joint materials evaluated on a multi-channel screening device. J Biomed Material Research 1982;15:619-653.

13. Mont MA, Rajadhyaksha AD, Hungerford DS: Outcomes of limited femoral resurfacing arthroplasty compared with total hip arthroplasty for osteonecrosis of the femoral head. J Arthroplasty 2001;16(8 Suppl 1):134-139.

14. Muller ME: The benefits of metal-on-metal total hip replacements. Clin Orthop. 1995; 311: 54-59.

15. Nelson CL, Walz BH, Gruenwald JM: Resurfacing of only the femoral head for osteonecrosis. Long-term follow-up study. J Arthroplasty 1997;12:736-740.

16. Postel M, Mekhaldi M: Vernon Huck adjustable cup arthroplasty : The treatment of nontraumatic femoral head necrosis. Int Orthop 1987;11:295-300.

17. Schmalzreid TP, Peters PC, Mauree BT, Bragdon CR, Harris WH: Long-duration metal-on-metal total hip arthroplasties with wear of the articulating surfaces. J Arthroplasty 1996;11:322-331.

18. Scott RD, Urse JS, Schmidt R, Bierbaum BE: Use of TARA hemiarthroplasty in advanced osteonecrosis. J Arthroplasty 1987;2:225-232.

19. Sedel L, Travers V, Witvoet J: Spherocylindric (Luck) cup arthroplasty for osteonecrosis of the hip. Clin Orthop 1987;219:127-135.

20. Townley CO: Hemi and total articular replacement arthroplasty of the hip with fixed femoral cup. Orthop Clin North Am 1982;13:869-894.

21. Van der Meulen MCH, Beaupre GS, Smith RL et al: Factors influencing changes in articular cartilage following hemiarthroplasty in sheep. J Orthop Res 2002;20:669-675.

CROSSLINKED POLYETHYLENE

Thomas P. Schmalzried, MD

There are several variables in the manufacturing of acetabular bearings with "intentionally" crosslinked polyethylene including a) the base resin, b) the method of consolidation, c) the method of crosslinking, d) the amount of crosslinking, e) stabilization methodology, f) packaging and g) terminal sterilization.

MarathonTM crosslinked polyethylene (DePuy, Warsaw, IN) is composed of GUR 1050 (calcium stearate-free) resin consolidated into cylindrical bars by ram extrusion. Crosslinking is achieved by gamma irradiation to 5 mrad. Residual free radicals are eliminated by heating the bulk material above the melting point (stabilization). Acetabular components are then machined from this material and placed into a traditional barrier package. Terminal sterilization is with gas plasma. In hip wear simulator studies, the wear of acetabular components composed of MarathonTM was 85% lower than that of non-irradiated components. The proportional increase in wear resistance was maintained in an abrasive environment (run against roughened balls) and after artificial aging (the material did not oxidize) (McKellop et al. Clin. Orthop. 369:73-82, 1999).

With a minimum of 2 years follow-up, patients with conventional polyethylene showed a mean linear wear rate of 0.13 mm per year and a mean volumetric wear rate of 87.6 mm3 per year. The group with MarathonTM crosslinked polyethylene showed a mean linear wear rate of 0.02 mm per year and a mean volumetric wear rate of 17.0 mm3 per year. Wear in the group with crosslinked polyethylene was 81% lower than in the group with conventional polyethylene ($p<0.00001$). Accounting for differences in patient activity, the adjusted wear rates per million cycles for 70 kg patient weight were 53.3 mm3 per million cycles for conventional polyethylene and 15 mm3 per million cycles for crosslinked polyethylene, a 72% reduction ($p=0.0002$). No factors, other than the type of polyethylene, were identified that influenced the difference in wear rates between the two groups. The in vivo wear reduction with this crosslinked polyethylene is consistent with the predictions of hip simulator studies. Longer follow-up is needed to determine if the occurrence of osteolysis, or revision for any reason related to the bearing, are similarly reduced (Heisel et al., JBJS (Am.) in press 2003).

TOTAL HIP ARTHROPLASTY USING CERAMIC BEARINGS

William J. Hozack, MD

1. Weak Link
a. Complications – 1970's
b. Loosening – 1980's
c. Wear – 1990's

2. Choices
a. Crosslinked poly – this is a new material
b. Metal on metal – systemic effects, runaway wear
c. Ceramic on ceramic
d. Wear is the ultimate issue!

3. Ceramic advantages
a. Wear reduction – ceramic on ceramic is best without question
- Extreme harness/scratch resistant
  - Low co-efficient of friction
- Hydrophilic = improved lubrication: Can use larger diameter femoral heads
- No potential for metal ion release

4. Ceramic disadvantages
a. Fracture – not really an issue
b. Stripe wear – related to subluxation

5. Technical issues
I. Ceramic Rim Protection
   a. Critical design issue
   b. Avoids alumina ceramic impingement on femoral neck which avoids ceramic chipping or notching of the weaker/softer femoral neck
II. Socket Preparation
   a. 40°-45° abduction & 25° anteversion assuming a femoral anteversion of 15° for a combined anteversion of 40° may be desired to maximize functional ROM before impingement
III. Placement of Femoral Head
   a. Used only with design specific femoral stem
   b. Placed on a clean trunion free of debris
   c. Fully seat before impaction
   d. Preoperatively plan for limited neck length selection
IV. Femoral component selection
   a. Reduced femoral neck diameter to minimize impingement
   b. Variable offset to maximize stability, and minimize impingement

6. Clinical results
ABC series
I. A New Experience with Alumina Ceramic Bearings
   a. Alumina ceramic study group (10/96-2/03) >1300 alumina ceramic bearing implants with no ceramic device related failures
   b. US IDE ABC System study design – prospective, controlled, randomized, multi-center, 2-yr. period implanted 514 hips comparing Al/Al bearings to CoCr/poly bearings (10/96-11/98)
   c. 3 cup designs - 2 with alumina-alumina randomized with 2/3 chance for alumina bearing & 1/3 chance for control CoCr on poly
   d. Demographics – no significant difference between ABC I, II, III
      1. ABC I – porous coated Ti socket with alumina insert & alumina femoral head
      2. ABC II – arc deposited Ti socket with HA coating & alumina insert & alumina femoral head
      3. ABC III - porous coated Ti socket with CoCr on poly
      4. All pts. received the same alumina femoral head & an Omnifit tapered Ti femoral stem

Clinical Data
I. 3-5 yrs. – No Significant Difference in Clinical Outcome
   a. Complications – revisions 16 = 2.6%
   b. Dislocations = 17 = 3.3% 1. 10 (2.9%) in alumina Systems I & II 7. 7 (4.2%) in control series
   c. Ceramic fx = 0
   d. Peripheral alumina ceramic insertional chip = 9
II. Revisions: Alumina Systems I & II = 6/349 = 1.7%
   a. 1 femur at 1 mo. p.o. femoral fx. (trauma)
   b. 1 femur at 4.6 yrs. for progressive subsidence that began at 6 mos. following trauma
   c. 1 acetabulum for recurrent dislocation
   d. 2 for sepsis
   e. 1 for suspected sepsis
III. Revision: System III Control = 10/166 = 6%
   a. 1 femur p.o. traumatic femoral fx.
   b. 1 femoral leg length discrepancy
   c. 1 sepsis
   d. 4 acetabular inserts for recurrent dislocation
   e. 2 acetabular components for aseptic loosening with 1 for linear wear & osteolysis at 5 yrs.

Radiographic results
I. Only statistically significant difference between Systems I, II & III is the absence of reactive lines around System II sockets, an arc deposited Ti surface with HA. Systems I & III (porous coated Ti sockets has 25-30% reactive lines.
II. Wear & Osteolysis
   a. 0% in Systems I & II (alumina bearing series)
   b. 2.4% proximal femoral lysis in System III (CoCr on poly control)

TRIDENT series
I. Prospective, Controlled, Nonrandomized, 6 Surgeons Implanted 209 Hips from 1998-2000
II. Demographics No Different Than Systems I, II & III
III. Clinical Results No Different Than Systems I, II & III
IV. Revisions
   a. 1 acetabular revision for loosening in 6 mos. (excessive cup anteversion with cup impingement)
   b. 2 femoral revisions for p.o. traumatic fx.
   c. 3 acetabular revision for recurrent dislocation = 1.4%
V. Ceramic Fx = 0
VI. Intraoperative Insertional Chips = 0
VII. Advantages of Trident Over ABC
   a. Trident has preassembled Ti sleeve around alumina insert
   b. More revision options (modular poly or reinsertion of Trident insert)
   c. No risk of peripheral chips – Trident has alumina insert encased in a Ti sleeve
   d. burst strength of acetabular component

Summary

I. Alumina Ceramic Bearings of Today Are of High Quality
   a. They have significantly less wear
   b. Superior lubrication
   c. No potential for metal ion release
   d. Increased ROM
   e. Avoids the potential risks of material changes of cross-linked polys

II. Alumina Ceramics Are Mated with Design Specific Implants
   a. Implants that have excellent fixation records
   b. Implants that have high taper tolerances
   c. Implants that provide for ceramic rim protection

III. All Ceramic Components Proof-tested for Burst Strength Prior to Shipping

IV. Ceramic Fracture Is No Longer an Issue

V. Alumina Ceramic Bearings Today Provide a Viable Option for the Younger & More Active

METASUL VS. DURASUL

Lawrence D. Dorr, MD

In young patients (60 years and younger), when performing total hip replacement it is critical to consider the maintenance of bone over a long period of time. One must not just consider the relief of pain and improvement in function. The decision on the total hip replacement to perform must also consider durability of this operation. In these patients there is even more pressure to be sure that the implants are mated correctly and that the fixation and articulation surface are optimal. The articulation surface must be proven to produce a low volume of particles. Every articulation surface has particles (including normal cartilage in a normal hip). However, it is the volume of particles that creates pain from inflammation and destruction of bone from osteolysis. Metasul has a proven track record over 15 years of production of low particles and a very low prevalence of osteolysis. The burden of proof to perform in a like manner is on the new polyethylene surfaces.

We have used Metasul since 1991. Initially 70 patients with 70 hips were operated with a cemented Weber Metasul cup with both cemented and non-cemented stems. Forty-nine of these patients with 49 hips with a 7-11 year followup are alive and not revised. In 1995 a modular Metasul couple was used with the APR cup. Fifty-two patients with 57 hips both cemented and non-cemented were operated. Forty-three patients with 47 hips with a 4-7 year followup were alive with complete followup. Four patients with 5 hips were clinically satisfactory without x-rays. This gave a total of 96 hips which could be evaluated for the presence of osteolysis or fixation changes. Four patients with 4 hips had been previously revised because of loosening in one, dislocation in two, and disassembly of the Metasul modular insert in the fourth. The clinical evaluation of the patients was done by the patient self assessment form.

Clinical results show 67 grade excellent, 22 good, 4 fair, 3 poor. Sixty-one were unlimited ambulators, 14 could ambulate 6 blocks, 13 could ambulate 2 blocks, and 8 were household ambulators. Radiographic results for Metasul showed no osteolysis in the pelvis or femur except for calcar resorption. This finding was limited to plain radiographs (AP pelvis and lateral with iliac oblique). There were no radiographically loose stem or cups. Twenty-two of 96 hips had radiolucencies at the interface of the acetabulum, but none were progressive; 14 of 96 hips had radiolucencies at the interface of the femoral component with none being progressive. With revision for any reason as the endpoint the survival rate was 96.1% + 1.9% at 5 and 11 years.

Fifty-one hips were operated consecutively in 1999 with metal-on-Durasul couples. There were 5 patients without followup, 6 less than 2 years, 13 for 2-3 years, and 27 for 3 years or more. The total polyethylene wear in year 1 was 0.027 + 0.043 mm; at 2 years was 0.092 + 0.082; and at 3 years was 0.105 + 0.087. The annual linear wear for patients with 2 or more years followup was 0.034 + 0.027 mm per year.

A randomized study between Metasul and Durasul was performed during the year 2002. The followup on these patients is certainly too short for any measurement of osteolysis. However, the clinical findings in these patients (both with bilateral hip replacements with one of each articulation surface and individual patients) show no differences in the patient results with metal-on-metal or metal-on-Durasul. There is no greater pain with one group of hips vs. the other and no difference in the patients' grade of excellent, etc.

The wear with Durasul polyethylene to-date has been very low. At 0.03 mm per year it is well below the threshold of wear for production of osteolysis. Metal-on-metal has not demonstrated any osteolysis out to 11 years. Literature reports that polyethylene sterilized and/or packaged in oxygenless environments have shown no significant osteolysis. Therefore, at this time it is difficult to say whether hard-on-hard bearing surfaces are necessary to provide an environment for the hip in which very low levels of osteolysis and osteolysis caused failures occur. There has been excellent results to 11 years for us with metal-on-metal articulations because all of our patients except four in this study group have maintained an intact hip with satisfactory performance during that time period.

Although there has been theoretical concern expressed by several scientists about the ion production with metal on metal articulations and the potential for cancer, there has never been a case of cancer that has been attributed to metal on metal, or specifically Metasul. Metasul has been in use for 15 years now, and this duration of time combined with the previous longevity of many patients with McKee-Farrar metal on metal articulations gives rise to serious question as to whether or not the theoretical concerns are just that. Secondly, there has been the issue of hypersensitivity raised by scientists who have looked at tissues from the metal on metal retrievals and have observed lymphocytes adjacent to blood vessels. In our personal series of 500 metal on metal articulation total hip replacements we have not one case that could be called hypersensitivity. We had three patients with unexplained pain with metal on metal articulations and we did reoperate two of those with the diagnosis of hypersensitivity. The tissues of one of these showed characteristics of the hypersensitivity diagnosis, but the patient in fact, did not improve from that operation in a way that would indicate it was a hypersensitivity problem. The other two patients healed over time and independent diagnoses were clearly the reason for what was unexplained pain for the first two years. Therefore, we cannot support the diagnosis of hypersensitivity as a clinical problem with the use of Metasul.

THE ROLE OF PHARMACOLOGICAL AGENTS IN FRACTURE HEALING AND IMPLANT FIXATION (AAOS/ORS)

Co-Moderators: David B. Burr, PhD, Indianapolis, IN
(a, b, d, e – Eli Lilly, Proctor&Gamble Pharmaceuticals, Merck)
and Randy N. Rosier, MD, Rochester, NY (*)

The use of pharmaceutical agents to treat osteoporosis or osteoarthrosis is now widespread. Because these agents act in various ways on bone remodeling and repair processes, their use can affect the progress of fracture healing or the fixation of prosthetic implants. The goal of this symposium is to describe the mechanisms by which the agents have their effect on bone repair, and their clinical significance in altering either the rate or nature of the repair process.

I. Effects of Cox-2 inhibitors on Fracture Healing
Regis J. O'Keefe, MD, Rochester, NY (n)

II. Effects of PTH on Fracture Healing
Louis G. Gerstenfeld, PhD, Boston, MA (a – Eli Lilly and Co., Contract Research)

III. Effects of Bisphosphonates on Fracture Healing
Joseph M. Lane, MD, New York, NY (a – Proctor & Gamble, Lilly)

IV. Pharmacological Agents in Implant Fixation
Rick Sumner, PhD, Chicago, IL (a – Zimmer, DePuy)

V. Biomimetic Agents for Implant Fixation
Kevin Healy, PhD, Berkley, CA (d – Bioengineered Materials Inc, Cardiometrix, Inc)

CYCLOOXYGENASE INHIBITORS AND BONE REPAIR

Regis J. O'Keefe, MD, PhD

I. Does COX inhibition impair fracture repair?

A. Cyclooxygenases (COX) are critical enzymes involved in the conversion of arachadonic acid to prostaglandins.
   1. COX-1 is constitutively expressed.
   2. COX-2 expression is regulated.

B. COX-2 is expressed in osteoblasts and is a source of prostaglandins in bone.
   1. COX-2 is up regulated in bone by mechanical forces, ultrasound, growth factors and cytokines (Naruse, 2003; Norvell, 2003).
   2. COX-2 is down regulated by corticosteroids (Pufe, 2003).

II Animal Studies examining the effects of COX inhibition.

A. COX-2 is up-regulated more than 10-fold in fracture callus within 3 days following fracture (Gerstenfeld, 2003).

B. COX-2 knock out mice have reduced fracture healing, bone formation, and mesenchymal cell differentiation into bone (Zhang, 2002).
   1. Radiographs, histology, and histomorphometry show reduced bone formation and fracture healing.
   2. Fracture callous forms normally, but there is a reduction of bone formation and a persistence of undifferentiated mesenchyme in the COX-2 knock fractures.
   3. Bone marrow stem cells from COX-2 knock out mice have reduced bone formation in cell culture under basal conditions, but have normal bone formation compared to wild type cells following treatment with PGE2 and BMP-2.
   4. Bone formation is reduced on the calvaria of COX-2 knock out mice following in vivo injection of FGF-2 compared to wild type mice.

C. Pharmacological agents that impair COX-2 activity reduce fracture healing in a rat fracture model (Simon, 2002).

III Does fracture healing recover over time following COX inhibition.

A. Control and parecoxib- and Ketoralac-treated rats had femur healing by 35 days. Mechanical strength was reduced only with ketorolac-treated animals (Gerstenfeld, 2002).

B. Control, celecoxib, and indomethacin-treated rats had similar fracture healing by 12 weeks following fracture with continuous treatment (Brown, 2004).

C. Allograft healing in the mouse femur is remains reduced at 5 weeks following an initial 2-week treatment with celecoxib (O'Keefe, unpublished data).

D. PGE2 stimulates bone formation in mice through EP-4 receptors (Yoshida, 2002).

IV. Human Studies of COX inhibition and fracture healing.

A. Limited data is available, primarily from retrospective studies.

B. Some data suggests a clinical effect on fractures and the healing of spine fusions (Giannoudis, 2000; Glassman, 1998; Deguchi, 1998), while other data suggest no effect (Bhandari, 2003).

V. Summary

A. COX-2/PGE2 is important for bone repair and stem cell differentiation.

B. Some animal studies suggest a recovery in fracture healing following COX inhibition.

C. Some animal studies show less inhibition with COX-2 specific inhibitors suggesting that residual COX-1 activity may be protective of fracture healing.

D. Human studies are inconclusive, but some retrospective studies show reduced bone formation and healing.

REFERENCES

1. Bhandari, M., Tornetta, P., 3rd, Sprague, S., Najibi, S., Petrisor, B., Griffith, L., and Guyatt, G. H. Predictors of reoperation following operative management of fractures of the tibial shaft. J Orthop Trauma 17:353-61; 2003.
2. Bonnarens, F., and Einhorn, T. A. Production of a standard closed fracture in laboratory animal bone. J. Orthop. Res. 2:97-101; 1984.
3. Brown, K. M., Saunders, M. M., Kirsch, T., Donahue, H. J., and Reid, J. S. Effect of COX-2-specific inhibition on fracture-healing in the rat femur. J Bone Joint Surg Am 86-A:116-23; 2004.
4. Deguchi, M., Rapoff, A. J., and Zdeblick, T. A. Posterolateral fusion for isthmic spondylolisthesis in adults: analysis of fusion rate and clinical results. J. Spin. Disord. 11:459-64; 1998.
5. Gerstenfeld, L. C., Thiede, M., Seibert, K., Mielke, C., Phippard, D., Svagr, B., Cullinane, D., and Einhorn, T. A. Differential inhibition of fracture healing by non-selective and cyclooxygenase-2 selective non-steroidal anti-inflammatory drugs. J Orthop Res 21:670-5; 2003.
6. Giannoudis, P. V., MacDonald, D. A., Matthews, S. J., Smith, R. M., Furlong, A. J., and De Boer, P. Nonunion of the femoral diaphysis. The influence of reaming and non-steroidal anti-inflammatory drugs. J. Bone Joint Surg. 82B:655-58; 2000.
7. Glassman, S. D., Rose, S. M., Dimar, J. R., Puno, R. M., Campbell, M. J., and Johnson, J. R. The effect of postoperative nonsteroidal anti-inflammatory drug administration on spinal fusion. Spine 23:834-38; 1998..
8. Naruse, K., Miyauchi, A., Itoman, M., and Mikuni-Takagaki, Y. Distinct anabolic response of osteoblast to low-intensity pulsed ultrasound. J Bone Miner Res 18:360-9; 2003.
9. Norvell, S. M., Ponik, S. M., Bowen, D. K., Gerard, R., and Pavalko, F. M. Fluid Shear Stress Induction of COX-2 Protein and Prostaglandin Release in Cultured MC3T3-E1 Osteoblasts does not Require Intact Microfilaments or Microtubules. J Appl Physiol; 2003.
10. Pufe, T., Scholz-Ahrens, K. E., Franke, A. T., Petersen, W., Mentlein, R., Varoga, D., Tillmann, B., Schrezenmeir, J., and Gluer, C. C. The role of vascular endothelial growth factor in glucocorticoid-induced bone loss: evaluation in a minipig model. Bone 33:869-76; 2003.
11. Yoshida, K., Oida, H., Kobayashi, T., Maruyama, T., Tanaka, M., Katayama, T., Yamaguchi, K., Segi, E., Tsuboyama, T., Matsushita, M., Ito, K., Ito, Y., Sugimoto, Y., Ushikubi, F., Ohuchida, S., Kondo, K., Nakamura, T., and Narumiya, S. Stimulation of bone formation and prevention of bone loss by prostaglandin E EP4 receptor activation. Proc Natl Acad Sci U S A 99:4580-5; 2002.
12. Zhang, X., Schwarz, E. M., Young, D. A., Puzas, J. E., Rosier, R. N., and O'Keefe, R. J. Cyclooxygenase-2 regulates mesenchymal cell differentiation into the osteoblast lineage and is critically involved in bone repair. J Clin Invest 109:1405-15.; 2002.

EFFECTS OF PTH ON FRACTURE REPAIR

Louis C. Gerstenfeld , Ph.D.

I. Introduction: Numerous pharmacological agents for the medical management of musculoskeletal conditions are currently being developed. Since many of the compounds that being examined for the treatment of osteoporosis are anabolic, they offer the potential as adjunct therapeutics for the enhancement of post-surgical skeletal tissue healing.(1-4) In this presentation we will specifically examine the use of PTH as a potential therapeutic for the enhancement of fracture healing and other forms of post surgical bone repair.

II. Comparisons of Strategies in the Development of Therapeutic Agents to Treat Osteoporosis Vs Fracture and Bone Repair.

A. Stages of Coupled Remodeling & Strategies to Enhance Bone Mass (1,2,4)

Activation Diminish Numbers of Osteoclast
Resorption Diminish Osteoclast Activity/Increase Rate of Osteoclast Turnover
Formation Increase Osteoblast Numbers/Osteoblast Activity

B. Stages of Fracture Repair & Strategies to Enhance Fracture Repair (5)

Initial Injury	Endochondral Formation	1°Bone Formation	2°Bone Formation
Inflammation	Periosteal Response	Cartilage Resorption	Coupled Remodeling

Factors That Promote Stem Cell Recruitment
Increase Ratio of Bone/Cartilage Differentiation
Factors That Change Rates of Endochondral Remodeling
Factors That Enhance Coupled Bone Formation

III. Historical Background in the Development of PTH as An Anabolic Agent

A. PTH as a systemic regulator of mineral homeostasis
Parathyroid hormone (PTH), an 84 amino acid polypeptide, is an essential regulator of calcium and phosphate metabolism. Its roles in mineral homeostasis are to increase serum calcium levels by enhancing gastrointestinal calcium absorption, increase renal calcium and phosphate reabsorption, liberate calcium from the skeleton in response to systemic needs and participate in the regulation of vitamin D metabolism.(6)

B. PTH and PTH and PTHrP and endochondral growth during development
Recent studies have reported a potential role for PTH and PTH-related peptides(PTHrp) in other musculoskeletal tissues.(7) Other studies have shown that the PTH/PTHrp receptor mediates the effects of Indian hedgehog and PTH or PTHrp on chondrocyte differentiation. (8) Other reports have demonstrated a role for PTH/PTHrp receptor mutations in the pathogenesis of various chondrodysplasias. (9) These studies suggest that PTH signaling plays an important role in a variety of mechanisms of bone formation including endochondral ossification.

C. Anabolic vs. Catabolic effects dependent on the continuous or intermittent mode of administration of PTH.
Although the effects of this hormone are usually associated with bone resorption, the response of osteoclasts to PTH are most likely mediated via osteoblastic activity and the receptors for PTH are found in the cell membranes of osteoblasts.(6) Indeed, while continuous exposure to PTH leads to an increase in osteoclast number and activity, low intermittent doses stimulate osteoblasts and result in increased bone formation in rats and humans (10,11). Thus, the characteristic effects of this hormone on the skeleton, which are produced primarily by its amino terminal portion (1-34), are anabolic with respect to bone.

D. Emergence of 1-34 PTH as the first anabolic agent for the treatment of osteoporosis
It has been shown to increase bone mineral density and reduce the risk of vertebral and non-vertebral fractures in post-menopausal women as well as improve the bone mass in osteoporotic men. (12, 13,14) A typical 40µg dose to an average adult human increased bone mineral density more than the 20µg dose but had similar effects on the risk of fracture. Daily treatment with PTH (1-34) reduced the risk of non vertebral fractures by 35% at the 20µg dose and by 40% at the 40µg dose and reduced the risk of non vertebral fragility fractures by 53 and 54%, respectively. (14) The clinical benefits of PTH (1-34) reflect its ability to stimulate bone formation and thereby increase bone mass and strength.(11-14) The development of recombinant human PTH (1–34) known as teriparatide (Forteo™) Teriparatide and its approval by the Food and Drug Administration (FDA) in 2002 as a treatment for osteoporosis, represents the first anabolic agent that can be systemically administered which can increase bone mass.

IV. Studies to Date of PTH Use in Bone Repair

A. Preclinical animals trials in fracture repair
In an early study using parathyroidectomised rats, PTH administration was shown to enhance fracture healing during the first five weeks after injury.(15) In a number of recent reports, doses ranging from 10µg to 200µg/kg in rat models of normal fracture healing all showed significant increases in both mechanical and histological properties.(16-21) In other studies, using models of impaired bone metabolism, PTH analogs were shown to reverse the inhibition of bone healing in ovariectomised rats (18)and rabbits treated with corticosteroids.(19) In one report, PTH (1-34) was shown to increase bone in growth and pull-out strength in porous metallic implants. (20)

B. Current studies of PTH at doses in range of clinical use in humans show positive effects on fracture healing
In a current robustly powered study in rats presented this year, data show that daily systemic administration of low-dose PTH (1-34) enhances fracture healing by increasing BMD, BMC, and strength, and produces a sustained anabolic effect throughout the remodeling phase of fracture healing.(21)

V. Summary

A. Future Need for Well Controlled Clinical Trials

B. Potential uses of PTH as a pharmacological adjunct for surgical treatments
1) Improving post operative implant fixation
2) Pre surgical therapy for improving poor quality bone bed for elective orthopedic procedures

REFERENCES/BIBLIOGRAPHY

1. Rosen CJ. Restoring aging bones. Sci Am. March 2003;288(3):70-7.
2. Whitfield JF. How to grow bone to treat osteoporosis and mend fractures. Curr Rheumatol Rep. February 2003;5(1):45-56.
3. Seeman E, Delmas PD. Reconstructing the skeleton with intermittent parathyroid hormone. Trends Endocrinol Metab. September 2001;12(7):281-3.
4. Rodan GA, Martin TJ. Therapeutic approaches to bone diseases. Science. September 2000;289(5484):1508-14.
5. Gerstenfeld LC, Cullinane DM, Barnes GL, Graves DT, Einhorn TA. Fracture healing as a post-natal developmental process: Molecular, spatial, and temporal aspects of its regulation. J Cell Biochem. April 2003;88(5):873-84
6. Rubin MR, Bilezikian JP. The anabolic effects of parathyroid hormone therapy. Clin Geriatr Med. May 2003;19(2):415-32.
7. Lanske B, Karaplis AC, Lee K, Luz A, Vortkamp A, Pirro A, Karperien M, Defize LH, Ho C, Mulligan RC, Abou-Samra AB, Juppner H, Segre GV, Kronenberg HM.PTH/PTHrP receptor in early development and Indian hedgehog-regulated bone growth. Science. August 1996;273(5275):663-6.
8. Vortkamp A, Lee K, Lanske B, Segre GV, Kronenberg HM, Tabin CJ. Regulation of rate of cartilage differentiation by Indian hedgehog and PTH-related protein. Science. August 1996;273(5275):613-22.
9. Schipani E, Langman C, Hunzelman J, Le Merrer M, Loke KY, Dillon MJ, Silve C, Juppner H. A novel parathyroid hormone (PTH)/PTH-related peptide receptor mutation in Jansen's metaphyseal chondrodysplasia. J Clin Endocrinol Metab. September 1999;84(9):3052-7
10. Iida-Klein A, Zhou H, Lu SS, Levine LR, Ducayen-Knowles M, Dempster DW, Nieves J, Lindsay R. Anabolic action of parathyroid hormone is skeletal site specific at the tissue and cellular levels in mice. J Bone Miner Res. May 2002;17(5):808-16
11. Dempster DW, Cosman F, Kurland ES, Zhou H, Nieves J, Woelfert L, Shane E, Plavetic K, Muller R, Bilezikian J, Lindsay R. Effects of daily treatment with parathyroid hormone on bone microarchitecture and turnover in patients with osteoporosis: a paired biopsy study. J Bone Miner Res. October 2001;16(10):1846-53
12. Neer RM, Arnaud CD, Zanchetta JR, Prince R, Gaich GA, Reginster JY, Hodsman AB, Eriksen EF, Ish-Shalom S, Genant HK, Wang O, Mitlak BH. Effect of parathyroid hormone (1-34) on fractures and bone mineral density in postmenopausal women with osteoporosis. N Engl J Med. May 2001;344(19):1434-41.
13. Black DM, Greenspan SL, Ensrud KE, Palermo L, McGowan JA, Lang TF, Garnero P, Bouxsein ML, Bilezikian JP, Rosen CJ. PaTH Study Investigators. The effects of parathyroid hormone and alendronate alone or in combination in postmenopausal osteoporosis N Engl J Med. September 2003;349(13):1207-15.
14. Orwoll ES, Scheele WH, Paul S, Adami S, Syversen U, Diez-Perez A, Kaufman JM, Clancy AD, Gaich GA. The effect of teriparatide [human parathyroid hormone (1-34)] therapy on bone density in men with osteoporosis. J Bone Miner Res. January 2003;18(1):9-17.
15. Andreassen TT, Ejersted C, Oxlund H. Intermittent parathyroid hormone (1-34) treatment increases callus formation and mechanical strength of healing rat fractures. J Bone Miner Res. June1999;14:960-8.
16. Holzer G, Majeska RJ, Lundy MW, Hartke JR, Einhorn TA. Parathyroid hormone enhances fracture healing. A preliminary report. Clin Orthop. September 1999;(366):258-63.
17. Nakajima A, Shimoji N, Shiomi K, et al. Mechanisms for the enhancement of fracture healing in rats treated with intermittent low-dose human parathyroid hormone (1-34). J Bone Miner Res. November 2002;17(11):2038-47.
18. Kim HW, Jahng JS. Effect of intermittent administration of parathyroid hormone on fracture healing in ovariectomized rats. Iowa Orthop J. 1999; 19:71-7.
19. Bostrom, MPG, Gamradt SC, Asnis P, Vickery BH, Hill E, Avnur Z, Waters RV. Parathyroid hormone-related protein protein analog RS-66271 is an effective therapy for impaired bone healing in rabbits on corticosteroid therapy. Bone. May 2000;26(5):437-42.
20. Skripitz R, Andreassen TT, Aspenberg P. Parathyroid hormone (1-34) increases the density of rat cancellous bone in a bone chamber. A dose-response study. J Bone Joint Surg Br. January 2000; 82(1):138-41.
21. Alkhiary YM, Gerstenfeld LC, Cullinane DM, Krall E, Sato M, Mitlak B, Einhorn TA. Parathyroid Hormone (1-34; Teriparitide) Enhances Experimental Fracture Healing. J Bone Mineral Res. 2003;18:S24.

BISPHOSPHONATES AND FRACTURE REPAIR

Joseph Lane

Bisphosphonates are synthetic analogues of inorganic pyrophosphates. Their main effect is to adhere to bone surfaces and prevent osteoclastic resorption. They are non-degradable enzymatically and when absorbed by osteoclasts inhibit the mevalonate pathway in osteoclasts, enhancing apoptosis and inhibiting resorption. Their main therapeutic applications are for the treatment of high turnover osteoporosis, Paget's Disease, metastatic bone disease, hypercalcemia, and hyperparathyroidism. Off labile uses include fibrous dysplasia and osteogenesis imperfecta.

Bisphosphonates have poor oral absorption(<1%) and a prolonged bone half-life (3-10 years). Burr has demonstrated that high doses (10X OP dose) in dogs leads to microfracture accumulation and derived biomechanical alterations. Long-term clinical data suggests continued fracture protection in osteoporotic patients without a fall-off. Since many patients with osteoporosis are first identified following a recent low energy fracture , there is uncertainty whether bisphosphonates can be safely initiated during the fracture healing process.

Long-term efficacy studies of alendronate and risedronate have demonstrated a significant decrease in the risk for both vertebral and appendicular fractures. In those patients in the bisphosphonate arm that did acquire a fracture, there is no report of delay in fracture healing or increased rate of non/delayed union. In several randomized studies directly of fracture healing in the upper (colles) and lower (tibia) extremity, bisphosphonates not only mitigated against fracture limb disuse osteoporosis but also lead to no measurable fracture healing impairment.

Numerous animal studies of fracture repair and bisphosphonates have evidenced larger callus size, delayed remodeling, and persistence of woven bone, but no significant alteration of biomechanical properties as compared to control (non-bisphosphonate) fractures. Etidronate, a first generation bisphosphonate, demonstrated evidence of a mineralization defect.

Several investigators have demonstrated that bisphosphonates can prevent osteolysis in rodent and canine models of arthroplasty and might enhance ingrowth.

Osteonecrosis is associated with collapse during the resorptive phase of repair. Bisphosphonates used in a rat model of AVN could prevent untoward resorption and retain head sphericity. Both necrotic bone and allografts underwent delayed diminished resorption in a bone chamber model when protected by bisphosphonates.

Summary: Bisphosphonates clearly decrease the risk of fracture specifically in osteoporosis. Both animal and clinical data suggest that bisphosphonates do not clinically impair fracture repair but certainly delay all elements of timely remodeling. Conversely, PTH in a large array of animal studies augments fracture healing. Bisphosphonates can be initiated in osteoporotic patients while healing fractures without deleterious side effects.

GROWTH FACTORS AND CEMENTLESS IMPLANT FIXATION

D. Rick Sumner, PhD

Basics of Cementless Implant Fixation[4,17]

- Necessary conditions
  - "Correct" surface characteristics
  - Initial stability (lack of micromotion)
  - Close bone-implant contact
  - Aseptic
- Strength of fixation
- Factors that inhibit cementless fixation
  - Necessary conditions unmet
  - Treatments to prevent heterotopic ossification
    - Radiation
    - EHDP (1st generation bisphosphonate)
    - Non-steroidal anti-inflammatory drugs (NSAIDs)
  - Other

Pharmacologic agents that enhance cementless fixation

- Locally delivered
  - Transforming growth factor-beta (TGF-_)[9-11,18-20]
  - Bone morphogenetic protein (BMP)[5,8,12,21]
  - Biomimetic surfaces[3]
- Systemically delivered
  - Parathyroid hormone (PTH)[15,16]
- Other potential agents (some tested in fracture healing models)

Pharmacologic agents that may affect cementless fixation

- Bisphosphonates[2,14]
- NSAIDs[25]

Mechanisms of growth factor-enhanced implant fixation

- Intramembranous bone regeneration cascades
  - Histologic phases[13]
  - Gene expression profiling[6,7,22]
- Effects of growth factors on these cascades
  - Histomorphometry[18]
  - Gene expression profiling[1,23,24]

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REFERENCES

1. De Ranieri A, Virdi AS, Kuroda S, Sumner DR: Exogenously applied rhTGF-b2 enhances bone regeneration and implant fixation by accelerating and up-regulating the innate gene expression profile in a rat model. Trans ORS, 2004
2. Frenkel SR, Jaffe WL, Valle CD, Jazrawi, Wright A: The effect of alendronate (Fosamaxtrade mark) and implant surface on bone integration and remodeling in a canine model. J Biomed Mater Res 58:645-650, 2001
3. Harbers GM, Barber TA, Stile RA, Sumner DR, Healy KE: Mimetic peptide modified materials for control of cell differentiation. In: Biomimetic materials and design: interactive biointerfacial strategies, tissue engineering and drug delivery, ed by AK Dillow and A Lowman., p 55. New York, Marcel Dekker, 2001.
4. Jacobs JJ, Goodman SB, Sumner DR, Hallab NJ: Biological response to orthopaedic implants. In: Orthopaedic Basic Science,Anonymous, p 401. Rosemont, Illinois, American Academy of Orthopaedic Surgeons, 2000.
5. Koempel JA, Patt BS, O'Grady K, Wozney J, Toriumi DM: The effect of recombinant human bone morphogenetic protein-2 on the integration of porous hydroxyapatite implants with bone. J Biomed Mater Res 41:359-363, 1998
6. Kuroda S, Virdi AS, Sumner DR: Expression profiling of regenerate after bone marrow ablation. ASBMR Annual Meeting, 2003
7. Liang CT, Barnes J, Seedor JG, Quartuccio HA, Bolander M, Jeffrey JJ, Rodan GA: Impaired bone activity in aged rats: alterations at the cellular and molecular levels. Bone 13:435-441, 1992
8. Lind M, Overgaard S, Jensen TB, Song Y, Goodman SB, Bunger C, Soballe K: Effect of osteogenic protein 1/collagen composite combined with impacted allograft around hydroxyapatite-coated titanium alloy implants is moderate. J Biomed Mater Res 55:89-95, 2001
9. Lind M, Overgaard S, Nguyen T, Ongpipattanakul B, Bünger C, Søballe K: Transforming growth factor-b stimulates bone ongrowth: hydroxyapatite-coated implants studied in dogs. Acta Orthop Scand 67:611-616, 1996
10. Lind M, Overgaard S, Ongpipattanakul B, Nguyen T, Bünger C, Søballe K: Transforming growth factor-b1 stimulates bone ongrowth to weight-loaded tricalcium phosphate coated implants. J.Bone Joint Surg.Br 78-B:377-382, 1996
11. Lind M, Overgaard S, Søballe K, Nguyen T, Ongpipattanakul B, Bünger C: Transforming growth factor-b1 enhances bone healing to unloaded tricalcium phosphate coated implants: an experimental study in dogs. J Orthop Res 14:343-350, 1996
12. Lind M, Overgaard S, Song Y, Goodman SB, Bunger C, Soballe K: Osteogenic protein 1 device stimulates bone healing to hydroxyapaptite-coated and titanium implants. J Arthrop 15:339-346, 2000
13. Patt HM, Maloney MA: Bone marrow regeneration after local injury: a review. Exp Hemat 3:135-148, 1975
14. Shanbhag AS, Hasselman CT, Rubash HE: The John Charnley Award. Inhibition of wear debris mediated osteolysis in a canine total hip arthroplasty model. Clin Orthop 344:33-43, 1997
15. Skripitz R, Aspenberg P: Early effect of parathyroid hormone (1-34) on implant fixation. Clin Orthop 392:427-432, 2001
16. Skripitz R, Aspenberg P: Implant fixation enhanced by intermittent treatment with parathyroid hormone. J Bone Joint Surg Br. 83:437-440, 2001
17. Sumner DR: Fixation of implants. In: The adult knee, ed by JJ Callaghan, AG Rosenberg, HE Rubash, PT Simonian and TA Wickiewicz., p 289. Philadelphia, Lippincott Williams & Wilkins, 2003.
18. Sumner DR, Turner TM, Cohen M, Losavio P, Urban RM, Nichols EH, McPherson JM: Aging does not lessen the effectiveness of TGF-ß2 enhanced bone regeneration. J Bone Miner Res. 18:730-736, 2003
19. Sumner DR, Turner TM, Purchio AF, Gombotz WR, Urban RM, Galante JO: Enhancement of bone ingrowth by transforming growth factor beta. J.Bone Joint Surg.Am 77-A:1135-1147, 1995
20. Sumner DR, Turner TM, Urban RM, Leven RM, Hawkins M, Nichols EH, McPherson JM, Galante JO: Locally delivered rhTGF-b2 enhances bone ingrowth and bone regeneration at local and remote sites of skeletal injury. J Orthop Res 19:85-94, 2001
21. Sumner DR, Turner TM, Urban RM, Turek T, Seeherman H, Wozney JM: Locally delivered rhBMP-2 enhances bone ingrowth and gap healing in a canine model. J Orthop Res (in press):2003
22. Suva LJ, Seedor JG, Endo N, Quartuccio HA, Thompson DD, Bab I, Rodan GA: Pattern of gene expression following rat tibial marrow ablation. J Bone Miner Res. 8:379-388, 1993
23. Tanaka H, Quarto R, Williams S, Barnes J, Liang CT: In vivo and in vitro effects of IGF-I on femoral gene expression in aged rats. J Bone Miner Res. 8:S155, 1993
24. Tanaka H, Quarto R, Williams S, Barnes J, Liang CT: In vivo and in vitro effects of insulin-like growth factor-I (IGF-I) on femoral mRNA expression in old rats. Bone 15:647-653, 1994
25. Virdi AS, De Ranieri A, Sumner DR: Bone regeneration and implant fixation strength are not adversely influenced by Cox-2 inhibition. Trans ORS in press: 2004

ADVANCED MATERIALS WITH DRUG-LIKE QUALITIES FOR FRACTURE HEALING AND IMPLANT FIXATION

Kevin E. Healy

Introduction
- Limitations in the performance of materials used in medical implants and devices
- Biological strategies to modify implants through either a molecular or cellular pathway

Biological Engineering of Implants and Grafts
- Definition: The design and synthesis of materials that circumvent their passive behavior in complex biological environments and actively regulate the response of either proteins or mammalian cells.

Biological Surface Engineering
- Surface properties of implants
- Initial host response to implants
- Control of host response via biological surface engineering

Protein modifications

Peptide modifications
- Current status and limitations
- The implications: the chemistry of a material can be modified to alter the kinetics of differentiation of mammalian cells, and may ultimately be used to control tissue regeneration surrounding orthopaedic implants

Engineering Regeneration of Bone with Synthetic Grafts
- Overview of biological and synthetic grafts and their limitations
- Biodegradable polyesters
- Minimally invasive materials for bone tissue engineering
- Current status and limitations
- The implications: biomimetic in situ forming materials may control bone tissue regeneration within bone defects, fractures, or surrounding orthopaedic implants and devices.

HOT TOPICS AND CONTROVERSIES IN PRIMARY TOTAL HIP ARTHROPLASTY (I)

Moderator: Daniel J. Berry, MD, Rochester, MN (a, c – DePuy)

Surgeons and patients are faced with many choices in primary hip replacement. This symposium will highlight the pros and cons of important choices and decisions in total hip arthroplasty. The symposium will focus on clinically relevant technical decisions and will update surgeons regarding controversies that are frequently inquired about by patients. The format will have 2 or 3 speakers for each topic, each will explain why they favor, prefer or believe in the merits of one method or approach to a specific problem. To maintain balance and minimize polarized views, each speaker will give a 5-minute talk; the topic then will be discussed by the rest of the panel under the guidance of the moderator. The goal will be spirited discussion but also rational consensus thinking about these controversial but clinically important topics.

I. Conventional Incision vs Mini-incision for Total Hip Arthroplasty
   a. I prefer a mini incision: Thomas P. Sculco, MD, New York, NY (n)
   b. I prefer to stick with conventional incision: Lester S. Borden, MD, Cleveland, OH (a, e – Stryker Howmedica Osteonics)
   c. Panel: Discussion

II. Choice of Bearing Surface
   a. Crosslinked PE: John J. Callaghan, MD, Iowa City, IA (a, b, c, e – DePuy)
   b. Metal-Metal: Thomas P. Schmalzried, MD, Los Angeles, CA (a, c – DePuy)
   c. Ceramic-Ceramic: William J. Hozack, MD, Philadelphia, PA (e – Stryker)
   d. Panel: Discussion

III. Choice of Femoral Head Size:
   a. Advantages of 28 mm or smaller: John J. Callaghan, MD, Iowa City, IA (a, b, c, e – DePuy)
   b. Advantages of 32 mm or larger: William J. Maloney, MD, St. Louis, MO (c – Zimmer)
   c. Panel: Discussion

IV. Femoral Fixation in Older Patients: Cemented vs Uncemented Stems
   a. I prefer uncemented stems in older patients: Charles A. Engh, MD, Alexandria, VA (a – Inova Health Care Services, d, e – Johnson & Johnson)
   b. I prefer cemented stems in older patients: Thomas S. Thornhill, MD, Boston, MA (a, c – DePuy, Johnson & Johnson)
   c. Panel: Discussion

V. DVT Prophylaxis After THA
   a. Mechanical prophylaxis and aspirin are enough: Paul F. Lachwiewicz, MD, Chapel Hill, NC (a – Zimmer, e – Aircast)
   b. Chemoprophylaxis is safer: Miguel E. Cabanela, MD, Rochester, MN (*)
   c. Panel: Discussion

VI. Panel/Audience Discussion; Case Presentations

MINIMALLY INVASIVE TOTAL HIP REPLACEMENT

Thomas P. Sculco, MD

A. Rationale
1. Less morbidity, faster rehabilitation, reduced length of stay, patient satisfaction
2. Must not compromise arthroplasty

B. Facilitates procedure
1. Arthroplasty experience, patient selection, customized instrumentation, experienced assistant/s
2. Thin patient, monoblock socket, epidural hypotensive anesthesia

C. Small incision not appropriate
1. Severely obese patients, heavy muscular patients, complex revision surgery

D. Technique
1. Standard posterolateral incision
2. Posterior trapezoidal capsulotomy
3. Custom acetabular retractors for exposure
4. Anterior capsular release
5. Femoral retractor to elevate femur
6. Capsular repair through trochanter

E. Clinical Experience: Randomized trial
1. Group 1 22 patients: 8 cm incision
2. Group 2 24 patients: 15 cm incision
3. Demographics similar for two groups
4. BMI 25.2
5. Significantly reduced blood loss in Group I
6. More rapid rehabilitation in Group I
7. Radiographic evaluation Group I
   a. Abduction angle 36.4 degrees
   b. Cement Grade: 93% A or B

F. Follow-up Study: 484 THR
1. Average follow-up 2.8 years (1-5.4)
2. Average skin incision: 8.2 cm (6-10cm)
3. Radiographic Evaluation
   a. Lateral abduction angle: 42.4 degrees (28-59)
   b. Cement Grade (Barrack): 95% A or B
   c. Femoral alignment: 93% neutral
4. Dislocation: 4
5. Femoral Fracture: 1
6. Neuropraxia: 2
   a. Must reduce posterior retraction
   b. Extend incision in excessive posterior retraction
   c. Release quadratus, gluteus maximus tendon if needed
   d. Hip extension whenever possible
7. Wound complications
   a. Hematoma 2
   b. Infection 0

CHOICES OF BEARING SURFACE: CROSSLINKED POLYETHYLENE

John J. Callaghan, MD

I. Forms of sterilization in past and present
- A. Gamma irradiation in air
  1. Polymer chain scission and oxidation
  2. Oxidative degradation increases over time
  3. Lowers wear resistance
  4. Lowers fatigue strength
  5. No longer used by most manufacturers
- B. Gamma irradiation in inert (nitrogen, argon, vacuum) atmosphere
  1. Promotes cross linking, improves wear resistance
  2. Free radicals may cause oxidation in vivo
- C. Gas sterilization (Et0, gas plasma)
  1. No change in UHMWPE chemistry
  2. Mechanical properties maintained
  3. No cross linking effects

II. Forms of highly cross linked UHMWPE processing
- A. Warm irradiated adiobatic melt (WIAM)
  1. Electron beam at 125°C
  2. Highly cross linked
  3. Annealing (above melt) neutralizes free radicals
- B. Melt irradiated
  1. Gamma irradiated while above melt temp (135°C)
  2. Polymer chains both in crystalline and amorphous phase crosslinked
  3. Wear rates dramatically reduced in hip simulators
  4. Crystallinity, tensile strength, yield strength, and fatigue strength reduced
- C. Cold irradiated subsequent melt (CISM)
  1. Gamma irradiation at room temperature
  2. Cross linking in amorphous region only
  3. Annealing (above melt temp) neutralizes free radicals
  4. Wear rate reduced
  5. Less degradation in mechanical properties than melt irradiated

III. Highly cross linked UHMWPE – Wear
- A. Hip simulator wear
  1. Decreased gravimetric wear rate
  2. More cross linking produces greater decrease in wear rate
  3. Particle size decreased
  4. No clinical results of current cross linked materials

IV. Highly cross linked UHMWPE – Mechanical Properties
- A. Static properties
  1. Ultimate tensile strength and yield strength decreased
  2. Static properties meet ASTM standards
- B. Fatigue strength
  1. Resistance to crack propagation decreased
  2. More cross linking produces greater decrease in fatigue strength
  3. Recent concern for surface cracks

V. Highly cross linked UHMWPE – Clinical applications for patient
- A. Hips
  1. May significantly improve wear rate in vivo
  2. Biologic effects of smaller particles unknown
  3. Stable liner locking mechanisms to avoid mechanical failure
- B. Knees
  1. May be beneficial in mobile bearing knee replacements
  2. Decreased fatigue strength may lead to mechanical failure in fixed bearing tibial components
- C. Controlled studies
  1. Several controlled studies becoming available demonstrating 50 to 80 percent less wear with crosslinked polyethylene.

REFERENCES:

1. Sutula LC, Collier JP, Saum KA, Currier BH, Currier JH, Sanford WM, Mayer MB, Wooding RE, Sperling DK, Williams IR: The Otto Aufranc Award. Impact of gamma sterilization on clinical performance of polyethylene in the hip. Clin Orthop 319:28-40, 1995.
2. McKellop H, Shen FW, Lu B, Campbell P, Salovey R: Development of an extremely wear-resistant ultra high molecular weight polyethylene for total hip replacements. J Orthop Res 17:157-167, 1999.
3. Baker DA, Hastings RS, and Pruitt L: Study of fatigue resistance of chemical radiation crosslinked medical grade ultrahigh molecular weight polyethylene. J Biomed Mater Res 46:573-581, 1999.
4. Bohl JR, Bohl WR, Postak PD, and Greenwald AS: The Coventry Award. The effects of shelf life on clinical outcome for gamma sterilized polyethylene tibial components. Clin Orthop 367:28-38, 1999.

METAL-METAL: PRO'S AND CON'S

Thomas P. Schmalzried, MD

There is now more than a decade of experience with second generation metal-metal bearings that have been combined with a variety of different total hip replacement and hip resurfacing systems. In aggregate, there is no discernable difference in pain relief or function or any other clinical outcome compared to hips with an UHMWPE bearing. Osteolysis can occur but the incidence is low. Given similar manufacturing parameters, the wear of a metal-metal bearing decreases with increasing head size: metal-metal favors large diameters. The in vivo wear performance has closely followed that predicted by wear simulator studies: wear rate during the run-in period is variably higher than the subsequent steady-state wear rate. In general, volumetric wear is a fraction of that seen with UHMWPE but is higher than that of well-functioning ceramic-ceramic bearings. There have been no reported cases of run-away wear or any type of gross material failure of the bearing.

There are measurable increases in the levels of cobalt and chromium ions in the red blood cells, serum and urine of patients with a metal-metal bearing. The clinical significance of this finding has not been determined. The cellular response to metal wear particles is predominantly lymphocytic, resembling an immune response more than a foreign-body response. Delayed-type hypersensitivity or DTH, a rare allergic reaction to metal haptens, may occur more frequently in association with metal-metal bearings and may rarely necessitate revision surgery. The aggregate clinical data do not indicate an increase in the risk of cancer associated with metal-metal bearings. Detailed clinical studies over several decades are needed to fully assess the risk:benefit ratios of the available bearing couples.

REFERENCES

Heisel, C.; Silva, M. and Schmalzried, T.P.: Bearing surface options for total hip replacement in young patients. J. Bone Joint Surg. 85-A: 1366-1379, 2003.

Tharani, R. Dorey, F. J. and Schmalzried, T.P.: The risk of cancer following total hip or total knee replacement. J. Bone and Joint Surg. 83-A:774-780, 2001.

TOTAL HIP ARTHROPLASTY USING CERAMIC BEARINGS

William J. Hozack, MD

1. Weak Link
- a. Complications – 1970's
- b. Loosening – 1980's
- c. Wear – 1990's

2. Choices
- a. Crosslinked poly – this is a new material
- b. Metal on metal – systemic effects, runaway wear
- c. Ceramic on ceramic
- d. Wear is the ultimate issue!

3. Ceramic advantages
- a. Wear reduction – ceramic on ceramic is best without question
  - Extreme harness/scratch resistant
    - Low co-efficient of friction
    - Hydrophilic = improved lubrication
      - Can use larger diameter femoral heads
    - No potential for metal ion release

4. Ceramic disadvantages
- a. Fracture – not really an issue
- b. Stripe wear – related to subluxation

5. Technical issues

I. Ceramic Rim Protection
- a. Critical design issue
- b. Avoids alumina ceramic impingement on femoral neck which avoids ceramic chipping or notching of the weaker/softer femoral neck

II. Socket Preparation
- a. 40°-45° abduction & 25° anteversion assuming a femoral anteversion of 15° for a combined anteversion of 40° may be desired to maximize functional ROM before impingement

III. Placement of Femoral Head
- a. Used only with design specific femoral stem
- b. Placed on a clean trunion free of debris
- c. Fully seat before impaction
- d. Preoperatively plan for limited neck length selection

IV. Femoral component selection
- a. Reduced femoral neck diameter to minimize impingement
- b. Variable offset to maximize stability, and minimize impingement

6. Clinical results

ABC series

I. A New Experience with Alumina Ceramic Bearings
- a. Alumina ceramic study group (10/96-2/03) >1300 alumina ceramic bearing implants with no ceramic device related failures
- b. US IDE ABC System study design – prospective, controlled, randomized, multi-center, 2-yr. period implanted 514 hips comparing Al/Al bearings to CoCr/poly bearings (10/96-11/98)
- c. 3 cup designs - 2 with alumina-alumina randomized with 2/3 chance for alumina bearing & 1/3 chance for control CoCr on poly
- d. Demographics – no significant difference between ABC I, II, III
  1. ABC I – porous coated Ti socket with alumina insert & alumina femoral head
  2. ABC II – arc deposited Ti socket with HA coating & alumina insert & alumina femoral head
  3. ABC III - porous coated Ti socket with CoCr on poly
  4. All pts. received the same alumina femoral head & an Omnifit tapered Ti femoral stem

Clinical Data

I. 3-5 yrs. – No Significant Difference in Clinical Outcome
- a. Complications – revisions 16 = 2.6%
- b. Dislocations = 17 = 3.3% 1. 10 (2.9%) in alumina Systems I & II 7. 7 (4.2%) in control series
- c. Ceramic fx = 0
- d. Peripheral alumina ceramic insertional chip = 9

II. Revisions: Alumina Systems I & II = 6/349 = 1.7%
- a. 1 femur at 1 mo. p.o. femoral fx. (trauma)
- b. 1 femur at 4.6 yrs. for progressive subsidence that began at 6 mos. following trauma
- c. 1 acetabulum for recurrent dislocation
- d. 2 for sepsis
- e. 1 for suspected sepsis

III. Revision: System III Control = 10/166 = 6%
- a. 1 femur p.o. traumatic femoral fx.
- b. 1 femoral leg length discrepancy
- c. 1 sepsis
- d. 4 acetabular inserts for recurrent dislocation
- e. 2 acetabular components for aseptic loosening with 1 for linear wear & osteolysis at 5 yrs.

Radiographic results

I. Only statistically significant difference between Systems I, II & III is the absence of reactive lines around System II sockets, an arc deposited Ti surface with HA. Systems I & III (porous coated Ti sockets has 25-30% reactive lines.

II. Wear & Osteolysis
- a. 0% in Systems I & II (alumina bearing series)
- b. 2.4% proximal femoral lysis in System III (CoCr on poly control)

TRIDENT series

I. Prospective, Controlled, Nonrandomized, 6 Surgeons Implanted 209 Hips from 1998-2000

II. Demographics No Different Than Systems I, II & III

III. Clinical Results No Different Than Systems I, II & III

IV. Revisions
- a. 1 acetabular revision for loosening in 6 mos. (excessive cup anteversion with cup impingement)
- b. 2 femoral revisions for p.o. traumatic fx.
- c. 3 acetabular revision for recurrent dislocation = 1.4%

V. Ceramic Fx = 0

VI. Intraoperative Insertional Chips = 0

VII. Advantages of Trident Over ABC
- a. Trident has preassembled Ti sleeve around alumina insert
- b. More revision options (modular poly or reinsertion of Trident insert)
- c. No risk of peripheral chips – Trident has alumina insert encased in a Ti sleeve
- d. burst strength of acetabular component

7. Summary

I. Alumina Ceramic Bearings of Today Are of High Quality
- a. They have significantly less wear
- b. Superior lubrication

c. No potential for metal ion release
d. Increased ROM
e. Avoids the potential risks of material changes of cross-linked polys

II. Alumina Ceramics Are Mated with Design Specific Implants
a. Implants that have excellent fixation records
b. Implants that have high taper tolerances
c. Implants that provide for ceramic rim protection

III. All Ceramic Components Proof-tested for Burst Strength Prior to Shipping

IV. Ceramic Fracture Is No Longer an Issue

V. Alumina Ceramic Bearings Today Provide a Viable Option for the Younger & More Active

CHOICES OF FEMORAL HEAD SIZE: ADVANTAGES OF 28 MM OR SMALLER

John J. Callaghan, MD

Charnley championed small head sizes in total hip replacement because of their low frictional torque around the acetabular implant. Mueller championed larger head sizes because of the larger surface area of contact provided at the bearing surface when larger heads were utilized.

Initial wear data of intermediate term follow-up radiographs demonstrated higher volumetric wear in cases with 32-millimeter head components and higher linear wear in cases with 22-millimeter head components. The volume of the particulates from polyethylene wear are now known to be the most important factor in producing osteolysis in the total hip arthroplasty construct. The recent implant retrieval data demonstrates an increase in volumetric wear with increasing head size. In addition computational finite element analysis confirms these studies. Finally wear simulator studies are in agreement with these findings. The reason for the decrease in wear with smaller head sizes is related to the decrease in sliding distance of a smaller head compared to a larger head throughout the gait cycle. Although the wear rates are lower with hyper crosslinked polyethylene wear, the rate with these materials still increases with head size in wear hip simulators. Our long-term data for both cemented and cementless implants demonstrate a lower volumetric wear rate in implants with smaller head sizes.

The concern with smaller head sizes is their property for instability and dislocation especially in the modular component era because of the relatively smaller femoral head to neck ratio created by the modular tapers. However the manufacturers are addressing this concern with dislocation friendly designs of femoral tapers and acetabular component chamfers. The surgeon should also be aware that although cup impingement is greater with smaller head sizes, bony impingement is greater with larger head sizes.

REFERENCES:

1. Callaghan JJ, Brown TD, Pedersen DR, Johnston RC: Choices and compromises in the use of small head sizes in total hip arthroplasty. Clin Orthop & Rel Res. 405:144-149, Dec. 2002.
2. Bartz RL, Noble PC, Kadakia NR, Tullos HS: The effect of femoral component head size on posterior dislocation of the artificial hip joint. J Bone Joint Surg 82A:1300-1307, 2000.

LARGE HEAD SIZES IN TOTAL HIP ARTHROPLASTY

William J. Maloney, MD

Volumetric wear of polyethylene is the critical factor in determining prevalence of osteolysis and the longevity of total hip arthroplasty. However, in the short run dislocation is the number one problem in total hip replacement. For that reason, the use of large femoral heads is attractive from a short-term standpoint as it improves range of motion, reduces impingement and thus should have a positive effect on dislocation, especially in high-risk patients.

With conventional polyethylene, increasing the head size has been associated with increase in volumetric wear. This is obviously undesirable and for many surgeons in the 90's 32 mm heads were abandoned in favor of 28 mm heads and in some cases 26 or 22 mm heads. Another consequence of using larger heads had previous to the current generation of implants is that the polyethylene liners associated with large heads were relatively thin.

With the development of highly cross-linked polyethylene, there has been a resurgence in the interest of large femoral heads. Laboratory analysis of the effect of head size on wear of both conventional and highly cross-linked polyethylene has been performed. The results are with conventional polyethylene support clinical studies that suggest that there is an increasing rate of volumetric wear with increasing head size. However, with highly cross-linked polyethylene, wear seems to be relatively insensitive to femoral head size with femoral heads up to 46 mm in diameter.

Based on this data, it appears that highly cross-linked polyethylene may allow the surgeon to once again consider using large femoral heads. Large femoral heads have several advantages when it comes to hip stability. These include a reduction in implant on implant impingement, increased translation required for dislocation, and the need for a larger soft tissue potential space for actual dislocation. The advantage of large femoral heads for the treatment of dislocation has been well documented. Thus for cases at high-risk for dislocation which include the elderly, cognitively impaired or neurologically impaired patients, as well as those patients undergoing revision surgery, one may once again consider the use of large femoral heads.

A more recent analysis has examined the effect of large femoral heads on hip stability as it relates to acetabular component position. The benefit of increasing head size on hip stability decreases as socket abduction ankle increases. In addition, as the socket becomes more abducted, the forces on the polyethylene can exceed the strength of the material. Malposition cups should be reused.

WHY I PREFER CEMENTED FEMORAL COMPONENTS IN SOME PATIENTS

Thomas S. Thornhill, MD

I Results of Primary Cemented Total Arthroplasty

A. Early Results-cemented
-acetabular failure -30-50% at 10-14 years
-femoral failure -20-30% at 5 years
-30-40% at 10 years

B. Improvements in cement technique
-improved stem design for cemented application
-improved femoral canal preparation
-pulsatile lavage
-distal plugging
-porosity reduction

C. Current U.S. Long Term Results-Cemented
Mancuso et al. J Arth 12(4) Jun 97-Patient Satisfaction: THR
-180 pts 2 yrs post-op (HSS)
-89% satisfied
-Lower satisfaction if
-less preoperative loss
-nonessential demands
-worse post-op function
-50% referred by patient/friend
-64% would refer others for surgery

Maloney and Harris- 105 hips/93 pts. 10-12.7 yr f/up
-femoral loosening- 3 loose/2.8% (24 possibly loose)
-acetabular loosening-42%

Eftekhar-1009 Charnley LFA THRS. 5-15 yr f/up
-over all failure rate of 4.5%
-higher incidence of late failure in the acetabulum
-poor pressurization, elasticity of pelvis.

Bosco- High modulus design (HD2,CAD). 86 hips 6.7 yrs f/up
-cement gun, 2nd gen. design, distal plug (1979-82)
-19 excellent; 44 good; 15 fair; 11 poor

-Survivorship	5 year	10 year
Acetabulum	97%	58%
Femur	93%	78%
Combined	91%	50%

Mulroy, Harris: JBJS 77 (12) 1995-Cemented THR Results
-Grit blasted stem – HD2
-162 hips (149 pts)
-51 patients died (60 hips)
-102 hips (90 pts): min. 14 yr F/up
-8 (10%) acetabular revision: 42% loose
-2% femoral loosening

Madey, Callaghan, Johnston et al. JBJS-A 79(1) Jan 1997-Long Term Charnley Results
-357 Charnley LFA (320) pts
-2nd generation cement technique
-189 pts (214 hips) died/1 lost
-130 pts (142 hips) available at 15 yrs
-356 hips with follow-up
-Acet loosening
-12% in whole group(356 hips)
-22% at 15 yrs(142 hips)
-Femoral loosening
-10(3%) in whole group
-6 (5%) at 15 years

II. Hybrid Hip Arthroplasty-Cemented Femur; Uncemented Acetabulum

A. Rationale
Difference in long term results with late socket loosening

B. Early Results-Hybrid
Wixson et al-131 pts 2-4 yr f/up
- uncemented femur in men <70 yrs, women <60 yrs and good bone quality.
- no clinical difference in cemented, uncemented and hybrid except;
  - 2/65 loose uncemented femurs(one revised)
  - 24% incidence of thigh pain at one yr in the uncemented group
  - higher incidence of migration and radiolucencies in the cemented sockets

Maloney and Harris-25 hybrid /25 uncemented min. 2 yr HHS 96 for hybrid, 84 for cementless ($p<0.02$) uncemented group had 24% thigh pain, 5 migrated, 4 revised.

Callaghan, Johnston: Clin Orthop 1997-THR in the Young Patient (<50 yo)
-93 cemented hips (20 yr f/up)
-5% femoral loosening
-19% acetabular loosening
-45 hybrid hips (5–10 yr f/up)
-18% femoral loosening
-0% acetabular loosening
-Current technique is hybrid with uncemented acetabulum with Charnley type polished stem.

-Early Cemented Stem Failure
-Stem debonding
-Surface finish
-Stem geometry
-Cement mantle

Verdonschot, Huiskes:J. Biomech 1997-Stem Debonding
-Finite element analysis
-Increases initial stresses
-Fourfold increase in failure
-Promotes pathway for debris

-Surface Finish
-Polished
-Matte finish
-Bead blasted
-Grit blasted
-RA (avg roughness µin)

Stem Geometry
-Influence of surface finish on subsidence
-1st order effect
-tapered stem
-2nd order effect
-"Charnley stem"

Cement Mantle
-Increased failure with
-Thin mantle
-Mantle fracture
-Weak perimantle bone

Early Loosening with Precoat Stems
-Callaghan

-Rubash
-Coutts, Santore

Santore, Coutts: Intl Soc Tech Arth 1997-Early Loosening with Precoat Stems
-110 THR (101 patients)
-4 deaths, 8 lost
-90 hips (89 patients)
-10 failures (11.4%) at 32.8 mos ave f/up
-Prosthesis cement Gruen 1 failure

Early Failure of Cemented Femoral Stems
84 Centralign femurs (76 patients)
ave flu 35.8 mos, ave age 48.2 yrs
10 loose (12%)
9 revised (11%)
failed by debonding
Sylvain, Kassib, Coutts, Santore
J Arthroplasty 16(2):141-8
Feb 2001

Early Loosening with Precoat Stems
-Associated factors
Inadequate cement mantle
Increased surface finish
Stem design
Small flexible stems
Precoat debonding

Grit Blasted vs. Pre-coat In Cemented Total Hip Replacement
-Iowa Hip
-36 hips (25 pts) bead blasted (0.8um)
-45 hips (37 pts) grit blasted pre coated (2.1um)
-Average follow up 11.3 years beaded blasted, 8.2 years precoated
-Revised or radiographically loose
4/36 (11%) bead blasted
11/45 (24%) pre coat (p = .007)

Sporer SM, Callaghan JJ., et al
J Bone Joint Surg Am 1999 Apr;81(4):481-92

III Results of Uncemented THR

Most investigators agree that uncemented femoral stems
-are technically more demanding
-require immediate stability in host bone
-transfer load by spot welding at endosteal cortex
-have a higher incidence of thigh pain postoperatively.

Engh et al. JBJS-A 79(2) Feb 1997- Uncemented THR-AML Long Term
- 223 hips (215 pts)
- 55 yr ave age (16-87 yrs)
- 21 lost, 27 died (174 hips left)
- 11 yr ave f/u (10-13 yr)
- 97% stem survival
- 92% cup survival

Bugbee, Engh et al. JBJS-A 79(7) July 1997- Uncemented THR- AML
- 48/207 hips (23%) showed stress shielding
- 10 yr minimum f/up
- No increase in loosening, pain, lysis in stress shielded stems

Capello et al. JBJS-A 79(7) Jul 1997-Uncemented THR-HA
-133 pts (152 hips)
-6.4 yr mean f/u (5-8.3 yr)
-Harris Hip Score 47Æ 93
-2 thigh pain
-32% Gruen 1,7 lysis
-One distal lysis
-All stems osseointegrated

Dorr et al. CORR (336) March 1997-THR in patients 65 yrs & older
- 89 hips (79 pts.)
- 5-9 yr f/up
- 22% died, 38% function limiting medical problems
- 10% with hip limitation (all cementless implants)

IV Options for fixation

Cemented
-acetabulum
metal backed
polyethylene
-Femur
collared, collarless

Uncemented
-acetabulum
threaded
porous coated
press fit
screws
spikes/tabs
-femur
collared, collarless
titanium, cobalt chrome
unitized, modular
proximal, 2/3's, fully porous coated

V Author's preference

There is a role for both cemented and uncemented THR. In virtually every case the acetabular component should be uncemented.

Threaded cups should be avoided. A porous coated, under-reamed cup should be press fit with ancillary screws if necessary. In elderly,sedentary individuals or those with type C bone, the femoral component should be cemented. A collared cobalt chrome implant is preferable for cemented situations. In young active people with good bone (Type A or B) the femoral component should be uncemented. A straight, collarless proximally porous titanium stem with proximal fit and distal fill is preferred for uncemented arthroplasty.

MECHANICAL PROPHYLAXIS IS SUFFICIENT FOR PRIMARY AND REVISION THR

Paul F. Lachiewicz, MD

- **Venous Thromboembolism**
  - Virchow's Triad
    venous stasis
    intimal injury
    hypercoagulable state
  - Genetic predisposition?
  - Relationship between deep vein thrombosis and pulmonary embolism with joint arthroplasty patients is controversial

- **Virchow's Triad**
  Activation in THR
  - Hip dislocation → kinking femoral vein
  - Femoral canal preparation → kinking femoral vein
  - Decrease antithrombin III levels
  - Activation clotting cascade during femoral canal preparation

- **Thromboembolism after THR**
  - Specific localized disorder in most THR patients
  - So-called classic risk factors for DVT do not correlate with DVT-PE in these patients
  - Perhaps, "localized" rather than system prophylaxis should be strongly considered

- **Goals of Prophylaxis**
  - Decrease prevalence of
    symptomatic DVT
    symptomatic PE
    fatal PE
  - Avoid bleeding complications
  - Easy for patient and surgeon

- **Pulmonary Embolism-THR**
  Historical Controls

Johnson et al (Charnley)	7,959 hips P.E. 7.9% Fatal P.E. 1.04%	Coventry et al (Mayo)	2,012 hips Fatal P.E. 3.4% (no prophylaxis) Delayed warfarin P.E. 2.2%

- **THR**

	Then	Now
Bed rest	1 week	<1 day
Hospital stay	2-3 weeks	1-4 days
EBL (mean)	1650 ml	300-600 ml
Blood	Homologous	Autologous
Transfusion	1144 ml	0-500 ml
Anesthesia	General	Regional

  – These changes suggest that our older ideas about chemoprophylaxis should be reconsidered in 2004.

- **THR Contemporary Techniques**
  No DVT Prophylaxis
  - U.K. data – Fatal P.E.
  Warwick0.34% (1162 hips)
  Murray 0.12% (130,000)
  Fender 0.19% (2111)
  - Perhaps, the routine use of pharmacologic prophylaxis to prevent death after THR should be reconsidered

- **Thromboembolism THR**
  Anesthesia
  - Spinal or epidural anesthesia reduces risk by 40-50%
  - Thrombi begin during surgery
  - Regional anesthesia increased blood flow in lower extremities during and after the procedure

- **Risk Factors DVT-THR**
  - Duration of operation
  - Genetics - Factor V Leiden; other (?)
  - Prior history DVT-PE (?)
  - History of cancer (?)
  - Classic risk factors (?)
  - Autologous donation reduces risk ?

- **Autologous Donation**
  - Retrospective study 2043 patients
  - Donation 1037; not 1006
  - DVT Donation 9% (p=0.003)
    (venogram) Not 13.5%
  - P.E. Donation 0.3% (ns)
    (clinical) Not 0.7%
  Bae et al JBJS (B) 2001

- **With contemporary techniques, mechanical prophylaxis is sufficient for primary and revision total hip arthroplasty**

- **Mechanical Prophylaxis THR**
  - Intermittent calf & thigh pneumatic compression
  - Begin use intra-op when thrombi begin!
  - Postop - RR and until discharge

- **Mechanical Prophylaxis THR**
  - Intraop use
  - Does not interfere with positioning, exposure, etc.

- **Mechanical Prophylaxis THR**
  - Intra-op and post-op IPC is specific localized prophylaxis:
  - Decreased venous stasis
    increase venous velocity
    increase venous volume

- **Mechanical Prophylaxis THR**
  - Intra-op and post-op IPC is specific localized prophylaxis:
    Inhibits coagulation cascade
    increase tissue factor pathway inhibitor
    decline factor VIIa
    increase nitric oxide and endogenous NO synthase

- **Mechanical Prophylaxis THR**
  - Wide variety of devices
    thigh-calf
    calf
    foot pump
  - Each device has its own mechanics and resultant change in peak venous velocity and venous volume
  - Optimal characteristics of pneumatic compression are not known

- **Venous Hemodynamics after THR**
  - Devices that provide for rapid inflation time produced the greatest increase in peak venous velocity
  - Devices that compress calf and thigh showed the greatest increase in venous volume

- **Mechanical Prophylaxis THR**
  Efficacy

Woolson & Watt JBJS 1991
- Prospective, randomized
- 3 Groups IPC alone
IPC + aspirin
IPC + warfarin
- 70 hips per group
- No difference in prevalence of DVT in 3 groups

- **Mechanical Prophylaxis THR**
Efficacy
Woolson JBJS 1996
- Prospective, consecutive
- 322 hips
- Ultrasonography
- 6% proximal DVT
4% regional
11% general (p=.02)
- Excluded "high risk" patients

- **Mechanical Prophylaxis THR**
Efficacy
Hooker, Lachiewicz, Kelley JBJS 1999
- Prospective, consecutive
- 502 hips
- Ultrasonography
- Risk factors 54% at least 1, 13% 2 or more
- Regional anesthesia 88%
- Hybrid hip 70%

- **Mechanical Prophylaxis THR**
Efficacy
Hooker, Lachiewicz, Kelley JBJS 1999
- Symptomatic DVT 0
- Asymptomatic DVT 4.6%
- Pulmonary embolism 0.6%
- Late DVT 0.6%
- No correlation between DVT and gender, age, risk factors

- **Mechanical Prophylaxis THR**
Efficacy
New data from UNC 2003
- Prospective, consecutive
- 1074 hips
- 35 thrombi (3.3%)
- 4 P.E. (0.4%)
- Late DVT 0.8%

- **Symposium**
Thromboembolism Prophylaxis
Mechanical Prophylaxis
- 8 studies
- 48-502 patients IPC
- Overall DVT 5-27%
- Proximal DVT 0-17%
- Pulmonary embolism 0-1%
Salvati et al JBJS 2000

- **Mechanical vs Chemoprophylaxis**
- Warfarin vs IPC
- 201 patients: venography
- Proximal thrombi 3% warfarin
12% IPC
- Calf thrombi 21% warfarin
12% IPC
*However, thigh cuff folded down and not used intraop!
Francis et al JAMA 1992

- **DVT Surveillance**
- Duplex ultrasonography screening has a role in prophylaxis
- Variable institutional sensitivity and specificity
- Proximal, asymptomatic thrombi are treated
- Others, aspirin is recommended after discharge for 6 weeks

- **Personal THR Mortality**
Nunley and Lachiewicz J Arthro 2003
- 1108 hips
- 30 day mortality 0.27%
- 90 day mortality 0.36%
- No fatal P.E.
- Symptomatic P.E. 0.7%

- **Future of Mechanical Prophylaxis THR**
- Pre-op genetic screening to defect highest risk patients
- Definition of most effective pumping pressure and duration for total hip patient
- Improved devices

- **Conclusion**
- Mechanical prophylaxis is safe, effective and acceptable for total hip patients
- Begin use intraoperatively!
- Use regional anesthesia
- Aspirin after discharge (?)
- Reasonable alternative to any chemoprophylaxis

REFERENCES

1. Antiplatelet Trialists' Collaboration: Collaborative overview of randomized trials of antiplatelet therapy.III. Reduction in venous thrombosis and pulmonary embolism by antiplatelet prophylaxis among surgical and medical patients. British Med J 308:235-246, 1994.
2. Bae H, Westrich GH, Schulco TP, Salvati E: Effect of preoperative donation of autologous blood on deep venous thrombosis in total hip arthroplasty. In abstracts for the Eastern Orthopaedic Association. J Bone Joint Surg 81-A:adv. 10, April 1999.
3. Westrich GH, Farrell C, Bono JV, Ranawat CS, Salvati EA, Sculco TP: The incidence of venous thromboembolism after total hip arthroplasty. A specific hypotensive epidural anesthesia protocol. J Arthroplasty 14:456-463, 1999.
4. Woolson ST: Intermittent pneumatic compression prophylaxis for proximal deep venous thrombosis after total hip replacement. J Bone Joint Surg 78-A:1735-1740, 1996.
5. Woolson ST, Watt JM: Intermittent pneumatic compression to prevent proximal deep vein thrombosis during and after total hip replacement. J Bone Joint Surg 73-A:507-512, 1991.
6. Nunley RM, Lachiewicz PF: Mortality after total hip and knee arthroplasty in a medium-volume university practice. J Arthroplasty 18(3):278-285, 2003.
7. Westrich GH, Specht LM, Sharrock NE, Sculco TP, Salvati EA, Pellicci PM, Trombley JF, Peterson M: Pneumatic compression hemodynamics in total hip arthroplasty. Clin Orthop 372:180-191, 2000.
8. Fender D: Harper WM, Thompson JR. Gregg PJ: Mortality and fatal pulmonary embolism after primary total hip replacement. Results from a regional hip register. J Bone Joint Surg 79-B(6):896-899, 1997.
9. Francis CW, Pellegrini VD Jr, Marder VJ, Totterman S, Harris CM, Gabriel KR, Azodo MV, Leibert KM: Comparison of warfarin and external pneumatic compression in prevention of venous thrombosis after total hip replacement. J Am Med Assn 267:2911-2915, 1992.
10. Hooker JA, Lachiewicz PF, Kelley SS: Efficacy of prophylaxis against thromboembolism with intermittent pneumatic compression after primary and revision total hip arthroplasty. J Bone Joint Surg 81-A:690-696, 1999.
11. Murray DW, Britton AR, Bulstrode CJK: Thromboprophyalxis and death after total hip replacement. J Bone Joint Surg 78-B(6):863-870, 1996.
12. Sharrock NE, Go G, Harpel PC, Ranawat CS, Sculco TP, Salvati EA: Thrombogenesis during total hip arthroplasty. Clin Orthop, 319:16-27, 1995.
13. Warwick D, Williams MH, Bannister GC: Death and thromboembolic disease after total hip replacement. A series of 1162 cases with no routine chemical prophyalxis. J BoneJoint Surg 77-B(1):6-10, 1995.
14. Salvati EA, Pellegrini VD, Sharrock NE, Lotke PA, Murray DW, Potter H, Westrich GH: Recent advances in venous thromboembolic prophylaxis during and after total hip replacement. J Bone Joint Surg 82-A:252-270, 2000.

THE CASE FOR CHEMOPROPHYLAXIS FOR DVT

M. E. Cabanela, MD

1. Few topics have:
   -- been investigated so extensively
   -- elicited more emotion
   -- produced diametrically opposed views

2. General agreement exists over these facts
   -- prevention of DVT after joint replacement is important
   -- it should be left to the orthopedic surgeon
   -- if this complication occurs, surgeon should be involved in its management
   -- any prophylaxis attitude will have literature support

3. Prospective clinical trials show repetitively an incidence of DVT of 40-60% in patients who do not receive prophylaxis and an incidence of PE of 2-38% and of fatal PE of 0.1-2%. Most symptomatic events occur after discharge from hospital. VTE is the commonest cause of hospital readmission after THR.

4. A recent study of 9791 patients who underwent hip and knee arthroplasty at our institution showed that obesity, poor ASA physical status classification and lack of thromboprophylaxis were independent risk factors for clinically relevant thromboembolic events.

5. Prophylaxis of VTE is advisable. While mechanical means provide some risk reduction in geneneral, protection against proximal DVT with intermittent compression, foot pumps and similar means is less than with chemoprophylaxis. Low molecular weight heparin, vitamin K antagonists (Coumadin) or fondaparinux are the recommended pharmacological agents by the AACP.

TECHNIQUES IN REVISION TOTAL HIP ARTHROPLASTY: VIDEO TECHNIQUES SHOWING HOW TO DO IT SAFELY, EFFECTIVELY AND EFFICIENTLY (L)

Moderator: David G. Lewallen, MD, Rochester, MN (a, b, c – Implex, Zimmer)

Techniques to perform revision THA have advanced rapidly. This symposium will highlight newly developed revision techniques with video by experts demonstrating how to perform the most import aspects of revision THA safely, effectively and efficiently. The program will be fast paced and will provide participants with many technical tips and pointers.

I. Techniques in Revision Total Hip Arthroplasty
David G. Lewallen, MD, Rochester, MD (a, b, c – Implex, Zimmer)

II. Extended Osteotomy
Wayne G. Paprosky, MD, Winfield, IL (c - Zimmer)

III. Extended Osteotomy: Variations
Daniel J. Berry, MD, Rochester, MN (a, c – DePuy)

IV. Getting Out Well-Fixed Uncemented Cups
Harry E. Rubash, MD, Boston, MA (a, e – Zimmer)

V. Cemented Liners
William A. Jiranek, MD, Richmond, VA (n)

VI. Jumbo Cups for Large Defects: Methods that Make Them Work
John J. Callaghan, MD, Iowa City, IA (a, b, c, e – DePuy, Zimmer)

VII. Jumbo Cups with Augmentation (Cage, Metal Augments)
David G. Lewallen, MD, Rochester, MN (a, b, c – Implex, Zimmer)

VIII. Triflange Cups
Michael J. Christie, MD, Nashville, TN (a – DePuy)

IX. The Femur: Getting Out Well-Fixed Stems
Andrew H. Glassman, MD, Columbus, OH (n)

X. Extensively Coated Stems: Tips to Make Them Work and Avoid Complications
William J. Maloney, MD, St. Louis, MO (c – Zimmer)

XI. Impaction Bone Grafting: Tips to Make Them Work and Avoid Complications
Miguel E. Cabanela, MD, Rochester, MN (c, e – Stryker Howmedica Osteonics)

XII. Fluted Tapered Modular: Tips to Make Them Work and Avoid Complications
William J. Hozack, MD, Philadelphia, PA (n)

XIII. Allograft Prosthetic Composites: Favored Methods
Allan E. Gross, MD, Toronto, ON Canada (n)

REMOVAL OF WELL FIXED STEMS

Wayne G. Paprosky, MD

We utilize a standard posterior approach for exposure to the acetabulum and proximal femur. A surgical skin incision is made based on the posterior 1/3 of the greater trochanter and is extended distally to expose the length of the proposed osteotomy. The tensor fascia lata and the fascia of the gluteus maximus are then split in line with the surgical incision and retracted with a Charnley bow. The posterior pseudocapsule and the short external rotators are then elevated as a flap. A portion of the gluteus maximus insertion is then released to allow mobilization of the femur. The femoral head is now dislocated and the hip is placed in internal rotation. The stability of the femoral component is now assessed. If the stem is grossly loose and the greater trochanter is not preventing extrication, the component is removed. The subsequent extended trochanteric osteotomy with the stem removed is now much easier to perform. However, if the trochanter is preventing component removal or the stem is well fixed, the osteotomy is performed with the component in place. The posterior margin of the vastus lateralis is now identified and the length of the osteotomy from the tip of the trochanter is determined. The vastus lateralis is mobilized anteriorly and the distal extent of the osteotomy is marked. The femur is held in full extension and internally rotated. An oscillating saw is now used to make the longitudinal arm of the osteotomy. The saw is directed from posterolateral to anterolateral. Ideally, the osteotomy fragment should encompass the posterolateral third of the proximal femur and is oriented perpendicular to the anteversion of the hip. Proximally, the oscillating saw is angled medially so that the entire greater trochanter is included in the osteotomy. When a well-fixed component is in place, it is important to use the pencil tip burr or the oscillating saw to begin the osteotomy on the proximal medial aspect of the femur before attempting to cause a greenstick fracture of the osteotomized segment. The distal transverse limb of the osteotomy is made with the used of a pencil tip burr and the corners are rounded. This will minimize stress risers and decrease the risk of propagating a fracture. Wide osteotomes are now utilized to gently lever the osteotomy site from posterior to anterior. The greater trochanteric fragment is now retracted with the attached abductors and vastus lateralis. Since the blood supply and innervation to the vastus enters anteriorly, it is important to minimize dissection along the anterolateral limb of the osteotomy.

Once the osteotomy has been completed, the femoral component can now be visualized.

EXTENDED GREATER TROCHANTERIC OSTEOTOMY: VARIATIONS

Daniel J. Berry, MD

I. Introduction

A. Extended greater trochanteric osteotomy has revolutionized revision THA

B. Advantages in selected patients:

1. Speeds implant/cement removal
2. Allows implant/cement removal with less bone loss
3. Gets upper femur out of the way Æ allows better preparation of distal femur for distally fixed uncemented stem
4. Preserves abductor attachments Æ provides better postoperative function and potentially less dislocation risk

C. Disadvantages

1. Nonunion potential (less than 2%)
2. Potential for fracture of osteotomy fragment or femur
3. To some degree dictates choice of revision femoral component → works best with distally fixed uncemented stem.

II. Traditional Extended Trochanteric Osteotomy in North America (Paprosky)

A. 1. Posterior approach to hip
2. Lateral extended greater trochanteric osteotomy

B. While excellent, this conventional extended greater trochanteric osteotomy has drawbacks in some cases.

1. Takedown all of posterior capsule Æ even if repaired, hip stability may be decreased
2. Not optimal for placement of distally fixed straight stem.

C. In selected cases two extended greater trochanteric osteotomy variants are useful.

III. Alternative Technique: #1: Lateral Extended Osteotomy with Preservation of Posterior Capsule and Anterior Dislocation of Hip

A. Advanatages/Uses

1. Advantages: Keeps hip capsule intact, potentially improving hip stability
2. Uses: Can be used in most cases when lateral extended greater trochanteric osteotomy is desired.

*Exception: with well fixed stem that fills canal completely and doesn't allow proximal anterior osteotomy cut to be made from the back, dislocating hip posteriorly first to allow making anterior proximal femoral osteotomy cut under direct vision is advantageous.

C. Techniques

1. Patient position: lateral decubitus
2. Divide IT band, split gluteus maximus
3. Expose posterior femur joint anterior to linea aspera, and elevate vastus lateralis from femur for about 2 cm only at planned transverse osteotomy site.
4. Make straight posterior osteotomy, transverse distal osteotomy, distal anterior osteotomy (about 3 cm long). Round corners if possible using small high speed burr to make corner cuts.
5. Use saw from back to front to cut anterior greater trochanteric osteotomy. Do so by sliding saw over the lateral shoulder of implant. Be careful not to damage anterior soft tissue structures.
6. Keep posterior capsule attached to posterior greater trochanter.
7. Elevate osteotomy fragment from posteriorly with broad osteotomies, completing fracture of anterior cortex between the short anterior proximal and distal osteotomy limbs.
8. Dissect abductors off of pseudo-capsule, elevate soft tissues off of the proximal medial femoral fragment Æ this allows the osteotomy fragment to be transferred anteriorly.
9. Perform superior and anterior capsulectomy.
10. Dislocate hip anteriorly.
11. Perform hip revision with leg adducted. Insert stem with hip externally rotated and lower leg in "pocket".
12. Reattach greater trochanteric osteotomy with at least 2 cables.

IV. Alternative Technique #2: Anterior Extended Greater Trochanteric Osteotomy (Wagner)

A. Advantages/Uses

1. Advantages: Lifts anterior proximal femur out of the way → allows straight "shot" down distal femur (gets you around the bow of the femur)
2. Uses: Good approach when inserting long stem with straight distal section (such as fluted tapered stem) Æ allows you to fill the canal well without perforating distally.

B. Techniques

1. Patient position: Lateral or supine
2. Straight lateral incision
3. Split IT band, interval between gluteus maximus/tensor
4. Split abductors in line with their fibers from tip of greater trochanter to about 4 cm proximal to tip of greater trochanter.
5. Split vastus lateralis longitudinally down the center of muscle to level of desired transverse osteotomy.
6. Osteotomize lateral femur from tip of greater trochanter to level of planned transverse osteotomy.
7. Perform anterolateral transverse osteotomy (1/3 circumference of femur).
8. Make distal anterior bone cut (extending approximately 3 cm from distal transverse osteotomy) with hip externally rotated.
9. Use small narrow osteotome or drill to make line of perforations for the proximal anterior osteotomy.
10. Lift osteotomy fragment away from femur with broad osteotomes completing osteotomy. Keep muscle attached to osteotomy fragment.
11. Resect anterior/superior pseudocapsule.
12. Dislocate hip anteriorly.
13. Perform revision with hip adducted/externally rotated.
14. Reattach osteotomy fragment with 2 cables or wires, use heavy suture to repair abductors.

THE SURGICAL MANAGEMENT OF OSTEOLYTIC LESIONS OF THE PELVIS

Harry E. Rubash, MD

I. Introduction
- The treatment algorithm for osteolysis differs depending on the location of the lytic process and the type of component

II. Cemented Acetabular Components
- A cemented cup is evaluated to determine if it is loose or stable
- Loose cups should be replaced by an uncemented cup +/- a graft
- Stable cups should be assessed for wear intra-operatively
- Minimal to - no wear, elderly patient, the cup is retained
- In all other cases of revise the implant!

III. Cementless Acetabular Components
- Pelvic osteolysis in cementless acetabular components is measured in three types (see Ref. 4)
- Type I is stable – the shell is retained, the liner exchanged +/- a graft
- Type II is stable – the component is revised +/- a graft (exceptions)
- Type III is unstable – the component is revised +/- a graft

IIIA. Type I
- Retain stable ingrown shell
- +/- graft to lytic areas
  - Graft Options
    - Autograft
    - Allograft
    - Osteoset
    - Others!
- Cross linked poly insert
- Can cement liner if locking mechanism failure!

IIIB. Type II
- Revise the component +/- a graft dependent on the following criteria:
  - Malpositioned cup
  - Incompetent locking mechanism – (consider cemented liner)
  - Damaged metal shell – revise
  - Inadequate thickness of polyethylene liner
  - Implant with unacceptable track record
  - Non-modular implant (consider cemented liner)
- Retain the cup – cement liner dependent on the following criteria:
  - Well-Fixed acceptable alignment
  - Elderly/Medical morbidities
- Torsional values for liner cementation into fixed acetabular shells (see ref. 1)

IIIC. Type III
- Revise component - +/- Graft
- Often will be associated with pain
- Serial x-rays or CT Scan extremely helpful t
  - make diagnosis and plan for revision

IV. Femoral Lysis Treatment Alogorithm
- The treatment algorithm for femoral osteolysis differs depending on if the component is cemented or uncemented

IVA. Classification of Defects
- Femoral
- AAOS (COTH)
  - Segmental (cortical loss)
  - Cavitary (contained lesion)
  - Combined
  - Others (malaligned, stenosis, discontinuity)

IVB. Cemented
- Determine if the component is loose or stable
- Loose components are revised: full porous (+/- modularity)
- Stable components are debrided and grafted (unlikely)

IVC. Uncemented
- If the component is ingrown fibrous stable, debride and graft
- If the component is unstable options:
  - Cement (rare)
  - Porous: use fully porous long stem

References

1. Haft GF, Heiner AD, Callaghan JJ, Dorr LD, et al: Polyethylene Liner cementation into fixed acetabular shells. J of Arthroplasty 2002; 17(4 Suppl 1):167-170.
2. Maloney WJ, Herzwurm P, Paprosky W, Rubash HE, Engh CA: Treatment of pelvic osteolysis associated with a stable acetabular component inserted without cemented as part of a total hip replacement. J Bone Joint Surg 1997;79A:1628-34.
3. Rubash HE, Sinha RK, Paprosky W, Engh CA, Maloney WJ, A new classification system for the management of acetabular osteolysis after total hip arthroplasty. Instructional Course Lectures. 1999; 48:37-42.
4. Rubash HE. Sinha RK. Maloney WJ. Paprosky WG. Osteolysis: surgical treatment. Instructional Course Lectures. 1998; 47:321-9.
5. Sinha RK, Shanbhag A, Maloney WJ, Hasselman CT, Rubash HE. Osteolysis: cause and effect. In: Cannon WD, editor. Instructional Course Lectures. Rosemont IL: American Academy of Orthopaedic Surgeons 1998, 47: 307-20.

A NEW CLASSIFICATION SYSTEM FOR THE MANAGEMENT OF ACETABULAR OSTEOLYSIS AFTER TOTAL HIP ARTHROPLASTY

Harry E. Rubash, MD, Raj K. Sinha, MD, PhD, Wayne Paprosky, MD, Charles A. Engh, MD, William J. Maloney, MD

Introduction

Periprosthetic osteolysis currently appears to be one of the most challenging problems that occurs after total hip arthroplasty. With increased awareness of this insidious process, joint replacement surgeons now have the ability to diagnose it with increasing accuracy and frequency.[1,2] In addition, considerable research efforts have provided an insight into the pathophysiologic mechanisms as well as the material concerns that lead to the development of osteolysis. This increased knowledge and understanding has helped institute improved methods of manufacture and implantation that will reduce the incidence of osteolysis in the future. Nevertheless, components implanted within the last 10 years continue to develop osteolysis at increasing rates, and will continue to pose surgical challenges.

The purpose of this chapter is to focus on acetabular osteolysis after implantation of cementless sockets. The original descriptions of this process were alarming, and the lesions often were mistaken for neoplasms.[3–5] Several early reports advocated complete removal of the components with revision and bone grafting if necessary.[3–5] However, through careful systematic study and increased experience at many centers, specific indications for observation, surgical intervention, and revision have been developed. The authors propose a new classification system for acetabular osteolysis around uncemented cups, and a treatment rationale based on current understanding and preliminary results.

Pathophysiology

Briefly, the osteoclastic bone resorption of osteolysis is particle-induced, macrophase-mediated, and cytokine-propagated.[1] The proposed cycle of events occurs as follows. Normal wear in a low-friction arthroplasty leads to the production of billions of particles yearly.[6] The most abundant and probably most biologically noxious particle is that of ultra-high molecular weight polyethylene (UHMWPE),[7–9] which is used to make the acetabular liner. Initially, the wear mechanism is adhesive,[6] but as increased numbers of metal and polymeric particles are generated, third-body wear predominates.[10] There are several potential sources for wear, including the irregularities in the articular surfaces of the femoral head and the polyethylene liner, and the incongruencies between the liner and the metal shell.[2] Additional sources include metallic particles produced by fretting, abrasion, and corrosion products that form at morse taper and screw-shell junctions. Eventually, clearance capabilities of the particles by the reticuloendothelial system are overcome, and the particles accumulate in large numbers and are distributed throughout the "effective joint space."[11–13] Like most foreign bodies, the particles are ingested by local macrophages, which secrete a variety of cellular mediators and cytokines. These mediators include interleukins (IL-1a and IL-6), tumor necrosis factor-alpha (TNF-a), prostaglandin E2 (PGE2), and others.[14–23] The mediators then stimulate osteoclasts to proliferate and actively resorb bone.[22,24] In severe cases, bone loss progresses to the point where the components ultimately become unstable.

An important concept to understand is that of the particle generator. This term refers to sources and causes of abnormal amounts of wear in a total hip arthroplasty. As mentioned above, a certain amount of wear is predictable even in well-functioning total hip replacements. However, excessive and accelerated wear occurs under certain conditions. Particle generators include: incongruous acetabular liner-shell interfaces;[25–27] thin polyethylene liners (< 8 mm), which are more susceptible to damage or fracture;[28] abraded polyethylene liners;[10] inferior quality polyethylene (certain batches with high numbers of asperities);[29] shelf-aged liners, which have oxidized;[30] machined polyethylene, which has inferior wear characteristics;[31,32] gamma-irradiated polyethylene, which oxidizes rapidly;[33] burnished femoral heads or implant surfaces;[34] titanium femoral heads;[35] 32-mm femoral heads;[36] damaged morse tapers on the femoral components;[37] loose or damaged porous coatings;[38] and broken cerclage wires or cable.[39] When surgical intervention is necessary, removal of the particle generators is an important part of the procedure.[2]

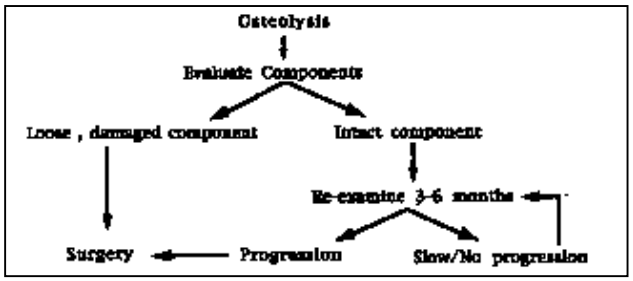


Fig. 1 Treatment algorithm for patients presenting with osteolysis. (Reproduced with permission from Rubash HE, Sinha RK, Maloney WJ, Paprosky W: Osteolysis: Surgical treatment, in Cannon WD (ed): Instructional Course Lectures 47. Rosemont, IL, American Academy of Orthopaedic Surgeons, 1998, pp 321–329.)

A general approach to the management of newly diagnosed osteolysis is outlined in Figure 1. If the components are stable and undamaged, and the osteolysis is focal, the patient can be observed initially. Serial radiographic examinations should be performed at 3- to 6-month intervals. If the osteolysis is documented to progress in size or extent, then surgical intervention should be considered. The appropriate surgical treatment depends upon the status of the cementless cup, as detailed below.

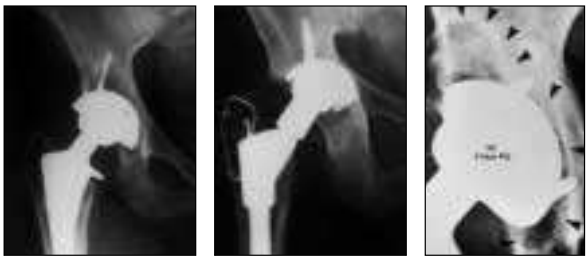


Fig. 2 Classification of acetabular osteolysis around uncemented components. **A,** Type I. Stable, functional: ingrown shell, worn polyethylene, focal lesion. **B,** Type II. Stable, damaged: nonfunctional shell due to excessive wear, broken locking mechanism, or nonmodular component. **C,** Type III. Unstable: Loosened component which has collapsed into osteolytic lesion.

Classification

Figure 2 outlines the new classification scheme for cementless sockets with osteolysis. The cups can be divided into types I, II, and III. In type I cups, the osteolysis is focal, located usually at the periarticular margins or adjacent to screws and screwholes. However, the cup itself is stable and ingrown, without radiolucencies at the implant-bone interface. Review of serial radiographs from the time of implantation to the initial appearance of the lytic lesion can be helpful in confirming whether the cup is stable or has migrated. However, though the metal shell may be stable, the polyethylene liner is worn, often visibly as detected on radiographs by the eccentric position of the femoral head within the cup. In these cases, with documented progression of the osteolysis requiring surgical treatment, type I shells can be retained because they are ingrown, are stable, and have functional locking mechanisms.

On the other hand, type II sockets must be removed. Although the radiographic appearance may be similar to that of a type I cup, at the time of surgery, type II cups are those that are found to be nonfunctional. For example, there may be excessive backsided wear of the shell, usually as a result of fracture of the polyethylene liner, or the locking mechanism may be broken (Fig. 3). In addition, nonmodular cups with excessive wear or burnishing of the polyethylene liner can be classified as type II. In both cases, the entire acetabular component must be revised.

Fig. 3 Example of Type II cup. The retrieved specimen has extensive polyethylene wear and a broken polyethylene insert.

Type III cups are those that have become unstable secondary to osteolysis. In most cases, loosening of the cup is obvious, as demonstrated by superior or medial migration of the component with change in orientation. However, in certain cases of linear osteolysis, the cup collapses into the osteolytic defect, and its stability cannot be determined on plain radiographs. However, computed tomography (CT) scans clearly show the line of demarcation between the osteolytic defect in the acetabular bone and the loose cup. All type III cups require revision.

SURGICAL TREATMENT AND PRELIMINARY RESULTS

Type I Acetabular Components

For most type I cups with documented progression of the osteolysis, surgical treatment is required. At the time of surgery, modular femoral heads should be removed to improve exposure of the acetabulum. In addition, examine the morse taper to determine whether excessive fretting corrosion has occurred. If the morse taper is undamaged, then the femoral component can be retained, provided that it is stable. Otherwise, the femoral component should generally be revised as well.

To facilitate exposure to the acetabular component, excise all scar and fibrous tissue carefully to allow visualization of the entire bony rim of the acetabulum. Subsequently, any overhanging osteophytes should be carefully osteotomized or rongeured to permit circumferential access to the liner-shell interface. In order to remove the liner, several techniques may be employed. If the manufacturer makes a specific device for removal of the liner, this device should be available. If this device is not available, backup methods are necessary. In shells that use tines for locking the liner in place, use a quarter-inch osteotome to gently pry the liner out of place. For ring-lock or cold-flow interference fit liners, carefully drill a 3.2-mm hole through the liner toward the shell (in a location where there is no screw hole). Then, insert a 4.5-mm cancellous screw through the drill hole into the liner. As the screw contacts the shell, it gently lifts the plastic liner away from the shell.

Once the liner has been removed, assess the locking mechanism to ensure that it was not damaged during liner extraction. If the locking mechanism is functional, test the shell for stability. A predictable method is to compress the shell with a ball or blunt impactor and look for fluid expressed from the interface. In addition, firmly grasp the cup rim with pliers or its concave surface through 2 screw holes with a Kocher clamp in order to twist or pull the cup out of its bony bed.

If the cup is stable, determine whether the osteolytic lesion is easily accessible. If the lesion is adjacent to a screw, carefully remove the screw. If there is no excessive bleeding, the cavity can be curetted and packed with morcellized bone graft (allo- or autograft, as available). If the lesion is not easily accessible, attempts to gain access unnecessarily may compromise stability of the cup, and therefore should be avoided. Note that although no graft can be placed in this scenario, it may not affect the eventual outcome.

The next step is reimplantation of a revision component. Insert a new modular 28- or 26-mm liner into the shell in order to maximize polyethylene thickness. Use trial femoral heads to determine the appropriate neck length needed for adequate stability. We routinely replace the femoral head, even though it may appear to be reusable. Adherence to these principles allows for uncomplicated revision of type I cups.

Type II Acetabular Components

For type II cups, exposure to the component and removal of the liner proceeds as for type I cups. Assessment of the metal shell is the next crucial step. If the locking mechanism is broken, if there is excessive back-sided wear of the shell, or if the cup is known to have a poor clinical track record, then it must be removed. Once this determination has been made, removal must be performed carefully to avoid penetration of the medial wall of the pelvis. The interface between the shell and the bony bed of the acetabulum must be clearly visualized by removing capsule, scar, and overhanging osteophytes. Specially shaped acetabular osteotomes are then used to disrupt the interface. Proceed sequentially from lateral to medial around the hemisphere of the cup. Generally, a cup cannot be removed until the interface is disrupted circumferentially for 180°, as well as all the way over to the medial quadrilateral plate. When the cup abuts the medial wall of the pelvis, the use of space-occupying tools such as gouges and osteotomes is precluded in order to prevent penetration and possible damage to underlying vessels and pelvic viscera. In this situation, the metal shell may need to be sectioned into 3 or more pieces using a metal-cutting burr and then removed piecemeal (Fig. 4). Attention to these details, along with careful preoperative preparation, helps the surgeon remove the component safely.

Fig. 4 Example of an acetabular component that has been sectioned prior to removal.

Once the component is extracted, curette all osteolytic membrane and pack the defects with morcellized graft. If there are significant rim defects that may compromise stability of the revision cup, then bulk allograft also may be necessary. In addition, pelvic discontinuity may occur and pelvic reconstruction plates or antiprotrusio cages should be available as well. After implantation of the new cup, the procedure can be completed as described above.

Type III Acetabular Components

Type III cups are unstable, and require removal. Often, in these cases, the radiograph does not show the full magnitude of the lesion, and the surgeon can rely on a computed tomogram to delineate the size and location of the defects. Although the component may be loose, it may not be easily removed. Often, as the cup migrates medially, the diameter of the mouth of the acetabulum will be smaller than that of the component. Removal of the overhanging osteophyte, as described above, opens up the mouth to expose the entire cup. In addition, dense fibrous tissue develops between the cup and the underlying bone bed. Development of the interface between the fibrous tissue and the bone may prevent unnecessary bone loss during component extraction. Once the component is removed, use hemispherical reamers to further open up the mouth in order to facilitate placement of a new porous-ingrowth shell. Adherence to meticulous techniques as described above for extraction of an ingrown cup will facilitate quick and simple removal of the loose cup. Reconstruction of osteolytic defects proceeds in a similar fashion as described above.

Particle Generators

Regarding the particle generators, several important concepts should be borne in mind. Generally, titanium monoblock femoral stems with burnished heads or stems with damaged morse tapers should be removed, especially in young, active patients. In extenuating circumstances, such as elderly or medically unstable patients, damaged stems may be retained when removal of a well-fixed stem may prolong operative time or cause excessive blood loss. A tap-out/tap-in technique can be used to remove a damaged stem with a good cement column, and then a smaller stem can be recemented.40 In addition, modular titanium heads should be replaced with cobalt-chrome heads because of superior wear characteristics. Likewise, 32-mm heads should be downsized to 28- or 26-mm heads, because the latter have been shown to result in smaller amounts of volumetric polyethylene wear. Polyethylene liners a minimum of 8 mm thick should be used, as thin liners are susceptible to fracture and accelerated wear. Damaged screws should be removed in well-fixed cups to eliminate fretting and corrosion products after the revision. Thus, exchange of the particle generators is a crucial part of the revision procedure.

Case

The patient is a 46-year-old man who underwent a primary total hip arthroplasty at age 41 secondary for end-stage osteonecrosis. At 5.5 years postoperatively, the patient was seen in the office for the gradual onset of progressive groin pain. As part of a routine evaluation, radiographs were obtained, which revealed moderate wear of the polyethylene liner without evidence of radiolucency at the implant-bone interface (Fig. 5, A). A CT scan was then obtained to further evaluate the extent of the pelvic lysis (Fig. 5, B). The CT scan demonstrated a circumferential radiolucency around the cup at the implant-bone interface with a sclerotic margin of bone, suggesting that the component was loose and had collapsed into an osteolytic defect. At revision surgery, the acetabular component was found to be loose and osteolytic defects were noted in the dome of the acetabulum with extension into the anterior and posterior columns (Fig. 5, C). The osteolytic defects were packed with morcellized femoral head allograft, and the cup was revised to a 60-mm porous ingrowth component. The patient has done well and at 6-month postoperative follow-up has no pain and has been advanced to weight-bearing as tolerated with a cane. Radiographs obtained at this time show incorporation of the allograft with the acetabular component in excellent position and without change from the initial postoperative films (Fig. 5, D).

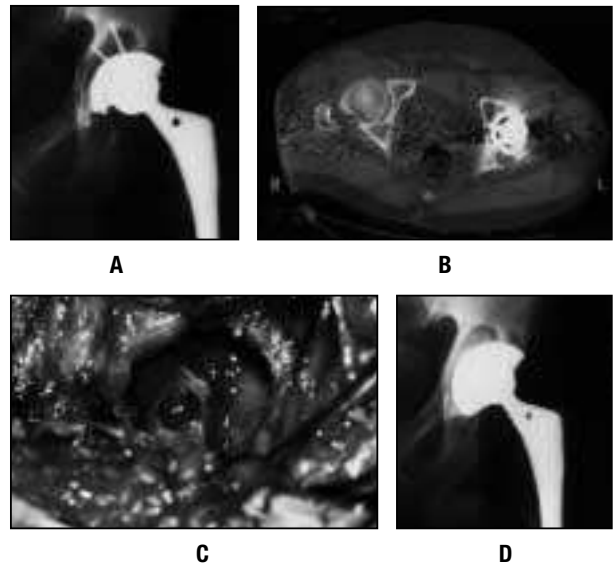


Fig. 5 Case report of a 46-year-old man with a loosened acetabular component and pelvic osteolysis. **A,** Preoperative radiograph. **B,** CT scan of the loosened component that had collapsed into an osteolytic defect. **C,** Defect seen intraoperatively. **D,** Six-month follow-up radiographs showing a stable component and allograft incorporation.

Preliminary Results

These principles have been instituted in several centers. It appears that removal of the particle generators is essential to arrest the osteolytic process in type I cups, as the use of bone graft does not necessarily determine whether the lesion will heal.41,42 However, at intermediate follow-up, there have been only rare cases of progression of the lesions after removal of the particle generators. Thus, preliminary results are encouraging that the approach outlined here will be safe and effective. Further study and review of collective experiences will help to refine the treatment approach for osteolysis in the future.

REFERENCES

1. Sinha RK, Shanbhag A, Maloney WJ, Hasselman CT, Rubash HE: Osteolysis: Cause and effect, in Cannon WD (ed): Instructional Course Lectures 47. Rosemont, IL, American Academy of Orthopaedic Surgeons, 1998, pp 307–320.
2. Rubash HE, Sinha RK, Maloney WJ, Paprosky W: Osteolysis: Surgical treatment, in Cannon WD (ed): Instructional Course Lectures 47. Rosemont, IL, American Academy of Orthopaedic Surgeons, 1998, pp 321–329.
3. Jasty MJ, Floyd WE III, Schiller AL, Goldring SR, Harris WH: Localized osteolysis in stable, non-septic total hip replacement. J Bone Joint Surg 1986;68A:912–919.
4. Santavirta S, Konttinen YT, Bergroth V, Eskola A, Tallroth K, Lindholm TS: Aggressive granulomatous lesions associated with hip arthroplasty: Immunopathological studies. J Bone Joint Surg 1990;72A:252–258.
5. Santavirta S, Hoikka V, Eskola A, Konttinen YT, Paavillainen T, Tallroth K: Aggressive granulomatous lesions in cementless total hip arthroplasty. J Bone Joint Surg 1990;72B:980–984.
6. Amstutz HC, Campbell P, Kossovsky N, Clarke IC: Mechanism and clinical significance of wear debris-induced osteolysis. Clin Orthop 1992;276: 7–18.
7. Willert HG, Bertram H, Buchhorn GH: Osteolysis in alloarthroplasty of the hip: The role of ultra-high molecular weight polyethylene wear particles. Clin Orthop 1990;258:95–107.
8. Howie DW: Tissue response in relation to type of wear particles around failed hip arthroplasties. J Arthroplasty 1990;5:337–348.
9. Gelb H, Schumacher HR, Cuckler J, Ducheyne P, Baker DG: In vivo inflammatory response to polymethylmethacrylate particulate debris: Effect of size, morphology, and surface area. J Orthop Res 1994;12:83–92.
10. McKellop HA, Campbell P, Park S-H, et al: The origin of submicron polyethylene wear debris in total hip arthroplasty. Clin Orthop 1995;311:3–20.
11. Willert HG, Semlitsch M: Reactions of the articular capsule to wear products of artificial joint prostheses. J Biomed Mater Res 1977;11:157–164.
12. Schmalzried TP, Harris WH: The Harris-Galante porous-coated acetabular component with screw fixation: Radiographic analysis of eighty-three primary hip replacements at a minimum of five years. J Bone Joint Surg 1992; 74A:1130–1139.
13. Schmalzried TP, Jasty M, Harris WH: Periprosthetic bone loss in total hip arthroplasty: Polyethylene wear debris and the concept of the effective joint space. J Bone Joint Surg 1992; 74A:849–863.
14. Thornhill TS, Ozuna RM, Shortkroff S, Keller K, Sledge CB, Spector M: Biochemical and histological evaluation of the synovial-like tissue around failed (loose) total joint replacement prostheses in human subjects and a canine model. Biomaterials 1990;11:69–72.
15. Haynes DR, Rogers SD, Hay S, Pearcy MJ, Howie DW: The differences in toxicity and release of bone-resorbing mediators induced by titanium and cobalt-chromium-alloy wear particles. J Bone Joint Surg 1993;75A:825–834.
16. Jiranek WA, Machado M, Jasty M, et al: Production of cytokines around loosened cemented acetabular components: Analysis with immunohistochemical techniques and in situ hybridization. J Bone Joint Surg 1993;75A:863–879.
17. Kim KJ, Rubash HE, Wilson SC, D'Antonio JA, McClain EJ: A histological and biochemical comparison of the interface tissues in cementless and cemented hip prosthesis. Clin Orthop 1993; 287:142–152.
18. Chiba J, Rubash HE, Kim KJ, Iwaki Y: The characterization of cytokines in the interface tissue obtained from failed cementless total hip arthroplasty with and without femoral osteolysis. Clin Orthop 1994;300:304–312.
19. Shanbhag AS, Jacobs JJ, Black J, Galante JO, Glant TT: Cellular mediators secreted by interfacial membranes obtained at revision total hip arthroplasty. J Arthroplasty 1995;10:498–506.
20. Dorr LD, Bloebaum R, Emmanual J, Meldrum R: Histologic, biochemical, and ion analysis of tissue and fluids retrieved during total hip arthroplasty. Clin Orthop 1990;261:82–95.
21. Schindler R, Mancilla J, Endres S, Ghorbani R, Clark SC, Dinarello CA: Correlations and interactions in the production of interleukin-6 (IL-6), IL-1, and tumor necrosis factor (TNF) in human blood mononuclear cells: IL-6 suppresses IL-1 and TNF. Blood 1990;75:40–47.
22. Horowitz SM, Gautsch TL, Frondoza CG, Riley L Jr: Macrophage exposure to polymethyl methacrylate leads to mediator release and injury. J Orthop Res 1991;9:406–413.
23. Blaine TA, Rosier RN, Puzas JE, et al: Increased levels of tumor necrosis factor-alpha and interleukin-6 protein and messenger RNA in human peripheral blood monocytes due to titanium particles. J Bone Joint Surg 1996;78A:1181–1192.
24. Glant TT, Jacobs JJ: Response of three murine macrophage populations to particulate debris: Bone resorption in organ cultures. J Orthop Res 1994;12:720–731.
25. Maloney WJ, Smith RL: Periprosthetic osteolysis in total hip arthroplasty: The role of particulate wear debris, in Pritchard DJ (ed): Instructional Course Lectures 45. Rosemont, IL, American Academy of Orthopaedic Surgeons, 1996, pp 171–182.
26. Chen PC, Mead EH, Pinto JG, Colwell CW Jr: Polyethylene wear debris in modular acetabular prostheses. Clin Orthop 1995;317:44–56.
27. Callaghan JJ, Kim YS, Brown TD, Pedersen DR, Johnston RC: Concerns and improvements with cementless metal-backed acetabular components. Clin Orthop 1995;311:76–84.
28. Bartel DL, Bicknell VL, Wright TM: The effect of conformity, thickness, and material on stresses in ultra-high-molecular weight components for total joint replacement. J Bone Joint Surg 1986;68A:1041–1051.
29. Li S, Chang JD, Barrena EG, Furman BD, Wright TM, Salvati E: Nonconsolidated polyethylene particles and oxidation in Charnley acetabular cups. Clin Orthop 1995;319:54–63.
30. Rimnac CM, Klein RW, Betts F, Wright TM: Post-irradiation aging of ultra-high molecular weight polyethylene. J Bone Joint Surg 1994; 76A:1052–1056.
31. Bankston AB, Cates H, Ritter MA, Keating EM, Faris PM: Polyethylene wear in total hip arthroplasty. Clin Orthop 1995;317:7–13.
32. Bankston AB, Keating EM, Ranawat C, Faris PM, Ritter MA: Comparison of polyethylene wear in machined versus molded polyethylene. Clin Orthop 1995;317:37–43.
33. Sutula LC, Collier JP, Saum KA, et al: Impact of gamma sterilization on clinical performance of polyethylene in the hip. Clin Orthop 1995; 319:28–40.
34. Dowson D, Taheri S, Wallbridge NC: The role of counterface imperfections in the wear of polyethylene. Wear 1987;119:277–293.
35. McKellop HA, Sarmiento A, Schwinn CP, Ebramzadeh E: In vivo wear of titanium-alloy hip prostheses. J Bone Joint Surg 1990;72A: 512–517.
36. Livermore J, Ilstrup D, Morrey B: Effect of femoral head size on wear of the polyethylene acetabular component. J Bone Joint Surg 1990; 72A:518–528.
37. Jacobs JJ, Skipor AK, Doorn PF, et al: Cobalt and chromium concentrations in patients with metal on metal total hip replacements. Clin Orthop 1996;329(suppl):S256–S263.
38. Sychterz CJ, Moon KH, Hashimoto Y, Terefenko KM, Engh CA Jr, Bauer TW: Wear of polyethylene cups in total hip arthroplasty: A study of specimens retrieved post mortem. J Bone Joint Surg 1996;78A:1193–2000.
39. Silverton CD, Jacobs JJ, Rosenberg AG, Kull L, Conley A, Galante JO: Complications of a cable grip system. J Arthroplasty 1996;11: 400–404.
40. Nabors ED, Liebelt R, Mattingly DA, Bierbaum BE: Removal and reinsertion of cemented femoral components during acetabular revision. J Arthroplasty 1996;11:146–152.
41. Maloney WJ, Herzwurm P, Paprosky W, Rubash HE, Engh CA: Treatment of pelvic osteolysis associated with a stable acetabular component inserted without cement as part of a total hip replacement. J Bone Joint Surg 1997; 79A:1628–1634.
42. Hozack WJ, Bicalho PS, Eng K: Treatment of femoral osteolysis with cementless total hip revision. J Arthroplasty 1996;11:668–672.

OSTEOLYSIS: CAUSE AND EFFECT

Raj K. Sinha, MD, PhD, Arun S. Shanbhag, PhD, William J. Maloney, MD, Carl T. Hasselman, MD, Harry E. Rubash, MD

Introduction

Osteolysis is the product of a particle-induced biologic process at the metal-bone or cement-bone interface, resulting in bone loss. Manifestations of this type of bone loss in patients range from new radiolucencies around previously well-fixed implants, which progress slowly and eventually result in mechanical instability, to rapidly expanding focal lesions that may or may not result in loosening. In the orthopaedic vernacular, the former process is generally termed "aseptic loosening" and the latter is widely known as "osteolysis." Because of the popular usage of these two terms, many orthopaedists mistakenly believe that each phenomenon represents a distinct clinical entity with dissimilar implications. However, research indicates that access to the metal-bone or cement-bone interface allows the same biologic phenomenon to result in both aseptic loosening and osteolysis.

Pathophysiology

The loosening of prosthetic components in the absence of infection has been a known clinical entity since the inception of joint replacement in the early 1960s. During revision of loose cemented cups, the implant invariably is surrounded by macrophage-laden fibrous tissue at the cement-bone interface.[1-5] Initially, this interfacial membrane was believed to form in response to the curing of acrylic cement. However, after evaluating tissues around failed prostheses, Willert and Semlitsch[6,7] proposed that loosening results from the macrophage response to wear debris. Wear particles generated within the joint space are phagocytosed and stored within cells in the joint capsule. Smaller particles (< 7 mm) generally are retained within macrophages, whereas larger nonphagocytosable particles are surrounded by foreign-body giant cells. Depending on the biocompatibility and toxicity of the debris material, there is a variable amount of cellular necrosis and associated infiltration by inflammatory cells. Particulate debris, cleared from the local area by the lymphatic drainage, has been recovered from regional lymph nodes.[8–10]

The generation of wear debris often exceeds the capacity of the capsule to clear or store the particles. In this case, all periprosthetic interfaces may be susceptible to infiltration by wear debris and granulation tissue.[7,11] The associated inflammation and interfacial bone loss can compromise bony fixation of the implant, resulting in loosening.[7,11] One manifestation of interfacial bone loss is a linear radiolucency about the implant, which may progress to circumferential canal enlargement and endosteal bone lysis. Alternately, the bone loss may appear to be focal, manifesting as a lytic, expansile lesion.[12–14] These focal lesions are associated with both stable and loose components, and they may progress in size.[12,15] If this process compromises the stability of the component, revision may be required. Revision may also be required for progressive bone loss in the absence of component instability.

Although Willert and Semlitsch's original observations involved cemented components, others have described a similar process adjacent to uncemented implants.[11,16-18] Schmalzried and associates[11] suggested that particulate wear debris generated at the articulation can be carried to all periprosthetic regions that are accessible to joint fluid. It has been further suggested that the flow pattern of the wear debris is determined by the degree of access to the interfaces.[19-21] Dispersion of particles along the interface results in linear osteolysis, whereas accumulation in discrete areas is thought to lead to focal osteolysis.

The pathology of the interfacial membrane has been studied extensively. Periprosthetic membranes with sheets of macrophages in a fibrous stroma intermingled with multinucleated giant cells, polymethylmethacrylate (PMMA) particles, and metallic wear debris are a common finding.[3,4,22,23] When interfacial tissues were placed in organ culture, they produced collagenase and prostaglandin E_2 (PGE_2),[24,25] both stimulators of osteoclastic bone resorption and matrix degradation in vivo. These data support the hypothesis of Willert and Semlitsch[7] that the interface tissue actively participates in bone resorption, possibly leading to loosening of the components.[24] Since this hypothesis was first proposed, numerous investigators have shown that the cellular activity within the membrane produces a variety of enzymes such as gelatinase, stromelysin and other metalloproteinases, prostaglandins, and cytokines such as interleukin-1a (IL-1a), IL-1b, IL-6 and tumor necrosis factor-a (TNF-a).[26–34]

Goodman and associates[26] reported that tissues around loose total hip replacement components were associated with significantly higher levels of PGE_2 than tissues around stable components. This finding supports those of other investigators, suggesting that PGE_2 and IL-1 are associated with osteolysis around loose prostheses.[26,28] Membranes from around loosened bipolar components have been shown to produce larger amounts of PGE_2 than those around loose total hip arthroplasties.[29] There appears to be no difference in the levels of various mediators between failed cemented and uncemented hip prostheses[31,34] or between failed titanium (Ti) and cobalt-chromium-molybdenum (Co-Cr-Mo) alloy components.[35] These findings reaffirm the hypothesis that the biologic response leading to interfacial bone loss results from exposure to particulate debris.

In the above studies, the pathologic process of linear versus focal osteolysis was not differentiated. However, Chiba and associates[32] specifically studied tissues retrieved from components with each particular radiographic appearance of osteolysis. Levels of IL-1, TNF-a, and IL-6 were significantly higher in granulomas from focal lesions than in those from regions of linear osteolysis. Focal osteolytic defects also contained more macrophages and ultra-high molecular weight polyethylene (UHMWPE) debris, possibly accounting for the increased levels of osteolysis-associated mediators. Thus, the particle burden and the intensity of the biologic response seem to be associated with the radiographic appearance of the osteolysis. Nevertheless, the pathophysiologic process appears to be similar in both types of defects.

In the studies cited above, actual levels of biochemical mediators were quantified. In addition, in situ hybridization showed IL-1b protein to be bound to both macrophages and fibroblasts, whereas the messenger ribonucleic acid (mRNA) was detected only in macrophages.[30] This research also supports the primary role of the macrophage response to wear debris in the development of osteolysis.

In tissues around failed components, macrophages are the predominant cell type containing intracellular wear debris. Consequently, macrophages cultured with particles in vitro have been used to model specific events at the bone-implant interface. Such in vitro macrophage-particle experiments permit the systematic study of several variables.

Transformed or immortalized macrophage cell lines such as $P388D_1$, J774, IC-21, and RAW 267 have been used to study macrophage-particle interactions in vitro.[36–42] However, the transformed nature of these cell lines may limit the correlation of these studies to actual clinical events.[43] Macrophages in inter-

facial membranes are believed to be derived from the circulating peripheral blood monocytes. Subsequently, primary monocytes may be more appropriate for studying cellular events occurring in aseptic loosening.[44,45]

Early studies on macrophage-particle interactions focused primarily on the toxicities of particles having different compositions. Several investigators have found that most particles in vitro are cytotoxic to some extent. According to Haynes and associates,[46] the most cytotoxic particles are composed of Co-Cr-Mo, followed by Ti-alloy. Horowitz and associates[37,39,47] demonstrated that PMMA particles (< 0.5 mm) inhibit DNA synthesis, and Shanbhag and associates[44] reported that UHMWPE particles retrieved from interfacial tissues or fabricated in the laboratory were less toxic to cells than PMMA particles. Investigators also have reported that particle-mediated cytotoxicity was dose-dependent.[41,44] Using similarly sized Co-Cr-Mo and Ti particles, Haynes and associates[46] found that Co-Cr-Mo particles had a limited ability to stimulate the release of inflammatory mediators or even inhibited their release, possibly because of cytotoxic effects. However, the less toxic Ti-alloy particles induced the synthesis and release of significant levels of PGE_2 and IL-1, IL-6, and TNF.[46]

Despite their inherent cytotoxicity, Co-Cr-Mo alloy particles can stimulate macrophages to release lysosmal enzymes such as b-glucuronidase and N-acetyl-b-D-glucose aminidase.[48] Glant and associates[40,49] and others[18] reported that $P388D_1$ macrophages challenged with PMMA and Ti particles released PGE_2 and IL-1 in culture medium. The secretion of PGE_2, IL-1, or TNF was reproducible with several different transformed and primary mouse peritoneal macrophages. Consistent with these findings was the release of the arachidonic acid metabolites PGE_1 and PGE_2 by $P388D_1$ cells cultured with PMMA particles.[39]

In addition to their composition and concentration, the size of the challenging particles can strongly influence the macrophage release of osteolytic mediators.[18,33,41] Horowitz and associates[18] noted that PMMA particles small enough to be phagocytosed (< 7 mm) will stimulate macrophages to release TNF, whereas larger particles will not. Within the phagocytosable range, the release of inflammatory mediators is also a function of particle size distribution. Fine particles appear to be more stimulatory than coarse particles in the osteolytic process.[6,22,27,33,39,50–52] Ti alloy, commercially pure (cp) Ti and UHMWPE particles retrieved from interface membranes, and fabricated UHMWPE particles in clinically relevant sizes were used to challenge human peripheral blood monocytes.[44,45,53] The metallic particles were more stimulatory for PGE_2, IL-1a, IL-1b, TNF-a, and IL-6 than both the retrieved and fabricated UHMWPE particles. The Ti alloy and cpTi particles also increased bone resorption from mouse calvaria in vitro, and they enhanced the proliferation of human dermal fibroblasts.

Whether it is termed aseptic loosening or osteolysis, interfacial bone loss occurs by the same pathologic process. The implication is that the various radiographic appearances represent different points on the continuum of a single pathologic process. This then raises the question: Why is bone loss manifested so differently in different patients? The answer may lie in the relationship between interfacial bone loss and several mechanical, genetic, and microenvironmental factors.

Mechanical Factors

Mechanical factors concern the stability of the interface. Fracture of the bone or cement mantle leads to loosening that can open conduits for particle migration around the interface. The "effective joint space" concept[11] underlines the importance of particle access in loosening of previously well-fixed components. The access of particles to the interfaces depends on such design features as stem shape, stem size, and extent of porous coating.

Microenvironmental Factors

Microenvironmental factors are patient-specific features, such as bone quality and nutrition, that affect healing. At the interface, the nature of the particulate debris also affects the degree of the inflammatory response. Particle characteristics such as size, shape, composition, and roughness all influence the degree and profile of the macrophage-induced cytokine elaboration.[33,41,46,47] Further study will likely determine the most important trigger(s) for the development of osteolysis in individual patients.

Genetic Factors

Genetic factors, such as the major histocompatibility complex loci, could explain the variable nature of the immunologic response. That is, some patients may be more genetically susceptible than others to interfacial bone resorption. In addition, the regulation of the expression of osteogenic genes depends on material characteristics of the implant.[54,55] Thus, without circumferential bone ingrowth, the interface of cementless components is accessible to wear debris. Although many investigations are currently underway, no firm data yet exist to link specific genetic factors to osteolytic processes.

In summary, research has identified certain key features of the pathologic response leading to periprosthetic osteolysis. Wear debris generated by the articulating components stimulates macro-phages to elaborate various cytokines. These cytokines subsequently result in osteoclast-mediated interfacial bone resorption. The size, shape, concentration, and composition of the particles, as well as their access to the interface, determine the intensity of the pathologic response and influence the radiographic appearance of the osteolysis.

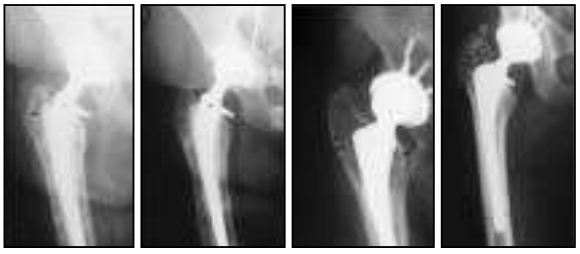


Fig. 1 Left, Radiograph demonstrating linear osteolysis (aseptic loosening) in the femur of a patient with a cemented stem (arrows). **Left center**, Radiograph of the same patient 6 months later, demonstrating progression of linear osteolysis (arrows). **Right center**, Radiograph demonstrating focal osteolysis in the proximal femur of a patient with a painless, stable femoral component (arrows). **Right**, Radiograph showing progressive osteolysis around an uncemented stem that has compromised stability of the component (arrows).

Diagnosis

In patients who have undergone total joint replacement, the implication of radiographic osteolysis depends on the surgeon's point of view. Based on radiographic appearance, "aseptic loosening" was first identified around cemented components, and subsequently was defined as the development of a radiolucent line around a previously well-fixed prosthesis (Fig. 1).[56] The natural history of this radiolucency with cemented components is slow progression.[57] When the zone of radiolucency is wider than 2 mm, or becomes circumferential, the prosthesis is considered to be at risk for loosening, and may already be clinically loose.[58] The radiolucency appears to progress from the intra-articular margin of the interface until it extends circumferentially. Alternatively, aseptic loosening may manifest as a circumferential periprosthetic endosteal scalloping of bone at the implant-bone or cement-bone interface. In addition to the thin zone of circumferential radiolucency, certain regions of the interface exhibit greater bone loss. It is possible that such focal areas of bone loss are more accessible to, or have a higher concentration of particles.[32] Regardless, aseptic loosening may appear as either a linear or expansile radiolucency. Once the component is loose, interfacial bone loss is progressive.[58]

"Osteolysis" is generally defined as a focal, often rapidly expanding radiolucency at the implant-bone or cement-bone interface[59] (Fig. 1). Such radiolucencies can represent small, clinically insignificant lesions that may not lead to loosening of the implant, such as with well-fixed, uncemented, fully porous-coated stems.[60] Alternately, the lytic lesion may progress to compromise fixation of cemented[61] and uncemented implants. Although the latter phenomenon rarely has been reported, the failure of the component is catastrophic. In addition, a common appearance of pelvic osteolysis in uncemented cups is that of a ballooning lesion that extends away from the component.[62] Despite interfacial bone loss, "osteolysis" results in loosening only when large amounts of structural bone loss occurs.

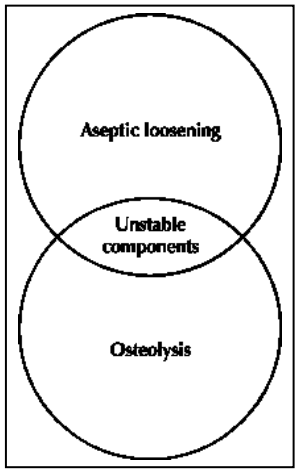


Fig. 2 Diagram depicting sets of patients with radiographic "aseptic loosening" and "osteolysis" that shows an overlapping subset of patients with both disease processes. Research shows that both processes are the same pathophysiologically, regardless of radiographic appearance, and that both may eventually lead to loosening of the component.

In patients with so-called aseptic loosening (ie, most commonly, a linear pattern of radiolucency typically associated with cemented components), a previously well-fixed implant has become loose. In patients with osteolysis (ie, the radiographic appearance of an expansile lytic lesion), there is focal loss of bone but the implant is stable. However, in some patients, osteolysis may result in loosening (Fig. 2). Nevertheless, despite the different radiographic appearances, the same pathologic phenomena occur in both sets of patients. This implies that both "osteolysis" and "aseptic loosening" are terms that merely describe different manifestations of the same disease process. Therefore, it is important to realize that each manifestation represents osteolysis and interfacial bone loss. For the purposes of this discussion, linear osteolysis will refer to what was previously termed aseptic loosening, whereas focal or expansile osteolysis will refer to large, scalloped or balloon-like periprosthetic lesions.

Clinical Symptomatology

The majority of patients with osteolysis are asymptomatic when the resorptive process begins. In fact, extensive bone loss can occur with focal osteolysis in the absence of symptoms. Cemented components can cause increasing pain, which is suggestive of loosening but which is not apparent until the osteolysis has caused severe bone loss.[62] Uncemented components may present initially with pain secondary to wear-debris induced synovitis or after periprosthetic fracture through the site of the lesion.[63,64] Osteolysis has been reported to occur as early as 12 months after implantation.[65] Once osteolysis has developed, it is likely to progress. If the component becomes loose, bone loss progresses more rapidly, resulting in defects larger than those seen with well-fixed components.[15] There-fore, most authors recommend routine serial, radiographic follow-up once osteolysis is identified.

Radiographic Appearance

Osteolysis is commonly described in characteristic patterns. On the acetabular side, the osteolytic regions may appear linear, focal, or expansile with both cemented and uncemented components.[11,60,62,65–73] Osteolysis also has been associated with both stable and unstable components.[62,66] Quite commonly, both the location and volume of bone loss will progress, resulting in extensive expansile lesions involving the pelvis and femur.[15,74–76] An important caveat is that radiographs consistently underestimate the size of osteolytic lesions. In addition, the radiographic appearance differs depending on the mode of fixation.

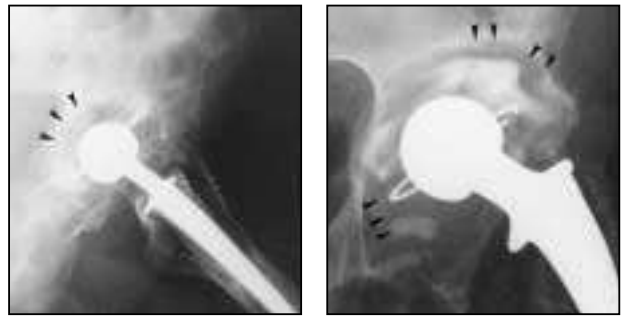


Fig. 3 **Left,** Linear osteolysis about a cemented socket, which has collapsed into the circumferential osteolytic cavity, giving the appearance of a thin linear region of radiolucency (large arrows). Also note the expansile osteolysis in femoral zones 8 and 14 (small arrows). The radiographic also demonstrates definite loosening of the femoral component as evidenced by stem-cement debonding (open arrow). **Right,** Focal osteolysis around a cemented cup, resulting in expansile lesion and subsequent catastrophic failure of the implant (arrows).

Cemented Sockets

With cemented acetabular components, the path of least resistance for joint fluid and wear particles is at the cement-bone interface. As demonstrated in autopsy studies by Schmalzried and associates,[77] after the implantation of a cemented socket, the subchondral bone reconstitutes and acts as a partial barrier that prevents joint fluid and particles from gaining access to the trabecular bone of the ilium. The soft-tissue membrane created by the biologic reaction to wear particles dissects along the cement-bone interface, leading to disruption of this interface. As the interfacial disruption progresses to the acetabular dome, fixation is lost. Radiographically, the osteolytic pattern is linear, and the radiolucency occurs at the cement-bone junction (Fig. 3). The component tends to migrate into the radiolucent areas in the superior and medial aspects of the acetabulum. Although cystic lesions are uncommon, bone loss can still be extensive, especially if the disease has been longstanding and untreated.

Zicat and associates[73] described patterns of osteolysis around all-polyethylene cemented components. In 12 of 63 patients, loosening necessitated revision of the cups within 7 years of implantation. Eight of these 12 cases (75%) had a circumferential linear pattern. Although 51 patients did not require revision of the acetabular component, 19 had unstable cups. Of these 19, four (22%) had a progressive linear pattern present in all three zones, and three (18%) had focal expansile lesions. These expansile lesions occurred predominantly in zone III.[78] Failure of the cemented cups requiring revision was more often associated with a higher patient weight (66 versus 55 kg) and younger age at the time of implantation (44 versus 60 years).

Radiographically, the hallmarks of cemented socket loosening are circumferential radiolucency, a cracked cement mantle, or component migration.[58]

Cemented Stems

In arthroplasties with a cemented femoral component, the path of least resistance for particle migration on the femoral side is along the cement-metal or the cement-bone interface. Linear, expansile, and focal lesions all have been seen with both stable

and unstable stems.[12,59,73,79,80] Several authors have demonstrated the potential for a passage to form at the stem-cement interface.[12,80] Anthony and associates[80] postulated that the formation of a membrane within the passage may be a causative factor for the focal lytic lesions that develop around the distal aspect of an otherwise well-fixed cemented femoral component. They suggested that fluid and particles are driven along the interface by the high intra-articular pressures generated during normal gait and reach the cement-bone interface via defects in the cement mantle. The resulting biologic reaction can lead to focal osteolysis in the presence of a well-fixed cemented stem.

As with cemented acetabular components, particles can migrate along the cement-bone interface of femoral components. However, the consequences are quite different. In the absence of cement fracture or debonding at the cement-metal interface, the femoral component usually does not loosen, probably because the articular surface area for femoral components is much smaller and the surface area for fixation is much larger than that of the acetabular component.[19] Thus, 2 cm to 3 cm of disruption of the proximal cement-bone interface due to linear osteolysis (ie, membrane formation) will not significantly compromise femoral component stability. In contrast, 2 cm to 3 cm of disruption at the cement-bone interface in a cemented socket is likely to have a significant effect on implant stability. Osteolysis around the proximal femur thus can result in progressive bone loss. With modern cementing technique, though, it is rarely the primary cause of loosening.[81,82] However, with stem debonding or cement fracture, cement debris is produced due to the instability of the implant. With adequate access to the cement-bone interface, the debris leads to the development of osteolysis as a secondary phenomenon.

Clinical studies of stems inserted using first-generation cementing techniques found osteolysis in all Gruen zones.[16,66] With second- and third-generation cementing techniques, radiolucencies at the cement-bone interface are primarily linear and are located in Gruen zones 1, 7, 8, and 14.[82] In addition, although the incidence of osteolysis in cemented stems is quite low, an increase from 3% to 9% has been reported for the same patients between the 11-year and 15-year follow-up.[81–83]

Cemented stems are definitely loose when the component has migrated, a new radiolucency at the cement-metal interface has developed, the stem is deformed or fractured, or when the cement mantle is fractured.[56,59] A complete radiolucency at the cement-bone interface suggests probable loosening, whereas 50% to 99% radiolucency suggests possible loosening. Significantly, interpretation of the radiolucent line is critical in determining whether the radiographic manifestations are suggestive of linear osteolysis or remodeling.[84]

Cementless Sockets

The pattern of osteolysis around cementless sockets is a function of whether bone ingrowth has occurred. If the socket is stable and bone-ingrown, the path of least resistance is via noningrown areas (eg, gaps and/or fibrous tissue) and screw holes, which allow particles to migrate into the trabecular bone of the ilium, ischium, and pubis. This results in two patterns of osteolysis in bone-ingrown cups that may be related to the local particle concentration (Fig. 4). High particle loads may be more likely to result in the first pattern, which is rapidly growing expansile lesions with indistinct margins. The consequences of osteolysis in these cases is progressive bone loss. Loosening does not result until bone loss is extensive, and failure is usually acute and catastrophic. The patient usually remains clinically asymptomatic until the component loosens.

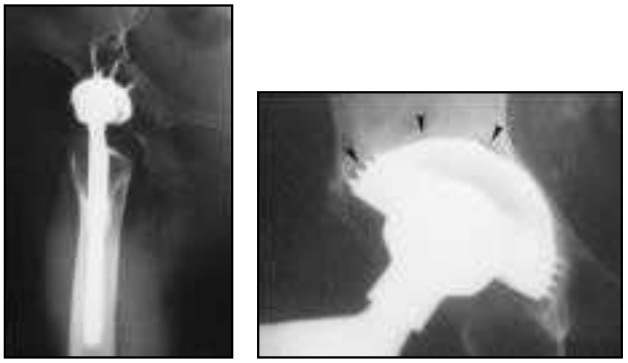


Fig. 4 Left, Rapidly expansile region of focal osteolysis adjacent to an uncemented socket (arrows). **Below,** Slowly progressive linear osteolysis around a threaded uncemented cup (arrows).

The second pattern of osteolysis is a more slowly growing lesion that has sclerotic margins. Sclerotic bone often forms at the implant-bone interface, probably as a result of micromotion. The pattern of osteolysis in this case is quite similar to that seen with cemented sockets. Linear osteolysis occurs with the implant migrating into the radiolucent area. In addition, if late migration of the component is noted in the absence of previous radiolucency, then fibrous fixation with progressive osteolysis should be assumed to have developed. The consequences of osteolysis in this case are progressive bone loss and clinical loosening.

The radiographic determination of whether a socket has bone ingrowth is quite difficult. Radiographic criteria of the type described for bone ingrown porous-coated cementless stems have not been delineated for cementless cups. A cementless socket that is radiographically stable is often presumed to be bone ingrown, although that may not be the case. Cementless sockets in which bone-ingrowth does not occur are predisposed to late migration.

In a study by Zicat and associates,[73] 71 of 74 one-piece metal-backed Anatomic Medullary Locking (AML, DePuy, Warsaw, IN) sintered-bead porous-coated cups, inserted with cementless techniques with three spikes and no screw holes, were well-functioning after 7 years. Fourteen (20%) had radiolucent lines in at least one zone, most commonly zone III. No component had circumferential linear osteolysis. One or more periarticular focal lesions occurred in 18% of the cups. Two cups (3%) also had osteolytic areas remote from the joint. Similarly, Porous Coated Anatomic (PCA, Howmedica, East Rutherford, NJ) cups have been associated with an equal incidence of focal osteolysis in all three zones.[68,71] Reports have noted the occurrence of nonprogressive radiolucent lines around Harris-Galante (HG-I, Zimmer, Warsaw, IN) cups, but no focal osteolysis has been noted at 7 to 11 years of follow-up.[13,85] Studies have shown that with screw-in cups, osteolysis occurs rapidly in a linear circumferential pattern with catastrophic migration of the components.[86,87] In addition, regardless of cup type, both linear and expansile osteolysis has been noted about the fixation screws.[67,86,87] With the HG cups after 5 years, the use of screws for initial fixation showed one lesion in 83 cups (1.2%);[88] no osteolysis was identified in the same cup fixed without screws in 122 hips.[89] Thus, the patterns of osteolysis around uncemented cups depend on the cup design.

When uncemented cups are used, migration greater than 5 mm is consistent with definite loosening.[90] Migration may be difficult to detect because of the variation in imaging planes of radiographs. Roentgenographic stereophotogrammetric analysis is more accurate[91] but is not widely used. Migration may occur with associated fracture of transacetabular screws, shedding of the porous coating, or implant fracture. Progressive radiolucent lines suggest imminent loosening, whereas static lines are of less concern.[90]

Cementless Stems

As with cementless sockets, the pattern of osteolysis with cementless stems depends on whether bone ingrowth has occurred. In addition, the implant design is a major factor in the location of osteolytic lesions (Fig. 5). With patch-porous coated implants, the path of least resistance is often along the smooth portion of the stem into the diaphysis of the femur. Thus, these types of stems are prone to diaphyseal osteolysis, as demonstrated in studies in which partially porous-coated cylinders were implanted into the distal femur of rabbits.[21] Polyethylene particles then were injected into the joint, and the femora were harvested several weeks after surgery. Histologic analysis demonstrated that the bone-ingrown areas were relative barriers to the ingress of joint fluid and polyethylene debris. In contrast, a periprosthetic cavity with a membrane formed around the smooth portion of the stem. Polarized light microscopy demonstrated that this soft-tissue membrane contained abundant polyethylene particles. Similar findings have been noted in studies examining patch-porous coated stems that were implanted in humans.[12,15,66,85,92]

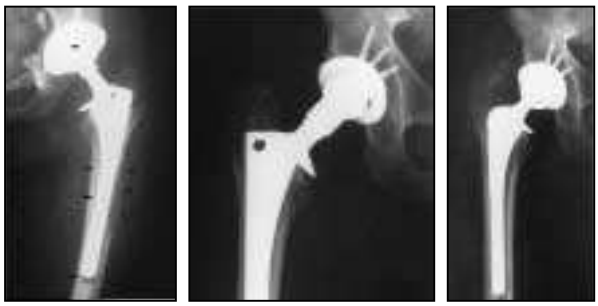


Fig. 5 Left, Typical radiographic appearance of progressive focal osteolysis about a noncircumferentially porous-coated Harris-Galante (Zimmer, Warsaw, IN) femoral component (arrows). **Center,** Typical radiographic appearance of proximal focal osteolysis in zones I and VII (arrows) adjacent to a stable Anatomic Medullary Locking (Depuy, Warsaw, IN) femoral component. **Right,** Radiographic demonstrating "windshield wiper" pattern of distal osteolysis in an uncemented femoral component. This pattern is believed to result from the concentration of particles in the diaphysis with subsequent loosening of the stem and toggling of the femur.

With circumferential porous-coated stems such as the AML or the PCA, focal osteolytic lesions occur most commonly in the proximal aspect of the femur. Occasionally, these lesions have presented as spontaneous fractures of the greater and lesser trochanter.[64] With AML femoral components, Zicat and associates,[73] and Engh and associates,[60] described primarily periarticular lesions occurring in zones 1 and 7 (greater and lesser trochanters, respectively). In these two studies, the clinical significance of the osteolysis was minimal. Osteolysis around the PCA stem also occurred in zones 1, 7, or both in some studies,[68,93] and in zones 1, 2, 3, and 7 in another study.[64]

In contrast, diaphyseal expansile osteolysis is much more common in patch-porous coated implants such as the original Harris-Galante porous-coated stem (HGP, Zimmer, Warsaw, IN),[92] the Anatomic Porous Replacement (APR-I, Intermedics Orthopedics, Austin, TX) stem,[94] and the initial S-ROM (Joint Medical Products, Stamford, CT) implant, which had a seam that allowed joint fluid to reach the diaphysis. For example, in a 5-year follow-up study of the HGP stem, Maloney and Woolson[76] reported a 52% incidence of femoral osteolysis. Sixty-seven percent of these lesions were in the diaphysis in Gruen zones 3, 4, and 5. Many other reports indicate a high incidence of osteolysis in all periprosthetic femoral zones of patients who received the HGP stem.[15,85,92] The consequences of osteolysis in these cases is progressive diaphyseal bone loss. Loosening can occur when significant support for the implant is lost along the smooth portion of the stem. Because load is then transferred across a small area of bone ingrowth, stress fracture of the ingrown area leading to implant loosening can occur and has been reported.[61,95] Thus, it is possible for the surgeon to predict the location, appearance, and prevalence of osteolysis as a function of the implant design.

If bone-ingrowth does not occur in a porous-coated cementless stem, a fibrous interface develops. Radiographically, sclerotic lines adjacent to the fibrous tissue suggest the presence of a partial barrier obstructing the access of fluid and particle to the endosteal surface of the femur. In these cases, linear osteolysis described as a "windshield wiper" pattern is often noted. Progressive loss of diaphyseal bone may occur, leading to expansion of the endosteal canal. These patients often have pain from the time of surgery that progressively worsens. Implant migration also suggests unstable fibrous ingrowth.

Uncemented stems are definitely loose if migration and subsidence are evident. Radiographic criteria for uncemented stems are in a state of evolution, but particular findings for individual implants have been described to help determine whether specific implants may be loose. Unstable PCA components demonstrate subsidence of greater than 2 mm, cortical hypertrophy, or cancellous hypertrophy at the stem tip (ie, pedestal formation).[96] Similarly, possible loosening of AML femoral components is indicated radiographically by widening circumferential radiolucencies adjacent to the porous surface, divergent lines of demarcation, shedding of the porous coating, absence of proximal stress shielding, or cortical hypertrophy with pedestal formation.[97] In addition, dynamic rotational computed tomography has been used to determine whether uncemented femoral components are loose.[98] In this technique, femoral component version is measured in maximal internal and external rotation. The component is considered loose if there is a difference of 2° or more between these angles.

Epidemiology

Acetabulum

The incidence of osteolysis in hip replacement is most easily described in terms of the components and their mode of fixation (Table 1). For cemented cups, the incidence of focal osteolysis has been reported to be from 0% to 19%, with loss of fixation occurring at rates between 0% and 44%.[13,57,82,99–106] Salvati and associates[99] reported on polyethylene cups implanted using first-generation cementing techniques. At 10 years, two of 54 patients (3.7%) demonstrated linear osteolysis at the cement-bone interface that led to component loosening; no patients had expansile osteolysis. Others have reported loosening rates due to linear osteolysis of 11% to 23% for first-generation cemented polyethylene cups after a minimum of 10 years.[57,105] MacKenzie and associates[106] used all-polyethylene cups implanted with second-generation cementing technique in patients with developmental dysplasia or chronic dislocation of the hip. They found focal osteolysis in seven of 37 patients (19%), and, in 16 of 59 patients (27%), linear osteolysis resulted in loosening after an average of 192 months. Second-generation cementing techniques fared no better in a study by Mulroy and associates,[82] with linear osteolysis leading to loosening in 44% of patients a minimum of 14 years after implantation. Some authors believe the rates of osteolysis will increase after longer follow-up, thus warranting a repeat evaluation of results.[81]

Acetabular components inserted without cement have shown better results at 5 to 7 years than those implanted with cement. The HGP cup consistently has achieved very low intermediate and long-term rates of osteolysis and loosening (0% to 2%).[15,85,92,104,107–111] However, other uncemented cups have not performed as well. For the PCA cup, rates of focal osteolysis have ranged from 1% at 4 years to 36% after more than 5 years.[68,71,72,111] The same reports noted that loosening had an incidence of

Table 1 Incidence of osteolysis in acetabular components after total hip arthroplasty

Reference	Prosthesis*	No. of Hips	Average Follow-up (months)	Onset of Lysis (months)	Incidence (%)	
Salvati et al[99]	1st-generation Charnley		54	120	N/A	0
Woolson and Maloney[107]	HGP	69	44	N/A	0	
Martell et al[85]	HGP	121	67	50	2	
Kim and Kim[68]	PCA	116	76	N/A	9	
Hozack et al[102]	Metal-backed cemented cups	70	49	N/A	0	
Schmalzried and Harris[115]	ARC or HGP	97	78	N/A	2	
Goetz et al[92]	HGP	41	74	42	0	
Schmalzried et al[89]	HGP	122	56	N/A	0	
Owen et al[71]	PCA	95	< 60	< 60	8	
		99	> 60	> 60	36	
Engh et al[60]	AML	227	> 84	N/A	20	
	Cemented AML	63	> 84	N/A	30	
Fox et al[86]	T-Tap	68	72	> 36	87	
Smith and Harris[108]	HGP	94	53	16	1	
Xenos et al[110]		PCA	100	84	N/A	2
Learmonth et al[72]	PCA	104	50	36	1	
Zicat et al[73]	AML	74	102	N/A	19	
	Cemented cups	63	107	N/A	46	
Mohler et al[104]	HGP	142	62	24-60	1	
Nashed et al[111]	Ti head	15	79	N/A	35	
	CoCr head	74	66	N/A	35	
	Cemented polyethylene	24	113	N/A	0	
	Cemented metal-backed	62	94	N/A	7	
MacKenzie et al[106]	2nd-generation Charnley	37	192	N/A	19	

*HGP = Harris-Galante porous-coated (Zimmer, Warsaw, IN); PCA = porous-coated anatomic (Howmedica, Rutherford, NJ); ARC = acetabular reconstruction component (Howmedica, Rutherford, NJ); AML = anatomic medullary locking (DePuy, Warsaw, IN); T-Tap = threaded titanium acetabular cup (Biomet, Warsaw, IN)

between 0% and 11%, but it was not attributed to osteolysis. However, certain variables in these studies have been implicated in the high rates of osteolysis. The patients tended to be younger with higher levels of activity, and 32-mm heads were commonly used. In addition, shedding of the porous coating can accelerate third-body wear. Engh and associates[60] and Zicat and associates[73] reported that focal osteolysis occurred in 20% of patients 84 to 102 months after receiving nonmodular AML cups with 32-mm heads, and the loosening rate was 4%.

Threaded cups such as the T-TAP (Biomet, Warsaw, IN) have also produced high rates of osteolysis (59 of 68 patients, 87%) and osteolysis-associated loosening (26 of 68, 38%) after only 6 years.[86] Similarly, 95 of 378 (25%) threaded Mecring (Mecron, Berlin, Germany) cups were found to be radiographically loose only 4 1/2 years after implantation.[87] Although initially quite stable, screw-in cups apparently cause a high concentration of local stress and possibly pressure necrosis. Bruijn and associates[87] also suggested that such stress causes bone resorption, decreased stability, increased micromotion, and greater access of wear particles to the metal-bone interface, resulting in rapidly progressive osteolysis. Regardless of the mechanism of failure, most studies have found that threaded acetabular cups fail at sufficiently high rates to preclude their continued use.

Femur

Whereas femoral components inserted with first-generation cementing techniques loosened at rates between 11% and 30%,[57,99,105] those inserted using second- or third-generation cementing techniques have enjoyed excellent results in terms of osteolysis, loosening, and revision rates. Several authors have reported the long-term incidence of focal osteolysis to be less than 8%, even in difficult reconstructions.[13,82,104,106] Intermediate to long-term rates of loosening associated with osteolysis have increased from 1.5% or 3% to 7% at latest follow-up (Table 2).[13,81,82,104]

On the other hand, the incidence of osteolysis in femurs that received uncemented stems is quite high. The HGP prosthesis was associated with focal osteolysis rates of 13% to 52% over short to intermediate follow-up periods.[15,76,85,88,92,107,108] The incidence of loosening of these components has been between 8% and 32%. With the PCA stem,[68,71,72,110] the incidence of osteolysis was also quite high (13% to 25%) at 50 to 84 month follow-up. As noted earlier, osteolytic lesions occurred in periarticular Gruen zones 1, 2, and 7, and were not the cause of loosening. Rather, implant micromotion and shedding of the porous coating appeared to be responsible.[68,93] Although studies suggested high rates (32% to 34%) of osteolysis with the AML stem,[60,73] these lesions also were confined to zones 1 and 7, were quite small, and did not result in loosening. Nashed and associates[111] reported that osteolysis occurred in 13 of 15 (87%) arthroplasties using a BIAS (Zimmer, Warsaw, IN) stem with a titanium head and in 16 of 74 (22%) arthroplasties using a cobalt-chrome head. Loosening associated with osteolysis occurred in 40% and 14% of these patients, respectively. The incidence of osteolysis was 9% for the Identifit (Thackray, Leeds, England) stem without porous coating, although loosening was more frequent (28%) and was not entirely the product of osteolysis.[79]

Risk Factors

The likelihood that osteolysis will develop after total hip replacement currently is difficult to predict. However, based on several retrospective studies, it is possible to identify certain features that may place a patient at increased risk. These factors include young age at the time of replacement,[105] developmental dysplasia of the hip (DDH) or osteonecrosis (ON) as the primary cause of coxarthrosis,[85,106] relatively high patient activity, and high wear

Table 2 Incidence of osteolysis in femoral components after total hip arthroplasty

Reference	Prosthesis*	No. of Hips	Average Follow-up (months)	Onset of Lysis (months)	Incidence (%)
Salvati et al[99]	1st-generation Charnley	54	120	N/A	11
Sutherland et al[100]	Muller	78	120	N/A	19
Woolson and Maloney[107]	HGP	69	44	N/A	22
Tanzer et al[15]	HGP	154	53	32	13
Martell et al[85]	HGP	121	67	50	18
Kim and Kim[68]	PCA	116	76	N/A	24
Hozack et al[102]	Trilock	70	49	N/A	0
	Dualock	71	52	N/A	0
Schmalzried and Harris[115]	HD-2 or Precoat	97	78	N/A	16
Owen et al[71]	PCA	95	< 60	< 60	7
		99	> 60	> 60	13
Goetz et al[92]	HGP	41	74	42	29
	Precoat	41	72	N/A	0
Engh et al[60]	AML, cementless cup	227	> 84	N/A	34
	AML, cemented cup	63	> 84	N/A	12
Smith and Harris[108]	HGP	94	53	16	31
Xenos et al[110]	PCA	100	84	N/A	25
Learmonth et al[72]	PCA	104	50	36	24
Zicat et al[73]	AML	74	102	N/A	32
Mohler et al[104]	Iowa	1941	N/A	24-120	1.5
Nashed et al[111]	BIAS, Ti head	15	79	N/A	87
	BIAS, CoCr head	74	66	N/A	22
	BIAS, cemented PE cup	24	113	N/A	0
	BIAS, cemented metal-backed	62	94	N/A	24
Mulroy et al[82]	Precoat	102	> 168	N/A	10
MacKenzie et al[106]	2nd-generation Charnley	37	192	N/A	8
Maloney and Woolson[76]	HGP	69	71	N/A	52

*HGP = Harris-Galante porous-coated (Zimmer, Warsaw, IN); PCA = porous-coated anatomic (Howmedica, Rutherford, NJ); HD-2 = Harris-Davey cobalt-chromium implant (Howmedica, Rutherford, NJ); AML = anatomic medullary locking (DePuy, Warsaw, IN); BIAS = biologic ingrowth anatomic system (Zimmer, Warsaw, IN)

rates.[68,112] The diagnosis of ON or DDH may be less of a predisposing factor than the young age of these patients at the time of arthroplasty. Many studies have shown that young patients have higher rates of acetabular loosening and osteolysis,[112,113] although femoral loosening does not depend on age. MacKenzie and associates[106] reported that cemented stems had an 85% survivorship at 15 years in patients with Crowe type II, III, or IV DDH. However, the cemented acetabulae had a survivorship of only 68% after the same interval. Osteolysis occurred adjacent to cups or stems in 55% of patients with ON, but only in 29% of those without ON.[85] Greater patient activity generates more wear debris, and particle load has been implicated in types of osteolysis.[32] Surgical risk factors include the types of implants used (see above) and poor cement technique.[114] The incidence of osteolysis has not consistently been associated with gender, weight, or postoperative range of motion.

REFERENCES

1. Charnley J: The bonding of prostheses to bone by cement. J Bone Joint Surg 1964;46B: 518-529.
2. Charnley J, Follacci FM, Hammond BT: The long-term reaction of bone to self-curing acrylic cement. J Bone Joint Surg 1968;50B:822-829.
3. Mirra JM, Amstutz HC, Matos M, et al: The pathology of the joint tissues and its clinical relevance in prosthesis failure. Clin Orthop 1976;117:221-240.
4. Mirra JM, Marder RA, Amstutz HC: The pathology of failed total joint arthroplasty. Clin Orthop 1982;170:175-183.
5. Bullough PG, DiCarlo EF, Hansraj KK, et al: Pathologic studies of total joint replacement. Orthop Clin North Am 1988;19:611-625.
6. Willert HG, Semlitsch M: Tissue reactions to plastic and metallic wear products of joint endoprostheses, in Gschwend N, Debrunner HU (eds): Total Hip Prosthesis. Baltimore, MD, Williams & Wilkins, 1976, pp 205-239.
7. Willert HG, Semlitsch M: Reactions of the articular capsule to wear products of artificial joint prostheses. J Biomed Mater Res 1977;11:157-164.
8. Gray MH, Talbert ML, Talbert WM, et al: Changes seen in lymph nodes draining the sites of large joint prostheses. Am J Surg Pathol 1989;13:1050-1056.
9. Urban RM, Jacobs JJ, Gilbert JL, et al: Migration of corrosion products from modular hip prostheses: Particle microanalysis and histopathological findings. J Bone Joint Surg 1994;76A:1345-1359.
10. Sauer PA, Urban RM, Jacobs JJ, et al: Particles of metal alloys in the liver, spleen, and para-aortic lymph nodes of patients with total hip or knee replacement prostheses. Proceedings of the American Academy of Orthopaedic Surgeons 63rd Annual Meeting, Atlanta, GA. Rosemont, IL, American Academy of Orthopaedic Surgeons, 1996, p 226.
11. Schmalzried TP, Jasty M, Harris WH: Periprosthetic bone loss in total hip arthroplasty: Polyethylene wear debris and the concept of the effective joint space. J Bone Joint Surg 1992;74A:849-863.
12. Maloney WJ, Jasty M, Harris WH, et al: Endosteal erosion in association with stable uncemented femoral components. J Bone Joint Surg 1990;72A:1025-1034.
13. Mohler CG, Callaghan JJ, Collis DK, et al: Early loosening of the femoral component at the cement-prosthesis interface after total hip replacement. J Bone Joint Surg 1995;77A:1315-1322.
14. Jacobs JJ, Kull LR, Frey GA, et al: Early failure of acetabular components inserted without cement after previous pelvic irradiation. J Bone Joint Surg 1995;77A:1829-1835.

15. Tanzer M, Maloney WJ, Jasty M, et al: The progression of femoral cortical osteolysis in association with total hip arthroplasty without cement. J Bone Joint Surg 1992;74A:404-410.
16. Willert HG, Bertram H, Buchhorn GH: Osteolysis in alloarthroplasty of the hip: The role of bone cement fragmentation. Clin Orthop 1990;258:108-121.
17. Willert HG, Bertram H, Buchhorn GH: Osteolysis in alloarthroplasty of the hip: The role of ultra-high molecular weight polyethylene wear particles. Clin Orthop 1990;258:95-107.
18. Horowitz SM, Doty SB, Lane JM, et al: Studies of the mechanism by which the mechanical failure of polymethylmethacrylate leads to bone resorption. J Bone Joint Surg 1993;75A:802-813.
19. Horikoshi M, Rubash HE, Macauley W: An analysis of the bone-cement and the bone-implant interface in failed cemented and cementless acetabular components after failed total hip arthroplasty, in Galante JO, Rosenberg AG, Callaghan JJ (eds): Total Hip Revision Surgery. New York, NY, Raven Press, 1995, pp 119-125.
20. Urban RM, Jacobs JJ, Sumner DR, et al: The bone-implant interface of femoral stems with non-circumferential porous coating. J Bone Joint Surg 1996;78A:1068-1081.
21. Bobyn JD, Jacobs JJ, Tanzer M, et al: The susceptibility of smooth implant surfaces to peri-implant fibrosis and migration of polyethylene wear debris. Clin Orthop 1995;311:21-39.
22. Vernon-Roberts B, Freeman MAR: Morphological and analytical studies of the tissues adjacent to joint prostheses: Investigations into the causes of loosening of prostheses, in Schaldach M, Hohmann D (eds): Advances in Artificial Hip and Knee Joint Technology. Berlin, Germany, Springer-Verlag, 1976, pp 148-186.
23. Vernon-Roberts B, Freeman MAR: The tissue response to total joint replacement prostheses, in Swanson SAV, Freeman MAR (eds): The Scientific Basis of Joint Replacement. New York, NY, John Wiley & Sons, 1977, pp 86-129.
24. Goldring SR, Schiller AL, Roelke M, et al: The synovial-like membrane at the bone-cement interface in loose total hip replacements and its proposed role in bone lysis. J Bone Joint Surg 1983;65A:575-584.
25. Goldring SR, Jasty M, Roelke MS, et al: Formation of a synovial-like membrane at the bone-cement interface: Its role in bone resorption and implant loosening after total hip replacement. Arthritis Rheum 1986;29:836-842.
26. Goodman SB, Chin RC, Chiou SS, et al: A clinical-pathologic-biochemical study of the membrane surrounding loosened and nonloosened total hip arthroplasties. Clin Orthop 1989;244:182-187.
27. Howie DW: Tissue response in relation to type of wear particles around failed hip arthroplasties. J Arthroplasty 1990;5:337-348.
28. Thornhill TS, Ozuna RM, Shortkroff S, et al: Biochemical and histological evaluation of the synovial-like tissue around failed (loose) total joint replacement prostheses in human subjects and a canine model. Biomaterials 1990;11:69-72.
29. Kim KJ, Rubash HE: Large amounts of polyethylene debris in the interface tissue surrounding bipolar endoprostheses: Comparison to total hip prostheses. J Arthroplasty 1997;12:32–39.
30. Jiranek WA, Machado M, Jasty M, et al: Production of cytokines around loosened cemented acetabular components: Analysis with immunohistochemical techniques and in situ hybridization. J Bone Joint Surg 1993;75A:863-879.
31. Kim KJ, Rubash HE, Wilson SC, et al: A histologic and biochemical comparison of the interface tissues in cementless and cemented hip prostheses. Clin Orthop 1993;287:142-152.
32. Chiba J, Rubash HE, Kim KJ, et al: The characterization of cytokines in the interface tissue obtained from failed cementless total hip arthroplasty with and without femoral osteolysis. Clin Orthop 1994;300:304-312.
33. Gelb H, Schumacher HR, Cuckler J, et al: In vivo inflammatory response to polymethylmethacrylate particulate debris: Effect of size, morphology, and surface area. J Orthop Res 1994;12:83-92.
34. Shanbhag AS, Jacobs JJ, Black J, et al: Cellular mediators secreted by interfacial membranes obtained at revision total hip arthroplasty. J Arthroplasty 1995;10:498-506.
35. Dorr LD, Bloebaum R, Emmanual J, et al: Histologic, biochemical, and ion analysis of tissue and fluids retrieved during total hip arthroplasty. Clin Orthop 1990; 261:82-95.
36. Rae T: A study on the effects of particulate metals of orthopaedic interest on murine macrophages in vitro. J Bone Joint Surg 1975;57B:444-450.
37. Horowitz SM, Frondoza CG, Lennox DW: Effects of polymethylmethacrylate exposure upon macrophages. J Orthop Res 1988;6:827-832.
38. Schindler R, Mancilla J, Endres S, et al: Correlations and interactions in the production of interleukin-6 (IL-6), IL-1, and tumor necrosis factor (TNF) in human blood mononuclear cells: IL-6 suppresses IL-1 and TNF. Blood 1990;75:40-47.
39. Horowitz SM, Gautsch TL, Frondoza CG, et al: Macrophage exposure to polymethyl methacrylate leads to mediator release and injury. J Orthop Res 1991;9:406-413.
40. Glant TT, Jacobs JJ, Molnar G, et al: Bone resorption activity of particulate-stimulated macrophages. J Bone Miner Res 1993;8:1071-1079.
41. Shanbhag AS, Jacobs JJ, Black J, et al: Macrophage/particle interactions: Effect of size, composition and surface area. J Biomed Mater Res 1994;28:81-90.
42. Macaulay W, Shanbhag AS, Marinelli R, et al: Nitric oxide release from murine macrophages when stimulated with particulate debris. Trans Soc Biomat 1995; 18:307.
43. Sinha RK, Tuan RS: In vitro analysis of the bone-implant interface. Semin Arthroplasty 1993;4:194-204.
44. Shanbhag AS, Jacobs JJ, Black J, et al: Human monocyte response to particulate biomaterials generated in vivo and in vitro. J Orthop Res 1995;13:792-801.
45. Blaine TA, Rosier RN, Puzas JE, et al: Increased levels of tumor necrosis factor-alpha and interleukin-6 protein and messenger RNA in human peripheral blood monocytes due to titanium particles. J Bone Joint Surg 1996;78A:1181-1192.
46. Haynes DR, Rogers SD, Hay S, et al: The differences in toxicity and release of bone-resorbing mediators induced by titanium and cobalt-chromium-alloy wear particles. J Bone Joint Surg 1993;75A:825-834.
47. Horowitz SM, Doty SB, Lane JM, et al: Mechanism by which cement failure leads to bone resorption in aseptic loosening. Orthop Trans 1991;15:540-541.
48. Rae T: The biological response to titanium and titanium-aluminium-vanadium alloy particles: I. Tissue culture studies. Biomaterials 1986;7:30-36.
49. Glant TT, Jacobs JJ: Response of three murine macrophage populations to particulate debris: Bone resorption in organ cultures. J Orthop Res 1994;12:720-731.
50. Charnley J: Tissue reactions to implanted plastics, in Charnley J (ed): Acrylic Cement in Orthoaedic Surgery. Edinburgh, Scotland, E & S Livingstone, 1970, pp 1-9.
51. Forest M, Carlioz A, Vacher Lavenu MC, et al: Histological patterns of bone and articular tissues after orthopaedic reconstructive surgery (artificial joint implants). Pathol Res Pract 1991;187:963-977.
52. DiCarlo EF, Bullough PG: The biologic responses to orthopedic implants and their wear debris. Clin Mater 1992;9:235-260.
53. Maloney WJ, James RE, Smith RL: Human macrophage response to retrieved titanium alloy particles in vitro. Clin Orthop 1996;322:268-278.
54. Groessner-Schreiber B, Tuan RS: Enhanced extracellular matrix production and mineralization by osteoblasts cultured on titanium surfaces in vitro. J Cell Sci 1991;101:209-217.
55. Sinha RK: Adhesion of Bone Cells to Orthopaedic Implant Materials. Thomas Jefferson University, Philadelphia, PA, 1993. Thesis.
56. Gruen TA, McNeice GM, Amstutz HC: "Modes of Failure" of cemented stem-type femoral components: A radiographic analysis of loosening. Clin Orthop 1979; 141:17-27.
57. Stauffer RN: Ten-year follow-up study of total hip replacement. J Bone Joint Surg 1992;64A:983-990.
58. Hodgkinson JP, Shelley P, Wroblewski BM: The correlation between the roentgenographic appearance and operative findings at the bone-cement junction of the socket in Charnley low friction arthroplasties. Clin Orthop 1988;228:105-109.
59. Harris WH, Schiller AL, Scholler JM, et al: Extensive localized bone resorption in the femur following total hip replacement. J Bone Joint Surg 1976;58A:612-618.
60. Engh CA, Hooten JP Jr, Zettl-Schaffer KF, et al: Porous-coated total hip replacement. Clin Orthop 1994;298:89-96.
61. Jasty M, Maloney WJ, Bragdon CR, et al: Histomorphological studies of the long-term skeletal responses to well-fixed cemented femoral components. J Bone Joint Surg 1990:72A:1220-1229.
62. Maloney WJ, Peters P, Engh CA, et al: Severe osteolysis of the pelvis in association with acetabular replacement without cement. J Bone Joint Surg 1993;75A:1627-1635.
63. Pazzaglia UI, Byers PD: Fractured femoral shaft through an osteolytic lesion resulting from the reaction to a prosthesis: A case report. J Bone Joint Surg 1984;66B: 337-339.
64. Heekin RD, Engh CA, Herzwurm PJ: Fractures through cystic lesions of the greater trochanter: A cause of late pain after cemenetless total hip arthroplasty. J Arthroplasty 1996;11:757-760.
65. Buechel FF, Drucker D, Jasty M, et al: Osteolysis around uncemented acetabular components of cobalt-chrome surface replacement hip arthroplasty. Clin Orthop 1994;298:202-211.
66. Jasty MJ, Floyd WE III, Schiller AL, et al: Localized osteolysis in stable, non-septic total hip replacement. J Bone Joint Surg 1986;68A:912-919.

67. Santavirta S, Konttinen YT, Bergroth V, et al: Aggressive granulomatous lesions associated with hip arthroplasty: Immunopathological studies. J Bone Joint Surg 1990;72A:252-258.

68. Kim YH, Kim VE: Uncemented porous-coated anatomic total hip replacement: Results at six years in a consecutive series. J Bone Joint Surg 1993;75B:6-13.

69. Kim YH, Kim VE: Cementless porous-coated anatomic medullary locking total hip prostheses. J Arthroplasty 1994;9:243-252.

70. Schmalzried TP, Guttmann D, Grecula M, et al: The relationship between the design, position, and articular wear of acetabular components inserted without cement and the development of pelvic osteolysis. J Bone Joint Surg 1994;76A:677-688.

71. Owen TD, Moran CG, Smith SR, et al: Results of uncemented porous-coated anatomic total hip replacement. J Bone Joint Surg 1994;76B:258-262.

72. Learmonth ID, Grobler GP, Dall DM, et al: Loss of bone stock with cementless hip arthroplasty. J Arthroplasty 1995;10:257-263.

73. Zicat B, Engh CA, Gokcen E: Patterns of osteolysis around total hip components inserted with and without cement. J Bone Joint Surg 1995;77A:432-439.

74. D'Antonio JA, Capello WN, Borden LS, et al: Classification and management of acetabular abnormalities in total hip arthroplasty. Clin Orthop 1989;243:126-137.

75. Paprosky WG, Perona PG, Lawrence JM: Acetabular defect classification and surgical reconstruction in revision arthroplasty: A 6-year follow-up evaluation. J Arthroplasty 1994;9:33-44.

76. Maloney WJ, Woolson ST: Increasing incidence of femoral osteolysis in association with uncemented Harris-Galante total hip arthroplasty: A follow-up report. J Arthroplasty 1996;11:130-134.

77. Schmalzreid TP, Kwong LM, Jasty M, et al: The mechanism of loosening of cemented acetabular components in total hip arthroplasty: Analysis of specimens retrieved at autopsy. Clin Orthop 1992; 274:60-78.

78. DeLee JG, Charnley J: Radiological demarcation of cemented sockets in total hip replacement. Clin Orthop 1976;121: 20-32.

79. Lombardi AV Jr, Mallory TH, Eberle RWW, et al: Failure of intraoperatively customized non-porous femoral components inserted without cement in total hip arthroplasty. J Bone Joint Surg 1995;77A:1836-1844.

80. Anthony PP, Gie GA, Howie CR, et al: Abstract: Localised endosteal bone lysis in relation to soundly fixed femoral components of cemented total hip replacements: A possible mechanism. J Bone Joint Surg 1990;72B:532.

81. Mulroy RD Jr, Harris WH: The effect of improved cementing techniques on component loosening in total hip replacement: An 11-year radiographic review. J Bone Joint Surg 1990;72B:757-760.

82. Mulroy WF, Estok DM, Harris WH: Total hip arthroplasty with use of so-called second-generation cementing techniques: A fifteen-year-average follow-up study. J Bone Joint Surg 1995;77A:1845-1852.

83. Harris WH, McCarthy JC, O'Neill DA: Femoral component loosening using contemporary techniques of femoral cement fixation. J Bone Joint Surg 1982;64A:1063-1067.

84. Kwong LM, Jasty M, Mulroy RD, et al: The histology of the radiolucent line. J Bone Joint Surg 1992;74B:67-73.

85. Martell JM, Pierson RH III, Jacobs JJ, et al: Primary total hip reconstruction with a titanium fiber-coated prosthesis inserted without cement. J Bone Joint Surg 1993; 75A:554-571.

86. Fox GM, McBeath AA, Heiner JP: Hip replacement with a threaded acetabular cup: A follow-up study. J Bone Joint Surg 1994;76A:195-201.

87. Bruijn JD, Seelen JL, Feenstra RM, et al: Failure of the Mecring screw-ring acetabular component in total hip arthroplasty: A three to seven-year follow-up study. J Bone Joint Surg 1995;77A:760-766.

88. Schmalzried TP, Harris WH: The Harris-Galante porous-coated acetabular component with screw fixation: Radiographic analysis of eighty-three primary hip replacements at a minimum of five years. J Bone Joint Surg 1992;74A:1130-1139.

89. Schmalzried TP, Wessinger SJ, Hill GE, et al: The Harris-Galante porous acetabular component press-fit without screw fixation: Five-year radiographic analysis of primary cases. J Arthroplasty 1994;9:235-241.

90. Whirlow J, Rubash HE: Aseptic loosening in total hip arthroplasty, in Callaghan JJ, Dennis DA, Paprosky WG, et al (eds): Orthopaedic Knowledge Update: Hip and Knee Reconstruction. Rosemont, IL, American Academy of Orthopaedic Surgeons, 1995, pp 147-156.

91. Onsten I, Carlsson AS, Ohlin A, et al: Migration of acetabular components, inserted with and without cement, in one-stage bilateral hip arthroplasty: A controlled, randomized study using roentgenstereophotogrammetric analysis. J Bone Joint Surg 1994;76A:185-194.

92. Goetz DD, Smith EJ, Harris WH: The prevalence of femoral osteolysis associated with components inserted with or without cement in total hip replacements: A retrospective matched-pair series. J Bone Joint Surg 1994;76A:1121-1129.

93. Heekin RD, Callaghan JJ, Hopkinson WJ, et al: The porous-coated anatomic total hip prosthesis, inserted without cement: Results after five to seven years in a prospective study. J Bone Joint Surg 1993;75A: 77-91.

94. Dorr LD, Gruen TA: Cement versus cementless fixation for total hip replacement in patients 65 and older. Proceedings of the American Academy of Orthopaedic Surgeons 61st Annual Meeting, New Orleans, LA. Rosemont, IL, American Academy of Orthopaedic Surgeons, 1994, p 250.

95. Jasty M, Bragdon C, Jiranek W, et al: Etiology of osteolysis around porous-coated cementless total hip arthroplasties. Clin Orthop 1994;308:111-126.

96. Callaghan JJ, Salvati EA, Pellicci PM, et al: Results of revision for mechanical failure after cemented total hip replacement, 1979 to 1982: A two to five-year follow-up. J Bone Joint Surg 1985;67A:1074-1085.

97. Engh CA, Bobyn JD: The influence of stem size and extent of porous-coating on femoral bone resorption after primary cementless hip arthroplasty. Clin Orthop 1988;231:7-28.

98. Berger R, Fletcher F, Donaldson T, et al: Dynamic test to diagnose loose uncemented femoral total hip components. Clin Orthop 1996;330:115-123.

99. Salvati EA, Wilson PD Jr, Jolley MN, et al: A ten-year follow-up study of our first one hundred consecutive Charnley total hip replacements. J Bone Joint Surg 1981; 63A:753-767.

100. Sutherland CJ, Wilde AH, Borden LS, et al: A ten-year follow-up of one hundred consecutive Müller curved-stem total hip-replacement arthroplasties. J Bone Joint Surg 1982;64A:970-982.

101. Bosco JA, Lachiewicz PF, DeMasi R: Survivorship analysis of cemented high modulus total hip arthroplasty. Clin Orthop 1993;294:131-139.

102. Hozack WJ, Rothman RH, Booth RE Jr, et al: Cemented versus cementless total hip arthroplasty: A comparative study of equivalent patient populations. Clin Orthop 1993;289:161-165.

103. Havelin LI, Espehaug B, Vollset SE, et al: The effect of the type of cement on early revision of Charnley total hip prostheses: A review of eight thousand five hundred and seventy-nine primary arthroplasties from the Norwegian Arthroplasty Register. J Bone Joint Surg 1995;77A:1543-1550.

104. Mohler CG, Kull LR, Martell JM, et al: Total hip replacement with insertion of an acetabular component without cement and a femoral component with cement: Four to seven-year results. J Bone Joint Surg 1995;77A:86-96.

105. Neumann L, Freund KG, Sorensen KH: Total hip arthroplasty with the Charnley prosthesis in patients fifty-five years old and less: Fifteen to twenty-one-year results. J Bone Joint Surg 1996;78A:73-79.

106. MacKenzie JR, Kelley SS, Johnston RC: Total hip replacement for coxarthrosis secondary to congenital dysplasia and dislocation of the hip: Long-term results. J Bone Joint Surg 1996;78A:55-61.

107. Woolson ST, Maloney WJ: Cementless total hip arthroplasty using a porous-coated prosthesis for bone ingrowth fixation: 3 1/2-year follow-up. J Arthroplasty 1992; 7(suppl):381–388.

108. Smith E, Harris WH: Increasing prevalence of femoral lysis in cementless total hip arthroplasty. J Arthroplasty 1995;10: 407-412.

109. Maloney WJ, Anderson MJ, Jacobs JJ, et al: Polyethylene wear and pelvic osteolysis in association with the Harris-Galante socket in primary total hip replacement. Proceedings of the American Academy of Orthopaedic Surgeons 63rd Annual Meeting, Atlanta, GA. Rosemont, IL, American Academy of Orthopaedic Surgeons, 1996, p 81.

110. Xenos JS, Hopkinson WJ, Callaghan JJ, et al: Osteolysis around an uncemented cobalt chrome total hip arthroplasty. Clin Orthop 1995;317:29-36.

111. Nashed RS, Becker DA, Gustilo RB: Are cementless acetabular components the cause of excess wear and osteolysis in total hip arthroplasty? Clin Orthop 1995;317: 19-28.

112. Amstutz HC, Campbell P, Kossovsky N, et al: Mechanism and clinical significance of wear debris-induced osteolysis. Clin Orthop 1992;276:7-18.

113. Sarmiento A, Ebramzadeh E, Gogan WJ, et al: Total hip arthroplasty with cement: A long-term radiographic analysis in patients who are older than fifty and younger than fifty years. J Bone Joint Surg 1990;72A:1470-1476.

114. Barrack RL, Mulroy RD, Harris WH Jr: Improved cementing techniques and femoral component loosening in young patients with hip arthroplasty: A 12-year radiographic review. J Bone Joint Surg 1992;74B:385-389.

115. Schmalzried TP, Harris WH: Hybrid total hip replacement: A 6.5-year follow-up study. J Bone Joint Surg 1993;75B:608-615.

CEMENTING A LINER INTO A WELL-FIXED SHELL

William Jiranek, MD

Introduction : Revision situations exist where the liner must be changed but the socket is well fixed. Removal of a well-fixed porous coated cementless liner is often difficult and carries the risk of substantial bone loss. Thus, there are revision situations where polyethylene liner exchange is desirable. Unfortunately, the locking mechanism of the metal shell is often damaged or incompatible with the desired polyethylene liner, or the well-fixed metal shell is not in the proper position. Consequently, many surgeons have advocated cementing a polyethylene liner into the existing shell. With appropriate liner selection and preparation, and with proper cement technique, it is possible to create a construct with reasonable lever out resistance.

Methods :

1. Preoperative evaluation
   a. "Is the shell stable?"
   b. "Do we know the size?"
   c. "Do we know the surface treatment of the shell?"
   d. "Is the position roughly acceptable?"
2. Intraoperative evaluation
   a. "Is the shell stable?"
   b. "Significant osteolytic lesion?"
3. Preparation of the shell
   a. Remove debris from shell
   b. Remove loose screws
   c. Score shell if polished (carbide bit)
4. Selection of the Liner
   a. Size which allows liner rim to sit flush against shell
   b. Allows a 1-2 mm cement mantle
5. Preparation of the liner
   a. Circumferential grooves more stable than cruciate
   b. Avoid deep grooves in thin poly
6. Cement thickness / technique
   a. Doughy cement
   b. Pressurize with bipolar trial
   c. Centralize liner

Important Variables

1. Liner size
2. Liner type
3. Liner Configuration
   a. Hemisphere or not
   b. Apron on liner
4. Shell surface characteristics
   a. Polished vs. grit blasted
   b. Screw holes or not
5. Liner surface characteristics
   a. Location of groove
   b. Depth of groove

Preoperative preparation is critical for success. First and foremost, the stability of the existing shell should be assessed radiographically (references). The presence of continuous radiolucent lines or significant osteolytic lesions may preclude the retention of the shell. The surgeon should know the diameter of the existing metal shell, the thickness of the shell (so that the inner diameter of the shell may be calculated) the surface treatment of the articular side of the shell, and the geometric configuration of the shell (ie. how much of a hemisphere). Bonner et al. have demonstrated the importance of accurately sizing the liner to be cemented, with oversized liners failing at much lower levels. In the operating room the surgeon should test the stability of the cup. If stable, the next step is to verify the sizing of the liner, which should be done with trials similar to the final liner. The literature is unclear regarding whether the shell needs to be roughened, and how much. Circumferential cuts in the shell made with a burr would seem to give more resistance to lever out. The need for these cuts is lessened if the shell has an inside rim, screw holes, or other surface disruption. There is little data to suggest whether the use of a cementable shell or a liner manufactured for use in cementless cups is preferential. Bonner et al. demonstrated that if the liner is sized appropriately, adding grooves in the liner does little to improve the lever out strength. Cement is mixed after liner selection and is inserted into the cup in dough phase. The cement may be pressurized with a round ball such as a bipolar trial, covered with a surgical glove, that is 4 mm smaller than the selected liner. The ball should be centralized as much as possible. Meldrum et al. recommend a 2 mm cement mantle at the dome, and the surgeon should avoid liner-shell contact at the dome. The use of face changing and lateralizing liners can compensate for socket malposition or soft tissue laxity, but the surgeon should be alert for positions which can cause neck – rim impingement during a normal arc of motion.

In some clinical situations cementing a liner may not be advisable, such as with a constrained socket, or when the angle of the liner needs to be substantially different from that of the shell.

REFERENCES

1. Bonner, K.F. et al. JBJS, V. 84A: 1587-1593, 2002.
2. Meldrum, R.D. and Hollis, J.M., J. Arthroplasty, V16: 748-752, 2001
3. Haft, G.F. et al. J. Arthroplasty, V. 17: 167-170, 2002

USE OF LARGE CEMENTLESS ACETABULAR COMPONENTS IN REVISION THR

John J. Callaghan, MD

The results with cemented acetabular revisions were less than optimal. In our own series at 10-year follow-up the revision prevalence of aseptic acetabular loosening was 16% and the radiographic loosening prevalence was 40% (Katz et al JBJS 79B, 1997). These results along with the excellent results of cementless acetabular fixation in the primary arthroplasty situation prompted surgeons to explore the use of cementless acetabular fixation in revision hip surgery.

Cementless revision acetabular techniques include:
1. Placement of an acetabular component on host bone in a superior position.
2. Placement of an acetabular component in combination with structural graft.
3. Placement of an extra large acetabular component.

Extra large acetabular components have the following advantages:
1. Increase contact between host bone and acetabular component.
2. Decrease the areas needing bone graft.
3. Normalize the center of rotation.

Disadvantages of extra large acetabular components:
1. Limit bone stock restoration.
2. Cannot work in oblong deficiencies.

Technique for inserting extra large acetabular components in revision hip surgery:
1. Identify remaining bone landmarks (anterior and posterior columns).
2. Identify any pelvic discontinuity.
3. Try not to remove excessive bone.
4. Critical to preserve posterior superior bone.
5. Can partially ream anterior column.
6. Can add bone graft for initial stability.
7. Need to ream out "flimsy" peripheral bone.
8. Reamer needs to be stabilized in acetabular deficiency.
9. Screws should be used for augmentation of the shell fixation.
10. May cement liner into acetabular shell.
11. Large shells are dislocation prone. Consider large heads or constrained liners.

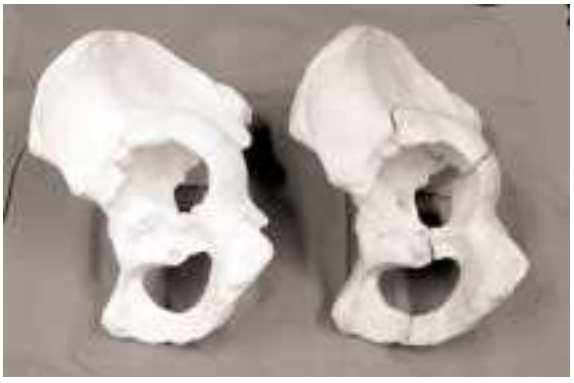
Technique for cementing constrained liner:
1. Score metal shell if no screw holes.
2. Score polyethylene liner.
3. Make sure not to cement component proud.

Results of cementless acetabular revision

Whaley et al JBJS 83A, 2001:
89 hips
8 yr 98% survival to revision
8 yr 95% survival to radiographic loosening

Templeton et al JBJS 83A, 2001:
61 hips
Min. 10 yr f/u
0% shell revision for loosening
2% acetabular migration
7% pelvic osteolysis

Contraindications for cementless acetabular fixation in revision THR:
1. Necrotic bone (post radiation).
2. Less than 50-60% host bone.
3. Pelvic discontinuity with poor bone stock.
4. Absent posterior column.



THE FEMUR: REMOVAL OF WELL-FIXED CEMENTLESS COMPONENTS

Andrew H. Glassman, MD

I. Stem Removal
A. Keys to Success
1. Preoperative planning
2. Adequate Exposure
3. Proper Instrumentation
4. Proper Technique
5. Patience!
B. Preoperative Planning
1. Need for removal
– History and physical
– Plain films
– Ancillary studies (aspiration, nuclear scans, CT)
2. Technical requirements for removal
– Plain film examination
- Canal fill
- Fixation mode (Table I)
- Stem type
Positive identification imperative!
C. Adequate Exposure
• Sliding trochanteric osteotomy
• Extended trochanteric osteotomy
D. Proper Instrumentation – Dedicated instruments!
• flexible osteotomes (flat and "gutter")
• "mini" oscillating saw
• high-speed "pencil tip" burr
• tungsten-carbide cutting tools
• Gigli saws
• Trephines
• Extraction handles (implant specific, universal)
E. Proper Technique
1. Unstable stems
• Manual extraction
• Beware of overhanging greater trochanter!
2. Mechanically stable stems - Interface access and division!
a. Proximal interface division – anterior, posterior, lateral
– Flexible osteotomes
– Oscillating saw
– Pencil tip burr
b. Proximal interface division- medial
– Collar removal, high speed burr
– Gigli saw
c. Stem transection – Tungsten carbide burrs
– Shield the soft tissues
– Copious irrigation
– May need to cut bowed stems more than once
d. Distal interface access and division
1) Hollow trephines
– Most cases
– Have several trephines available
– Copious irrigation!
2) Gigli saw technique
– Requires extended trochanteric osteotomy the whole length of the stem
– Reserved for medically compromised, septic patients
F. Patience!!!!
If a stem (or portion of a stem) cannot be easily removed after initial interface access and division, those interfaces must be revisited and divided again. Never resort to brute force!

Table I. Radiographic Features of Stem Fixation

Stable Fixation Modes
Bone Ingrown
• No implant motion (subsidence, tilting, rotation)
• No reactive lines adjacent to ingrowth surface
• Endosteal hypertrophy at the distal limit of the ingrowth surface
• Proximal atrophy

Stable Bone-Fibrous Tissue encapsulation
• No implant motion, or minimal motion that ceases within one year
• Reactive lines parallel to the ingrowth surface
• Minimal proximal atrophy

Unstable Fixation
• Progressive implant motion
• Divergent reactive lines surrounding the implant
• Pedestal formation at the stem tip
• Hypertrophy beneath the implant collar

BIBLIOGRAPHY

1. Glassman AH, Engh CA, Bobyn JD. A technique of extensile exposure for total hip arthroplasty. J Arthroplasty 2:11, 1987
2. Glassman AH; Engh CA: The Removal of Porous Coated Femoral Hip Stems. Clin Orthop 285:164, 1992
3. Younger TI, Bradford MS, Magnus RE et al. Extended proximal femoral osteotomy. J Arthroplasty10:329,1995

EXTENSIVELY COATED STEMS: TIPS TO MAKE THEM WORK AND AVOID COMPLICATION

William J. Maloney, MD

Extensively porous coated stems are the workhorse for revision total hip arthroplasty in North America. Although there is a growing interest in the use of tapered stems, cylindrical porous coated stems have been in use now for more than 15 years with in general good results.

There are several keys to making extensively porous coated stems work. Developing an appropriate plan preoperatively is important so that one has the appropriate implants available at the time of surgery. The objectives of preoperative planning include the following.

1. Determining technical requirements for removal of the implant
2. Assessing and classifying bone loss to be able to select the appropriate type of implant and determine any special needs such as allograft or adjuvant fixation.
3. Determining the component size, length and shape (straight verses bowed)
4. Templating to determine the appropriate height of the implant as well as the offset

There are several classifications systems for assessing bone loss. I prefer the classification by Paprosky et al. That classification is as follows.

1. Type I – Femoral deficiency: no significant bone loss
2. Type II – Femoral deficiency: cavitary bone loss and thinning of the cortices
3. Type III – Femoral deficiency: uncontained segmental bone loss less than 5 cm length extending to the level of the lesser trochanter.
4. Type IV – Femoral deficiency: uncontained segmental bone loss greater than 5 cm length extending into the diaphysis.

Extensively porous coated stems, especially cylindrical stems work best in Type I, Type II and Type III bone. In general, it is necessary to have approximately 4 to 5 cm of intact tube in order to get a good scratch fit with cylindrical stems. Once one goes to a bowed stem, it tends to be more of a three-point type of fixation, however, one still needs approximately 4 to 5 cm of bone for good fixation. In Type IV femurs where the tube is significantly compromised distally other options may be more appropriate.

A good cross-table lateral x-ray of the hip and femur is helpful preoperatively to determine whether a bowed or straight stem is most appropriate. In general, straight stems longer than 8 inches are difficult to utilize and most if not all stems longer than 8 inches should be bowed, especially if the tube is intact. One of the most common complications with the use of extensive porous coated stems longer than 6 inches is impingement of the distal end of the stem on the anterior femoral cortex. This in some cases is unavoidable, however, one would like to if possible avoid fracturing as well as creating defects anteriorly. Use of the appropriate stem length and stem geometry can help in this and preoperative planning gives one a reasonable idea of what will be found in surgery.

Preparation of the femur is also important as it relates to anterior stem impingement. When one is straight reaming the femur if using an 8 inch stem one has to try and keep the proximal end of the reamer anteriorly so the tip of the stem goes posteriorly and not through the anterior cortex. In general, when one is using bowed stems, a flexible reamer is more important.

Preparing for stem insertion is dependent on whether an extended trochanteric osteotomy has been done or not. With bowed stems, as noted above, I utilize primarily a flexible reamer. However when one is into the diaphysis near the isthmus, one may use a straight reamer, as the distal end of a bowed stem is straight and if that is all that is seated, a straight reamer may be more appropriate. If the tube is intact with an 8 or 10 inch stem it is often necessary to ream between 0.5 mm and 1.0 mm over the stem size to allow safe insertion of the stem and maintain stem stability. However if an extended trochanteric osteotomy is performed one would either ream line to line or under ream 0.5 mm with a bowed stem. This is in part based on how much contact area one has and where the stem is fitting into the diaphysis of the femur. This requires not only a trial reduction but at times starting with a slightly under reamed technique, starting to insert the stem and then backing out if it does not go. It is not an exact science and reflects in part the art of surgery. Occasionally, one will have to waste a stem because the canal has been reamed too large and the stem is not stable.

When the stem is being inserted if the proximal femoral bone is very osteopenic or if any cracks occur during rasping one can prophylactically cable the femur to reduce the risk of fracture. Similarly, if an extended trochanteric osteotomy is performed a cable just below the osteotomy level around the femoral shaft will aid in protecting it from crack formation and propagation.

Despite optimum manufacturing standards, the diameter of beaded cementless stems can vary by as much as 0.04 mm. It is advisable to measure the provisional, the spline or smooth tip rasp tip and the implant itself so that one has an idea of how the femur is prepared in relation to the final stem.

As one is inserting an extensively porous coated stem one has to control femoral anteversion. With bowed stems, the distal end of the stem tends to rotate along the natural bow of the patients femur. One can get an idea what the final anteversion will be using the trial implants.

IMPACTION BONE GRAFTING: TIPS TO MAKE IT WORK AND AVOID COMPLICATIONS

Miguel E Cabanela, MD

This method of femoral component revision was first used by Ling, reported by Gie, and is based on a method for acetabular revision first reported by Slooff. The method uses compressed morselized cancellous allograft to rebuild bone stock in the endosteal aspect of the femur combined with a cemented collarless polished tapered stem. Favorable and , more rarely, less favorable results have been reported both from the U.S. and Europe and the technique remains very popular in Europe, particularly in the U.K., where it is used as the only femoral revision technique in more than a few centers.

TECHNIQUE

Complete removal of femoral component, cement, fibrous membrane and all debris. Endosteal surface must be perfectly cleaned.

Reconstruction of segmental defects with Co-Cr screen or vicryl mesh and allograft struts as necessary.

Canal occlusion 3 cm below distal-most cavitary deficiency or tip of CPT implant. Usually plastic cement restrictor suffices.

Cancellous allograft bone from femoral heads and/or distal femora prepared using rongeurs and/or mechanized bone mill. Small fragments of 4-6 mm are advisable.

Using centering guide, packers of increasing size and oversized tampers, graft is impacted vigorously into femoral canal until a neomedullary canal is obtained. Impaction is to be very vigorous.

After trial reduction, cement is vacuum mixed and injected in a retrograde fashion, pressurized and CPT stem is inserted.

POSTOPERATIVE CARE

- Routine mobilization
- Encourage ambulation with TWB for 8 wks
- Progress as tolerated

EXPERIENCE

1993-1997
57 revisions done with this technique using CPT prosthesis
3 surgeons, 404 revisions done during same period (14% of practice)
All cases had severe cavitary or combined deficiencies (types II or III AAOS) or Paproski types III-IV
25 males – 29 females, 3 bilateral
Age 62.7 yrs (36-79)
Strut allografts used in 40
42/57 sockets revised
Follow-up mean 6.3 yrs (3-9.3 yrs). No patient lost.

Results

3 patients died with functioning hips (3,5.3 and 6 yrs. p.o.)
1 pt infected and implant removed at 18 mos.
46 pts had moderate or severe pain preop
2 had moderate pain at follow-up
No radiographic loosening
Subsidence (cement-metal interface) 1-3 mm. in 44 hips, 4-6 mm. in 2
Partial-complete cancellous graft remodeling observed in 42 hips

Complications

1 infection
3 instability (5.3%)- 2 revised
1 peroneal palsy- resolved
4 intraoperative fractures (7.0%)
6 postoperative fractures (10.5%)
3 occurred early (0-6 mos p.o.)
None associated with prosthetic loosening
All healed with ORIF (plate-strut allograft at 90∞ to each other)

HISTOLOGY OF GRAFTED BONE

Studied in 15 instances at different intervals after arthroplasty and in goats as well.

In goats a remodeling front was seen moving through the impacted allograft from host-bone junction to cement-graft junction.

Biopsies in humans suggests same sequence of events.

Why does technique work?

Graft impacted on vascularized bed. This may enhance potential for substitution and incorporations.

Hoop stresses on cement mantle and therefore on graft may help revascularization.

Stability may facilitate remodeling.

CURRENT INDICATIONS

- Large diameter femoral canals with significant cavitary deficiencies where other techniques would not be applicable .
- Particularly valuable when distal femur deformed or occupied.
- Small segmental deficiencies not a contraindication.
- Our use of this technique has decrease significantly as other techniques are quicker and cheaper.

TECHNICAL TIPS

- Prepare receiving bone well: clean endosteum, reinforce when needed (with wire not cable), augment p.r.n. (if strut augmentation used, carry the strut distal enough and avoid cables at the tip of the prosthesis)
- Occlude distal canal with plastic (not cement-think of the future)
- Use morselized femoral heads or distal femora and pack the bone vigorously.
- Pay careful attention to tamp version when packing
- Pressurize cement.
- Use polished prosthesis

BIBLIOGRAPHY

1. D'Antonio J et al: Classification of femoral abnormalities in total hip arthroplasty. Clin Orthop 296:133, 1993.
2. Elting JJ, Zicat BA, Mikhail WEN, et al: Impaction grafting: Preliminary report of a new method for exchange femoral arthroplasty. Orthop 18:107-112, 1995.
3. Gie GA, Linder L, Ling RSM, et al: Infected cancellous allografts and cement for revision total hip arthroplasty. J Bone Joint Surg 75B:14-21, 1993.
4. Gie GA, Linder L, Ling RMS, Timperly AJ: Constrained morselized allograft in revision total hip arthroplasty. Paper No. 592, AAOS Annual Meeting, San Francisco, 1997.
5. Ling RSM, Timperley AJ, Linder L: Histology of cancellous impaction grafting in the femur. J Bone Joint Surg 75B:693, 1993.
6. Meding JB, Faris PM, Keating EM: Impaction bone grafting with a cemented stem: minimum two year follow-up. Ortho Trans 20:93, 1996.
7. Schreurs BW, Buma P, Slooff TJ, Schimmel JW, Gardeniers JW: The incorporation of impacted morsellized cancellous bone allografts. Paper No. 546, AAOS Annual Meeting, San Francisco, 1997.
8. Slooff TJ, Huiskes R, et al: Bone grafting in total hip replacement for acetabular protrusion. Acta Orthop Scand 55:593-596, 1984.
9. Slooff TJ, Schimmel JW, Buma P: Cemented fixation with bone grafts. Orthop Clinics NA 24:667-677, 1993.

FLUTED TAPERED MODULAR REVISION STEMS

William J. Hozack, MD

Non-modular fluted tapered revision stems have enjoyed immense popularity in Europe. Wagner introduced his stem in 1987 as a means of treating severe femoral bone deficiencies. The tapered stem was designed to obtain fixation distally in the femoral canal beyond areas of significant bone damage. In cross-section, these stems had a number of titanium flutes projecting from the central stem core. These flutes created immediate rotational stability for the stem within the femoral canal, and ultimately allowed for osseointegration.

Very little is published. Kolstad reported 31 revision hip replacements using the Wagner stem with a mean follow-up of 3 years. A transfemoral osteotomy was employed in all cases, and restoration of proximal bone quality was noted. While the mean subsidence was low, 6 hips (20%) subsided more than 10 mms. Bohm reported on 129 Wagner stems with a mean follow-up of almost 5 years. Subsidence of the stem was a significant problem: >5mms in 34%, >10mms in 20%. On the other hand, 88% of stems achieved osseointegration with a survivorship of 93% at 11 years.

In summary, while non-modular fluted stems achieved reasonable clinical results, several problems have been identified: subsidence, lack of modularity leading to difficulty with leg length restoration, and instability related to inadequate offset of the Wagner design.

Modular fluted tapered stems have achieved some degree of popularity in the USA. The philosophy of the modular design is to allow solid impaction of the fluted stem to a position of complete stability, thus minimizing subsidence. Then the surgeon chooses one of several proximal bodies of different lengths (to eliminate leg length discrepancy), placed in optimal version (to maximize joint stability).

Certain technical aspects are very important for success of these tapered modular revision stems.

1. It is critical to prepare a precise taper within the femur to accept the tapered stem. Inadequate preparation due either to under-reaming or inadequate exposure will compromise the ultimate result.

2. The transfemoral osteotomy is a key aspect of the overall technique. Using a TFO, preparation of a precise cone within the femur to accept the femoral stem is facilitated. While a precise cone can be prepared without the TFO, it is not so reliably done. The TFO has also simplifies removal of components and cement. The osteotomy may also play a role in the regeneration of proximal bone stock seen with the tapered conical revision stems.

3. Place a cerclage cable just distal to the osteotomy site. This allows more security with respect to proper preparation of the femoral canal.

4. After placing the distal stem, use the proximal body trials to adjust for leg length, offset and stability. The proximal bodies should be porous coated to encourage proximal bone ingrowth. This will provide more proximal load sharing and also block the femoral canal from osteolytic debris.

The advantages of a modular tapered revision stem are its versatility for a variety of bone defects, the simplicity of use and instrumentation, the substantial rotational stability achieved, and the significant proximal bone remodeling seen.
Disadvantages include the potential for fracture (newer modular stems are manufactured to higher tolerances) and the problem of subsidence (reduced or eliminated through surgical technique with TFO and cerclage). Newer designs are likely to eliminate concerns about proximal bone ingrowth and long-term osteolysis.

PROXIMAL FEMORAL ALLOGRAFTS FOR REVISION HIP SURGERY

Allan E. Gross, MD, FRCSC

Surgical Technique (Fig 1):

Allograft bone is brought into the operating room at the beginning of the case, unwrapped when infection has been ruled out by operative findings and gram stain, cultured, and immersed in warm Betadine. The bone is obtained from the hospital bone bank, where it has been deep-frozen at -70oC after being irradiated with 2.5 megarads.

The transtrochanteric approach is used most commonly because of the need for extensive exposure. We now prefer a longitudinal splitting osteotomy or a sliding osteotomy because both are more stable than a transverse osteotomy. The proximal femur is exposed by reflecting the vastus lateralis off the intermuscular septum anteriorly, being careful not to strip any residual bone of its soft tissue completely.

A Steinmann pin is inserted into the iliac crest as a reference point to adjust leg lengths. The distance from the pin to the rough line (insertion of the vastus lateralis) is recorded prior to dislocation. The acetabulum is reconstructed first in order that the length of the femoral allograft can be determined.

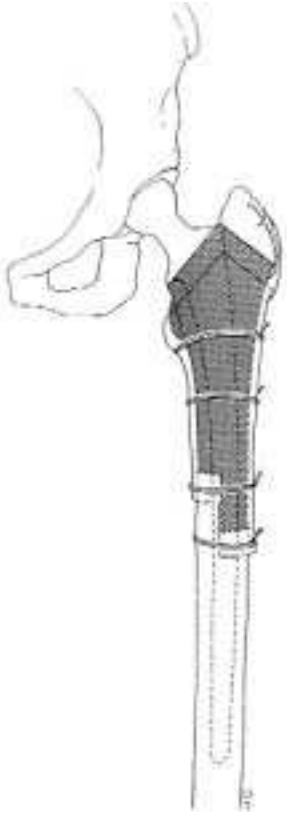
Long-stem femoral components designed to be used with allografts are used. It is narrow proximally compared to standard implants so that the allograft does not have to be reamed too much to allow the implant to fit. The residual proximal femur is split longitudinally distally to good bone. The transverse cut is done at the level of good host bone and is done only through half of the circumference so that a step cut can be fashioned later. As much soft tissue as possible is left attached to the residual bone for later use as a vascularized bone graft. The cement is then removed.

The distal host femur is then reamed gently over a guide wire to assess canal size for the implant rather than to enlarge the canal. The allograft, which is either proximal femur or tibia, is then reamed and broached until a good fit for the implant is achieved. It is important not to over-ream the allograft in order to get a press-fit of the femoral component into the host. The host canal is always larger than the allograft and therefore it is usually impossible to get a press-fit into the host without over-reaming the allograft which would weaken it. We therefore cement the implant to the allograft and use a step-cut at the junction of host and allograft to gain stability rather than worry about the press-fit. If there is a large discrepancy between the diameter of host femur and allograft a step cut may be technically difficult and stabilization may have to be achieved by other means. Cortical struts fixed by circumferential wires may be used. If the diameter of the host bone is significantly larger than the allograft, then stabilization may be achieved by telescoping the allograft inside the host for a distance of 1 or 2 cms. The length of the allograft necessary is assessed in vivo by placing the femoral implant into the host bone and reducing it into the trial cup. The selected length depends on stability and leg length discrepancy. A step-cut of about 2 cm x 2 cm or an oblique osteotomy is carried out in the allograft and in the host.

When the correct length of allograft is obtained and the stability of the reconstruction is acceptable, the implant is cemented into the allograft after drill holes are made and wires are passed for trochanteric reattachment. It is very important to keep the cement off the interface that will oppose host bone. The allograft with the long stem femoral component cemented in place is inserted into the host and cerclage wire is used to stabilize the step-cut. The junction of host and allograft is also autografted by reamings or other host bone that is available. The residual host proximal femur is wrapped around the allograft and held by cerclage wires. An attempt is made to bring these vascularized pieces distally to wrap around the osteotomy junction to encourage union. Cortical strut allografts may be used to stabilize the allograft host junctions.

Once union is achieved at the osteotomy because the implant is cemented to the allograft, the femoral reconstruction is stabilized. The implant is always cemented to the allograft but not to the host.

Figure 1:



◆ COMPUTER NAVIGATION IN ADULT RECONSTRUCTIVE SURGERY: THE INTERNATIONAL EXPERIENCE (AA)

Moderator: James B Stiehl, MD, Milwaukee, WI (e – DePuy, Zimmer)

Computer assisted navigation has emerged as an important tool in adult reconstructive surgery such as total hip and total knee arthroplasty, anterior cruciate ligament reconstruction, and high tibial osteotomy. There are few centers in North America with early experience. This symposium will provide an overview of the technology available and will highlight the current data available from several German centers where CAOS is commonly used.

I. Option, Options, What Do I Do Next?
James B. Stiehl, MD, Milwaukee, WI (e – DePuy, Zimmer)

II. Robotics, State of the Art
William L. Bargar, MD, Sacramento, CA (d, e – Integrated Surgical Systems)

III. Overview of the Current Technology in CAOS and The German experience with CAOS, Data on THA
Rolf G. Haaker, MD, Brakel, Germany (b – Aesculap)

IV. Application to Knee Arthroplasty and MIS
S. David Stulberg, MD, Chicago, IL (e – Aesculap)

V. Applications to Hip Arthroplasty and MIS
Anthony M. DiGioia, MD, Pittsburgh, PA (a, e – Zimmer, a – NTA, NSF, d – CA Surgical)

VI. The German Experience with CAOS, The Data on Total Knee Arthroplasty
Werner Konermann, Hessich-Lichtenau, Germany (*)

VII. Emerging Technologies, Where Are We Going?
Eric Stindel, MD, Cedex, France (a - French Ministry of Industry)

VIII. Navigation in High Tibial Osteotomy
Joachim Hassenflug, MD, Kiel, Germany (b – Aesculap/B.Braun)

IX. Navigation and Robotics in Anterior Cruciate Ligament Reconstruction
Andree Ellerman, MD, Mannheim, Germany (n)

OPTIONS, OPTIONS, WHAT DO I DO NEXT?

James B. Stiehl, MD

Basic Questions:

1. Am I satisfied with my current total joint outcomes or would like better results?
2. Do I use a computer for email, powerpoint, or personal checking or do I leave it to others?
3. Am I content with my current practice or am I interested in cutting edge technology that will make my practice visible as a "center of excellence"
4. Am I willing to add time and expense to learn about this technology, convince my hospital administrator that the hospital need to buy it, and the add 15 to 20 minutes operating room time to every primary total joint that I do?
5. Do I have the patience and ability to tolerate a new technology that has a short but relatively steep learning curve?
6. Does the potential new information about my current practice excite me?

Upside Advantages:

1. Increasing practice volume is a distinct possibility with computer navigation
2. Surgeons will learn interesting things about their current technique, particularly cup placement in THA and ligament balancing in TKA.
3. Case documentation with the computer will diminish surgical errors and provide a level of comfort
4. New MIS and small incision techniques will become easier and safer with computer navigation

Which System Do I Choose?

1. Companies actively marketing navigation systems:
   - Praxim-Medivision: French company merged with Medivision, of Switzerland. Medivision pioneered CT referencing in hip and knee surgery. Has recent software for imageless knee, fluoroscopic referencing of the hip. Praxim has a "bone morphing" algorithm for the knee
   - Brainlab: Swiss company with over 800 systems worldwide in neurosurgery, ENT, spine, etc. Currently offers imageless total knee, CT of hip and knee. The imageless knee system requires CAD models from the manufacturer.
   - Stryker Leibinger: CT Based and imageless hip and knee.
   - Medtronic: Over 1600 systems in place worldwide. Currently offers fluoroscopic hip and knee, and imageless knee system. Works off a universal platform that may be used with any total knee instrumentation.
   - Aesculap: Orthopilot system offers both CT and imageless for the hip and knee. Knee system requires the use of the Columbus total knee system.

Navigation Options:

1. CT Based: Requires preoperative CT Scan, data manipulation for preoperative planning, referencing done intraoperatively matching touch points to the scan. Accurate to 1∞ or 1 mm. Total hip, knee and spine applications commercially available.
2. Imageless Total Hip and Total Knee: Uses various methods for referencing including hip rotational digitization, touch pointing landmarks, using a standard bone morphology or "bone morphing" with touch pointing of many local points. Accurate to about 2-3 mm.
3. Fluoroscopic Total Hip and Total Knee: Requires intraoperative knee and hip fluoroscopy with both the patient marked with an active marker and the fluoroscopy machine setup with a matching grid. Accurate to 1∞ or 1 mm.

Operating System and Software Options:

1. Computer operating system- Unix is best option for high data transfer requirements. Microsoft less attractive and prone to 'freeze'.
2. CCD or Camera- must be easily moveable on articulating extension that allows easy positioning. Laser pointer to field is valuable. Medtronic offers the camera and computer on separate stands that move independently
3. Software- must be user friendly, can it be advanced with a foot pedal, touch screen or mouse? Is screen data easily readable from 10-15 feet. Is it easy to go to any point in the navigation process and can you take steps out of order? Can case data be copied from the hard drive?

Field Service Support:

1. Critical element!!
2. Must have rep "in house" for at least 10-15 cases to make certain technical issues are understood and dealt with.
3. Rep then must be available at moments notice for software issues.
4. Surgeon must be as knowledgeable as his staff on all computer functions as a 'key' nurse or tech may not always be available. He then must be able to interface with the rep.

Conclusion:

1. Surgical navigation and robotics are time tested, beneficial, and a future reality for orthopaedic surgeons
2. Scientific literature presented to date supports this evolutionary technology
3. Technical skill may favor younger surgeons who have grown up with computers
4. Substantial time, experience and resource commitment are needed to venture into this area.

ROBODOC: THE INTERNATIONAL EXPERIENCE

William L. Bargar, MD

Robodoc: The Idea. Robodoc was conceived in 1986 to address the problems of failure of ingrowth into the femoral component and post-operative thigh pain following cementless total hip replacement, which were common in the 1980's. By optimizing the implant selection, the position of the implant and the surgical preparation of the femur, the Robodoc System was designed to insure ingrowth and provide more uniform stress transfer. The device consists of a computer workstation (Orthodoc), on which to view a pre-operative CT and plan the surgery, and a 5-axis robotic arm with a high-speed cutting tool as an end-effector (Robodoc).

Development. The development process began in 1987 with a feasibility study at The IBM Thomas Watson Research Center. IBM had developed a new experimental language (AML-X) that for the first time would allow robots to be programmed for complex tasks similar to the way computers were programmed. The in vitro development took place under a grant from IBM at UC Davis from 1987 to 1989, followed by a canine study from 1989 to 1991. In Nov. 1992, the first human case was performed as a part of a 10 patient FDA feasibility. An FDA multicenter, randomized, controlled trial was conducted from 1993 to 1995, with 2-year follow-up completed in 1997.

The Original Procedure. Three fiduciary markers ("Locator Pins") were placed under local anesthesia in an outpatient setting. A CT scan was then performed and the data imported into the Orthodoc Workstation. The surgeon then planned the surgery by viewing three orthogonal views and manipulating three-dimensional templates using the mouse. Once the surgeon was satisfied with the plan, the data was saved on a tape to be used later in surgery. On the day of surgery, after a conventional surgical approach (either anterior, direct lateral or posterior), the hip was dislocated and placed in an external fixator. The three pins were exposed and the robot was guided to the top center point of each pin. If the inter-pin distances found by the robot matched those from the CT scan, the "registration" was accepted and the robot would proceed to mill out the proximal femur for the intended implant. Following this, the robot was disconnected and the procedure completed in the conventional manner.

Results of the Initial FDA Trial. There were 136 hips (71 robot, 65 control) in the study. The Robodoc cases had an average Harris Score of 88.9 versus 91.1 for the controls (NSD). Radiographic review by an independent blinded radiologist showed statistically better fit and alignment of the implants for the Robodoc group. Complications were few and not different between the groups with the exception of 3 intra-operative femur cracks in the control group and none in the Robodoc group. There were no device related complications. The mean surgical time, however was significantly longer for the Robodoc group (258 min. versus 134 min.) with a relatively long learning curve. Blood loss was also more for the Robodoc group (1189 cc versus 644cc), which directly correlated with the longer time. Despite this difference, there was no difference in the number of transfusions required.

The Early German Experience. Robodoc was approved for sale in Europe in 1994. The first center was the BGU Clinic in Frankfurt, under the direction of Dr. Martin Borner. Over the next few years, the number of centers grew to over 30. Significant technological improvements in the device were made in Germany. The device was applied to revision surgery in 1998 allowing for simultaneous removal of cement and preparation of the femur2. The "Two-Pin" technique was also introduced in 1998. In 1999, the "Pinless" technique was introduced. In 2000 the device was applied to total knee replacement. Over these years the device became more efficient, with faster cutting times and a more robust error recovery system. Surgical times were reduced to only 20-30 minutes longer than the conventional technique.

The Current FDA Multi-center Study. This study was designed to address the issues of increased time and blood loss found in the first study, as well as to validate the "pinless" technique that eliminates the need for the initial pin placement surgery and the transient morbidity associated with the pin sites. The study began in 2001 and consists of three centers. Initial data on 80 patients shows that average blood loss is now statistically equivalent to controls and the average surgical time is only 36.9 minutes longer for the robot group. Again, there have been no failures and no robot-related complications.

The International Experience. There are nine systems now in Japan and two in Korea. Over 12,000 cases have been performed worldwide. Additional applications available outside the U.S. are: primary total knee, revision total hip and unicompartmental knee replacement. Currently, controversy exists in Germany. A recent paper by Honl, et. al. in the September 2003 JBJS was critical of Robodoc citing an alarming incidence of hip instability due to damage to the abductor muscles. In this paper the implant used was the SROM, which is longer and has a significant lateral flare at the proximal sleeve. This would require the cut-path for the robot to encroach more into the trochanter. In some cases with "trochanteric overhang" of the canal, this might result in damage to the abductor muscle insertion. The cut-path of the robot can be viewed on Orthodoc at the time of planning the surgery, and such cases should be excluded. Despite the accuracy and reproducibility of the robot, it is still the surgeon's responsibility to plan the surgery correctly on Orthodoc, selecting the appropriate implant for the individual patient, as well as to protect the soft-tissues from injury at the time of surgery. Certain cases may need to be excluded, although this was infrequently encountered in the US experience. A review of the initial and current USFDA studies shows that there have been no failures and there is no difference in the incidence of limp or use of ambulatory aides between the Robodoc and control groups. The results found in the Honl paper seem to be an isolated experience. The device continues to be used successfully worldwide.

Robotics vs. Navigation. The development of computer navigation systems has created competition for Robodoc for those surgeons and patients interested in computer-aided surgery. These systems are cheaper and are more easily adopted by the surgeon. They also have some potential risks and limitations. It is useful to compare and contrast Robodoc to computer navigation. Of course, the major difference is that for navigation systems, the surgeon still performs the actual surgery, whereas with Robodoc the robot executes the pre-op. plan. Many surgeons are reluctant to commit to a specific pre-op plan and they consider this a major disadvantage for Robodoc. On the other hand, it can be considered a major advantage for

the robot to execute the plan since it can reduce variation and eliminate human error. Both robotics and navigation require registration of the bone to the device. The accuracy of registration is critical. The Robodoc system has an accuracy of a fraction of a millimeter1. Studies showing the accuracy and reproducibility of many navigation systems are lacking. Bone tracking is also a part of both the Robodoc system and navigation systems. For Robodoc, the bone is held tightly in a fixator and a mechanical bone-motion monitor is used to detect unwanted motion. In navigation systems, optical arrays are attached to the bone, which is allowed to move freely. If an array loosens, it can go undetected and significant errors can occur. In the Robodoc system, if the motion monitor loosens or unwanted motion occurs, the robot stops and the surgeon is prompted to re-register the bone, thereby avoiding error. Both Robodoc and navigation systems require extra time for registration and execution. For Robodoc, after registration is complete (usually about 10 minutes), the milling time is a predictable 12-20 minutes depending on the implant size and type. For most navigation systems, the registration time is also approximately 10 minutes, but the execution time depends upon how the surgeon chooses to act on the computer information and whether he decides to correct any minor variations detected. This extra time for navigation can be highly variable. Of course extra time is potentially detrimental to the patient and also affects the acceptance by surgeons of the technology. How much extra time is too much is yet to be decided.

A Blend of Robotics and Navigation. Over the next few years the choice between robotics and navigation will be clarified. Perhaps the most logical choice will be a hybrid of both fields. Some parts of a surgery that require less precision may be better done with navigation (e.g. acetabular cup placement). Other parts requiring more precision and pre-op. planning may be better done using robotics (e.g. femoral stem placement). A system combining both may be most versatile.

Robodoc and MIS. Minimally invasive surgical techniques are changing the practice of orthopaedic surgery. MIS offers decreased morbidity and more rapid recovery. The challenge is to maintain the required standard of precision with limited exposure. Robodoc offers the potential to work through a small skin incision (~3 cm) and execute the plan without the need for visualization or intraoperative imaging. This has yet to be developed, however, and will have to surmount the hurdles of percutaneous registration and soft tissue protection.

REFERENCES:

1. Paul, HA, Bargar, WL, et al. Development of a surgical robot for cementless total hip arthroplasty. Clin Orthop. 1992 Dec;(285):57-66.

2. Bargar, WL, Bauer, A, Borner, M. Primary and revision total hip replacement using the Robodoc system. Clin Orthop. 1998 Sep;(354):82-91

OVERVIEW OF THE CURRENT TECHNOLOGY IN CAOS

R. Haaker

Conceptual Structure
Each clinically used CAOS system consists of three components that are related to each other in a certain way . The type of relation differs depending on wether it is a surgical robot or one of the navigation systems that will be described below. In any case, each of the three components is required to guarantee proper functioning of the entire setup. From a mathematical standpoint, the components are regarded as non-deformable rigid bodies, each of them featuring a three-dimensional coordinate system. Geometric entities such as points, angles, planes, axes, or volumes are defined with respect to these local frames of reference.

Therapeutic Objekt
The therapeutic object represents the target of the surgical intervention. In the domain of orthopaedic applications, the therapeutic objects are usually bony structures. However, the target may also be an implantat, e.g., when a locking screw is supposed to be placed through the distal hole of an intramedullary nail that has been implanted to stabilize a femoral fracture. In a few cases, the aforementioned rigid body principle is violated. For instance, in traumatology the individual fragments of an unstable fracture have to be treated as separate therapeutic objects.

The steps described in the following paragraphs then have to be applied to each of the fragments.

Pure soft tissue surgery, however, cannot be supported by the principles described in this lecture. Only if the tissue in question is very close to some bony structure is it a valid assumption to regard both as one rigid body. For example, nucleotomies could be supported by a CAOS system if one of the vertebrae, which are linked by the treated disk, was defined as therapeutic object.

Navigator
The navigator represents the central element in each CAOS system. It defines a global or "world" coordinate system, in which the positions and orientations of the acting instruments are given. While a robot is also referred to as an "active navigator", navigation systems use passive navigators that track the position of instruments usually remotely. During active navigation surgical instruments are mounted onto the actuator of the robot and are guided by the machine.

For passive navigation, different physical principles to achieve remote position sensing have been described, but neither ultrasonic determination nor the use of magnetic trackers (1) proved to be successful techniques. The former measurement principle is very sensitive to temperature variations and therefore requires accurate calibration prior to each usage. Moreover, no commercial ultrasound-based tracking product is currently available, on which a surgical navigation system could be based. Wallny et al. Used a custom-made ultrasonic tracker in their setup. Electromagnetic field and then measure the characteristics of that field. Although this is the only technique not relying upon a direct line-of-sight between the measuring device and the object of interest, electromagnetic tracking suffers from a severe disadvantage. The field characteristics are very vulnerable to the presence of metallic and even non-metallic objects. Neither the qualitative nor the quantitative nature of this undesired influence and the resulting measurement errors can be predicted. Consequently, it is also not possible to compensate for them.

Optoelectronic tracking of surgical instruments shall be described in more detail in the following section. This technology is nowadays used within free-hand navigation systems. In order to determine the spatial position of any rigid surgical instrument, it is sufficient to acquire the exact location of at least three non-collinear points on this object. These points are created by actively infrared light reflecting spheres with a specially coated surface. Using light at infrared wave lenghts guarantees an OR-compatible set-up. Moreover, the influence of other light sources on the measurement device is minimised. In the following, LEDs and spheres are refered to as "markers" . They are mounted onto the instruments to be tracked in sets of three, four, or even larger quantities. Camera systems that consist of two or three single CCD (charged coupled device) cameras then observe the signals coming from the markers. Using larger numbers of markers creates redundancy and allows for the determination of an instrument`s position at an arbitrary spatial orientation, even when one or more markers are currently not facing the camera system. When LEDs are used, they are flashed in a fast sequence one after the other. For the cameras, only one light flash is visible at a time, and it can be assigned to one particular LED, allowing easy identification of a large number of different, simultaneously used instruments. Passive markers are illuminated by flashes of infrared light originating from a light source on the camera system. They reflect patterns or single light points. Analysing consecutive image frames enables the system to recognise marker signals that move synchronously and thus must represent one rigid body. In order to unambiguously distinguish several instruments within a set, different sphere arrangements are chosen for different rigid bodies. Both tracking approaches have their advantages and disadvantages. The most obvious difference is the presence of cables that almost every active marker system requires in order to control the LEDs.

They demand a certain discipline and tidiness at the operating table, especially when large instrument sets are used. Passive marker systems, on the other side, contribute considerably to the per-case costs, because the spheres should be regarded as disposables. Moreover, the accuracy by which the center of reflection is determined decreases if the sphere is partly covered, e.g., by a blood splash.

Referencing
The so-called referencing is essential for navigation systems as well as robots. It allows expressing of an instrument`s position relative to the therapeutic object. Referencing establishes a local frame of reference on this object and thus integrates it into the coordinate space of the navigator. During active navigation the therapeutic object is rigidly connected to the robot, e.g., by means of a bone clamp or with a screw attachment. Surgical navigation requires a marker shield to be clamped or screwed onto the therapeutic object as soon as surgical exposure allows it. The attached probe is known as a "dynamic reference base" (DRB), because it makes a loose coupling rather than a statically rigid connection to the navigator. In either case, a stable link to the bone is certainly mandatory during the entire time of CAOS usage.

Virtual Object
Lust but not least, the virtual object represents an image of the therapeutic object. The first navigation systems were introduced

when no medical imaging modalities were available. Anatomical atlases were used instead, and surgeons accepted that deviations from such "normalized anatomies" necessarily must lead to inaccuracies.

Nowadays, a wide variety of methods are available, permitting imagine of basically every structure within the human body (12). However, this chapter focuses only on those methods that are of importance for the application of CAOS technology in orthopaedics and traumatology. To further organize the significant number of potential virtual objects, They are categorized according to the time and method of image generation.

Preoperative Imaging

Computed tomography (CT) is definitely the most important representative of preoperative imaging for orthopaedic surgery. A CT is a three-dimensional, geometrically precise data set that is well suited for the visualization of bone, because interior structures are displayed clearly and with a high bone-soft tissue contrast. Moreover, CT scans are created digitally, so post-processing within computer-based systems is easy. Magnetic resonance imaging (MRI) is also three-dimensional and digital, and furthermore does not expose the patient to any radiation. However, MRI scans so far are not regularly used in CAOS systems. Compared to CT`s, geometric inaccuracies and a rather low bone-soft tissue contrast limit their broad usage as virtual objects.

Theoretically, the use of digital X-rays or scanned conventional X-rays would be possible. However, the missing third dimension in these projection images and the difficulties related to a precise calibration of X-ray machines make computed tomography superior in most cases.

Intraoperative Imaging

Preoperative imaging is the method of choice for a large number of navigation systems, and it is compulsory for the usage with orthopaedic surgical robots. Nevertheless, several disadvantages exist. The acquisition of a CT requires additional financial and logistic efforts. In many cases in which navigation is supposed to be applied, no diagnostic CT scan is available or it cannot be used, because it had, for instance, been created by an external facility and is retrievable as conventional film only, rather than as digital data. For the acquisition of a CT for a navigated intervention, the patient is usually required to come to hospital earlier, again causing additional costs. Last but not least, bony topology is often altered by the operation causing as mismatch between the intraoperative situation ant the preoperative image. Examples are the reduction of complicated fractures or repositioning osteotomies.

As an alternative, C-arm imaging can be applied to create virtual objects intra-operatively (10,11). When compared to CT as imaging means, fluoroscopy suffers from the fact that a series of projection images serves as the navigation basis rather than a three-dimensional data set. These disadvantages are –at least partly- offset by a novel C-arm device that will be presented in chapter 3 (The intraoperative usage of ultrasonic and endoscopic equipment within orthopaedic navigation systems is still in its laboratory phase, and they will not be presented here. Interested readers are referred to chapter 71).

Registration for Intraoperative Imaging

In theory the projection model of a C-arm is that of a simple pinhole camera (7). In this analogy, the position of the X-ray source is equivalent to the aperture of the camera. In reality,however, effects such as Earth`s magnetic field considerably distort the images acquired with a fluoroscope. Would these adverse effects not be accounted for, they would prohibit precise navigation within C-arm images. To correct these errors, the image intensifier unit is equipped with a plate carrying a regular pattern of metal spheres or other markers. The precise location and relationship of one marker to another is well-known and allows for the adjustment of image distortions.

If a tracking system is observing both the fluoroscope and a DRB while such intrinsically calibrated images are acquired, the coordinate transformation between virtual object and therapeutic object can be determined automatically without a manual paired-points or surface registration.

For this purpose,markers are attached to the image intensifier unit of a C-arm, allowing its spatial position to be determined during image acquisition. If the location of the X-ray source is known in addition, the aforementioned projection model can be applied to the measured instrument position,which eventually is displayed at its correct spot in the image. However, it must be noted that C-arms deform under their own weight. Consequently, the X-ray source location with respect to the measured intensifier position slightly varies from image acquisition to image acquisition. Sufficient accuracy can only be achieved if this negative effect is also considered. Two alternative solutions have been developed.

For the two-plates-method, a second marker plate is affixed in front of the image intensifier, paralell to the first one. The projection shadows of all the sheres can be detected automaticcaly in the acquired images. They enable estimation of the unknown X-ray location by means of triangulation. In order to achieve as high an accuracy as possible, a large plate distance would be desirable. However,the second plate limits the volume of operation of the fluoroscope. Consequently, a compromise between precision and practicality has to be found.

With a one-plate-calibration, only the first described plate for image distortion correction is required intraoperatively. During set-up of the C-arm for navigation use, the position of the X-ray source is determined once using the two-plate-method. In a subsequent calibration procedure, the tracking system measures the source`s shift with respect to the intensifier location, as a function of the C`s orientation.

For this purpose, the X-ray source is temporarily equipped with markers, and the fluoroscope is moved through its full range of motion step by step. The acquired data are stored in a file for intraoperative usage. The advantage of this method is obvious. The pre-calibration is carried out extra-operatively. Therefore, an extremely large distance between both calibration plates may be chosen making this approach potentially more accurate.

Kinematic Navigation:

A third method which is established in the most navigatiopn systems abvailable nowadays, is the kinematic navigationsystem. The hip and ankle joint center is defined using a pivoting algorythem. Additional definition of joint surfaces are defined by bony landmarks like epicondyles, malleoli and so on. The pelvic entrance plane is defined using the bony landmarks available there like superior iliac spine and pubic tubercal. In this kinematic navigation systems there is no use of additional imaging and the registration of the operative situs is done only intraoperativly.

Currently available indications and navigation systems:

Trademark	Developer	THA	TKA	Trauma	others	Spine
Navitrack	Sulzer/Zimmer	Cup + stem	XX		ACL	XX
StealthStationn	Medtronic		XXX		OLT	XX
OrthoPilot	Aesculap	Cup	XXX+Uni		ACL, HTO	
Surgetic, SurgiGate	Medivision, Praxim	Cup + Stem	XXX	XXX	ACL	XX
Vector-Vision	Brainlab	Cup + Stem	XXX			XX
Galileo*	PI-Systems	Cup	XXX			

(Abbreviations: ACL = anterior cruciate ligament, HTO = high tibial osteotomy; OLT= Osteochondral lesion of the talus; Uni = unicondylar TKR; XX = available; XXX with soft tissue balancing available; *additional small cutting robot)

Trademark	Developer	Image based	Kinematic
Navitrack	Sulzer/Zimmer	CT	XX
StealthStation	Medtronic	fluoroscopy	XX
Surgetic, SurgiGate	Praxim, Medivision	CT, 3-d-fluoroscopy	XX
Vector-Vision	Brainlab	CT	XX
Galileo	PI-Systems		XX
OrthoPilot	Aesculap		XX

Tab.II technology of the currently available systems

THE GERMAN EXPERIENCE WITH CAOS, DATA ON THA

R. Haaker

Optimal positioning of both cup and shaft is essential for both reduction of the risk of dislocation and for the improvement of longevity [1]. During the last five decades significant progress in hip arthroplasty was achieved due to improvement of materials, fixation techniques, reduction of wear and longevity [1, 20]. Still it is not always possible to achieve perfect individual cup position. The final result usually depends on experience and subjective intuition of the surgeon. Improper cup positioning may lead to reduced range of motion, impingement [8], increased wear [3, 11] and to a higher risk of dislocation. It is reported to occur between 1 and 9% [1, 6]. The "safe zone" [16], with 45±10° for inclination and 15±10° for anteversion, cannot be reached when using conventional technique even by experienced surgeons in up to 42% [9]. The range varies from 14 to 65° for cup inclination and from 27° of retroversion up to 47° of anteversion [15]. The main cause for these facts is the lack of information about the three dimensional position of the pelvis due to unknown amounts of lordosis or kyphosis [5]. Assuming a patient's straight position, the surgeon uses the position of the operating table as his only eye controlled orientation on which his manual instruments are based on. Even when using fluoroscopy, the angle of lordosis, and therefore inclination and anteversion angles, cannot be defined exactly.

Modern navigation technologies might offer the possibility to achieve better control over the three dimensional position of the pelvis and the implants. CT based techniques compete with kinematic procedures. In theory, the CT based techniques might provide higher precision [4, 10], but they are time consuming, expensive, require high technical efforts and inflict radiation. Kinematic procedures provide less information about the individual skeletal anatomy, but are easier and faster to use [2].

The kinematic navigation system OrthoPilot® [2] was proven to be efficient in knee arthroplasty for four years and more than 5000 applications [12, 14, 17]. This technique now was adapted for hip surgery. As the cup position is more crucial than the shaft orientation [9, 15], the navigation device for the cup was developed first. Since the first application of the system 18 months ago the surgeons grew more experienced [13].

Comparison of image based and Kinematic cup Navigation

Principle

In human upright standing position the plane defined by both anterior iliac spines and the symphysis runs more or less vertical and parallel to the coronal plane. We call it pelvic entrance plane. In a normally configurated pelvis there is a highly significant anatomical relationship of the acetabular position to this plane. Using kinematic systems this plane is defined only intraoperatively via surface matching by palpation of these bony landmarks with a pointer. Using image based systems the bony landmarks are defined twice once in the preoperative 3D-Ct-model and as a so called pairpoint matching intraoperatively. In addition there are taken some surface points in the acetabulum floor. Both navigation systems work by showing the surgeon via computer screen how to guide the acetabular reaming and cup positioning instruments. The cup can be firmly implanted in the desired position with respect to the pelvic entrance plane, independent on the patient's position on the table.

Opponents to CT guided navigation of acetabulum components in total hip arthroplasty (THA) argue that this technique is not problem oriented, time consuming with additional radiation, and too inconvenient for practical routine use. Therefore, two- and three-dimensional fluoroscopic systems have been developed as well as on purely kinematic based systems, such as the OrthoPilot (Aesculap, Tuttlingen, Germany).

Having gained considerable experience in the field of CT guided hip acetabulum navigation in two controlled comparative trials with 150 CT cases, we now extended the indication to perform SurgiGate CT navigation on dysplatic and revision THA as well. There were 20 dysplatic hips that entered the second study, in which the alignment of the acetabular cup was confirmed by CT scan. Revision cases had preoperative CT scans. Due to considerable artifacts caused by the metal cups, we recommend CT scans in loosened cemented polyethylene cups only, however, a metal head makes interpretation and planning difficult.

Cup Navigation in Dysplastic Hip Joints

CT based planning of cup alignment in dysplatic hips bears the advantage of exact calculation and prediction of component positioning with regards to the hip center. Both 2D fluoroscopy and fully kinematics based system software are able to accomplish these goals. Dysplastic hips are usually combined with pathologic femoral shaft versions, which require implant adaptation in terms of a deviation from the norm. This technique has been established using the conventional technique and individually increases range of motion. A variety of implant products is needed (screwed cups, press-fit cups…), therefore, open navigation systems become a necessity with a "library" that allow for different manufactures implants.

Case Report 1:

This case demonstrate a secondary dysplastic hip OA 20 years after Chiari osteotomy. The opposite side was treated conventionally 4 years ago using a Burch-Schneider cage and autologous bulk bone grafting with 5 cm leg lengthening. A screwed cup plus autologous bone grafting was planed for navigation of the remaining dysplastic hip. Preoperative computed tomograms included artefacts from the metal implants, which led to software and cup positioning problems. However, cup size and cranial acetabular reconstruction could be planed.

Since the acetabular congruency was pathological, the anterversion angle was changed from an ideal 25 degrees to 15 degrees with 45 degrees inclination. The hip center was calculated from the opposite side, because of the missing tear drop structure. Required anatomical landmarks were non-existing in this case, therefore, intraoperative pair point matching by repetition of these landmarks was impossible. Preoperative planning and surgical execution should be performed by the same person. Intraoperative navigation necessitate both two-plane orientation and perfect acetabular positioning. Preoperative panning and postoperative results show exact consensus. The surgeon can check upon the accuracy of the navigation system throughout the operation. The implantation of an acetabular 2.7mm temporary reference screw, which carries a reproducible pointer housing has proven to be useful.

Case Report 2
The challenge in this case was complicated by high hip dislocation with 5cm leg shortening of the right side with a normal opposite hip joint. Soft tissues attachment would not allow full leg length restoration, but preoperative expander treatment was refused. According to the literature medium term Harris Hip Score results were comparable with a hip center located either in the primary, secondary or tear-drop position.

The goal was to use a press-fit implant (ECM-Cup, Stratec), which allows fixation of bulk autograft via component implemented screw holes. In order to accomplish vertical screw positioning the cup had to be put into 45 to 50 degrees of inclination and 15 degrees of anteversion. Preoperative planning led to a less than ideal hip center and decreased anteversion compared with the opposite side because of pathological shaft position.

Although CT data indicated dysplatic anterior and posterior columns a satisfactory positioning of the cup could be achieved intraoperatively, a difficult maneuver when performed manually. One of the main advantages of 3D preoperative planning is the possibility of predictive cup positioning despite massive bone defects and acceptable compromises.

Kinematic System (OrthoPilot)
The OrthoPilot system consists of optoelectronic Polaris, stereo cameras that detect the infrared signals of the so-called „rigid bodies". These carry infrared transmitters and are firmly attached to the supraacetabular bone and the surgical instruments in use (i.e. pointer, acetabular reamer, cup placement jig). A computer program calculates the hip center from the data obtained by surface matching and kinematic acquisition. Acetabular position, direction and depth of reaming, and the orientation of trial and final cup are calculated by a sophisticated algorithm [2]. The results are displayed and shown to the surgeon step by step on the monitor, as surgery is going on. Easily understood graphical and numerical elements as well as virtual instruments on the screen help the surgeon during the entire procedure. In case of a technical malfunction manual surgical procedure is always possible.

Clinical application
From January (2003) to January 2004 100 patients underwent total hip arthroplasty for primary coxarthrosis using the kinematic navigation technique. In 82 cases a porous coated Plasmacup® and a Bicontact® stem were pressfit implanted in 18 cases cemented cups using a special device were implanted. Patients were mobilized from the first postoperative day, and increasing weight bearing was allowed with respect to pain, wound healing, muscle function and joint motion. The average age of the 37 men and 63 women during surgery was 78 (75-83) years in the cemented cases and 54 (27-75) in the uncemented cases.

For standardized evaluation of these cases a special designed balance level weight has been used to create flouroscopic pictures right after the procedure on the OR layer. In this pictures the inclination and anteversion angles could be measured.

Results
The data of the 100 patients were evaluated. No specific intraoperative complications were seen. The average blood loss as measured with the cell saver system was 850ml. The surgical time was 90±19 (55-130) minutes including standardized fluoroscopic controls. It was prolonged for nine minutes with respect to a conventionally treated collective. Intraoperatively, the mean inclination angles were determined with the OrthoPilot system as

43.6±8.7° for the definite implant, and thus were close to the postoperatively measured data of 44.2±9.6°.

The single data varied from 36.5° to 48° intraoperatively, and from 38.3° to 54° postoperatively. The results for the mean intraoperative and postoperative anteversion angles were found as 17.0 +3.5° and 16.6+3.5°, while the single data varied between 10.1° and 24.1° intraoperatively and between 11.3° and 26.1° postoperativly. So we realited no outlyers according to the definition of the safe zone by Lewinnek.

In this collective no postoperative hip dislocation occurred. All patients demonstrated a normal postoperative recovery with respect of wound healing, range of motion, and time conform mobilization.

Conclusion
For the every day case the kinematic navigation system is sufficient to avoid malposition of the cup in THA. Especially in minimal invasive approaches it will become a necessary tool for THA.

Cup Navigation in Revision Cases
In revision cases, intraoperative matching is complicated by metal artifacts including markers in cemented polyethylene (PE) cups. In addition a loosened PE cup does not represent a fixed landmark for matching purposes. Therefore, severely loosened or subluxed cups can make navigation impossible. In those cases a laser surface mapping and matching as used by neurosurgeons can be helpful. Another advantage is the 3D fluoroscopic C-arm. In some cases kinematic systems are helpful because they are able to define the acetabulums floor intraoperatively right after explantation of the loosened cup.

As demonstrated both implantation and correct version of a cemented cup or cage version is possible with the navigation system. Satisfactory solutions are not available with current software module.

In summary, CT based navigation of cups using the SurgiGate system in dysplastic hip cases showed promising applications. Additional 3D geometric preoperative planning as is available with the MediCad system (see chapter 2.11) would enhance the accuray and reproducibility of the right hip center. Virtual implantation and reconstruction of the acetabular bone defect with the patient's own femoral head would be desired. The current SurgiGate system is not recommended for revision cases yet. The kinematic system has its advantages in every day cases as a time and cost preserving tool and in addition in revision cases.

Future Perspectives
For perfect soft tissue balancing of total hip arthroplasties a combination of both cup and stem navigation is required. Data for best cup positioning with a low risk for dislocation in the so-called "save zone" were first advocated by Lewinnek in 1978 and were recently confirmed in 2001 by Widner et al. and Bader et al. with 40 degrees inclination and 26 degrees anteversion plus a stem anteversion of 15 degrees. Dysplastic hip joints are frequently associated with an increased shaft anteversion raising the question whether anatomical reduction of this anteversion is desired or whether balancing of the shortened soft tissues have priority. We believe that these key questions may be answered with new evolving computer navigation of total hip arthroplasty, which includes correct positioning of the hip center, alignment of the cup, stem anterversion, off set and soft tissue balancing.

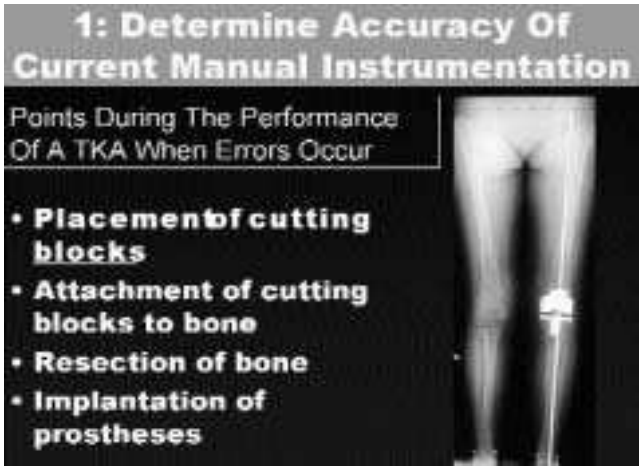
Situation	CT-based	Kinematic
Every day case	Reliability (+++)	Reliability (++)
	Time consuming (-)	Time saving (++)
	Radiation inflict (-)	No radiation (++)
Dysplastic cases	3D-model with ideal planning opportunities (+++)	Reliable depth control (++)
Exchange situations	Image artefacts (-)	
	Matching failure (-)	Intraoperative registration after explantation (+++)

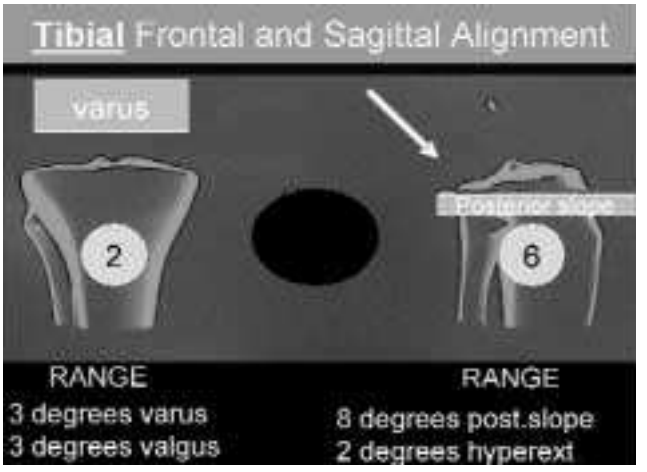
REFERENCES:

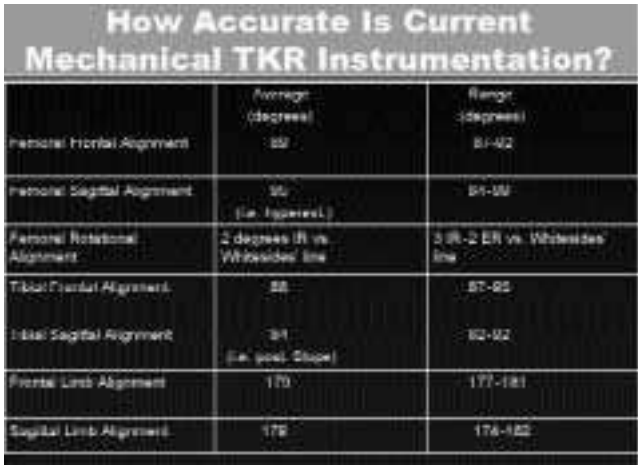
1. Bader R, Willmann G (2000) Influence of Implant design and – position on the Range of Motion and Impingement in total hip replacement. Z. Orthop. 138 (S1): 19-20
2. Bernsmann K, Langlotz U, Ansari B, Wiese M (2000): Computer Assisted Navigated Acetabulum Placement in Hip Prothesis Implantation – Application study in Routine Clinical care. Z. Orthop. 138: 515-521
3. Bernsmann K, Langlotz U, Ansari B, Wiese M (2001): Computer Assisted Navigated cup Placement of different cup types in Hip Arthroplasty – a randomised controlled trial. Z. Orthop. 139: 512-516
4. DiGioia AM, Jaramaz B, Blackwell M, Simon DA, Morgan F, Moody JE, Nikou C, Colgan BD, Aston CA, Labarca RS, Kischell E, Kanade T (1998): The Otto Aufranc Award. Image guided navigation system to measure intraoperatively acetabular implant alignment.Clin Orthop. 355:8-22.
5. Eddine TA, Migaud H, Chantelot C, Cotten A, Fontaine C, Duquennoy A (2001): Variations of pelvic anteversion in the lying and standing positions: analysis of 24 control subjects and implications for CT measurement of position of a prosthetic cup. Surg Radiol Anat 23: 105-110
6. Ekelund A, Rydell N, Nilsson OS (1992): Total hip arthroplasty in patients 80 years of age and older. Clin Orthop 281:101-106
7. Hirakawa K, Mitsugi N, Koshino T, Saito T, Hirasawa Y, Kubo T (2001): Effect of acetabular cup position and orientation in cemented total hip arthroplasty. Clin Orthop 388:135-42
8. Gondi G, Roberson JR, Ganey TM, Shahriari A, Hutton WC (1997):Impingement after total hip arthroplasty related to prosthetic component selection and range of motion. J South Orthop Assoc 6: 266-272
9. Hassan DM, Johnston GH, Dust WN, Watson G, Dolovich AT (1998): Accuracy of intraoperative assessment of acetabular prosthesis placement. J Arthroplasty 13: 80-84
10. Jaramaz B, DiGioia AM 3rd, Blackwell M, Nikou C (1998): Computer assisted measurement of cup placement in total hip replacement. Clin Orthop 354:70-81
11. Kennedy JG, Rogers WB, Soffe KE, Sullivan RJ, Griffen DG, Sheehan LJ (1998): Effect of acetabular component orientation on recurrent dislocation, pelvic osteolysis, polyethylene wear, and component migration. J Arthroplasty 13:530-534
12. Kiefer H (2003): OrthoPilot cup Navigation – how to otimise cup position? Int Orthopaedics (SICOT) 27 (Suppl. 1): S37-S42
13. Lewinnek GE, Lewis JL, Tarr R, Compere CL, and Zimmerman JR (1978): Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg 60A:217-220.
14. Mielke RK, Clemens U, Jens JH, Kershally S (2001): Navigation in Knee endoprothesis implantation – preliminary experiences and prospective comparative Study with conventional Implantation technique. Z Orthop 139:109-116
15. Paterno SA, Lachiewicz PF, Kelley SS (1997): The influence of patient-related factors and the position of the acetabular component on the rate of dislocation after total hip replacement. J Bone Joint Surg 79A:1202-1210
16. Pradhan R (1999): Planar anteversion of the acetabular cup as determined from plain anteroposterior radiographs. J Bone Joint Surg 81B : 431-435
17. Soderman P, Malchau H, Herberts P (2001): Outcome of total hip replacement: a comparison of different measurement methods. Clin Orthop 390:163-172
18. Haaker R, Tiedjen K, Rubenthaler F, Stockheim M (2003): Computer-Assisted Navigated Cup Placement in primary and secondary dysplastic cases. Z. Orthop. 141: 105-111
19. Hauser R (1991) Die Balgrist-Pfanne in der zementfreien Endoprothtik von Dysplasiecoxarthrosen und von anderen Acetabulumdefekten. Z Orthop 129: 183-187
20. Jerosch J, Steinbeck J, Stechmann J, Güth V (1997) Influence of a high hip center on abductor muscle function. Arch Orthop Trauma Surg 116: 385-389
21. Widmer KH, Ackermann JP, Bereiter H (2001) Ergebnisse der manuellen und computernavigierten Implantation einer Monoblock-press-Fit-Pfanne mit Tantalumoberfläche. Z. Orthop 139: S 59

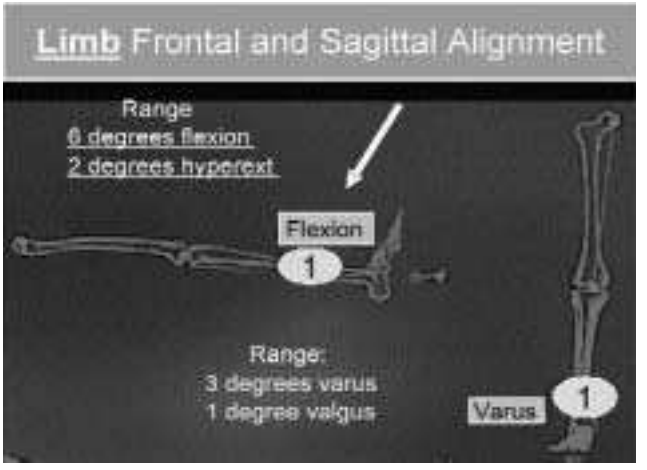
COMPUTER ASSISTED TOTAL KNEE SURGERY: 10 REASONS TO NAVIGATE TKA

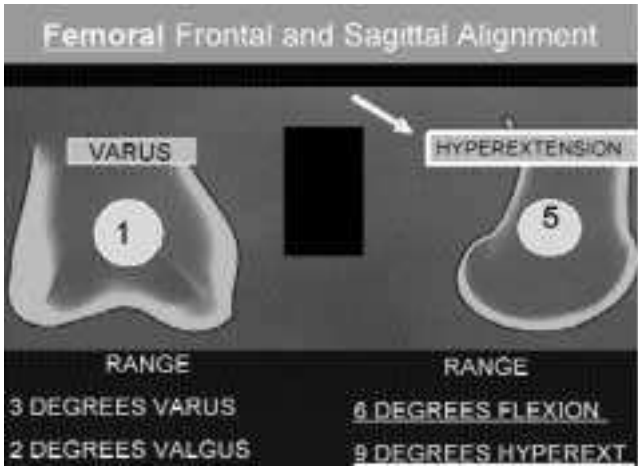
S. David Stulberg, MD

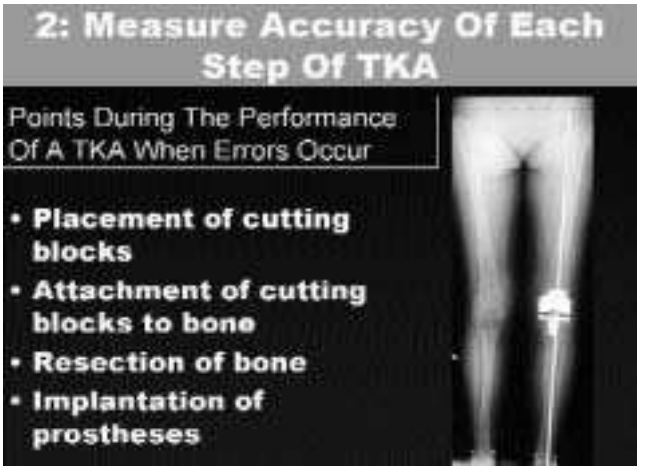












At What Steps In The Performance Of A TKA Do Errors Occur When Manual Instrumentation is Used?

- 25 Primary TKR
- Aesculap Columbus™ TKA Instrumentation
- OrthoPilot™ navigation to monitor steps of the TKA

- Effect of placing pins on position of cutting blocks
- Effect of carrying out cut on position of blocks
- Effect of cutting block slot and saw blade stiffness
- Effect of placing implants

Conclusions

- In comparison to the errors produced when manual cutting blocks are positioned, the errors which occur during each subsequent step of a TKA are:
  - Smaller
  - Less variable
- These errors can be can be reliably eliminated without the need for monitoring with Navigation

Effect of placing pins on position of cutting blocks

- Placing pins by hand is likely to move a cutting block:
  - Oblique pins
  - Osteoporotic bone
- Manual: 1.2 (0-3)
- Power: .04 (0-1)

MEASURING EFFECT OF PIN PLACEMENT IN BLOCKS

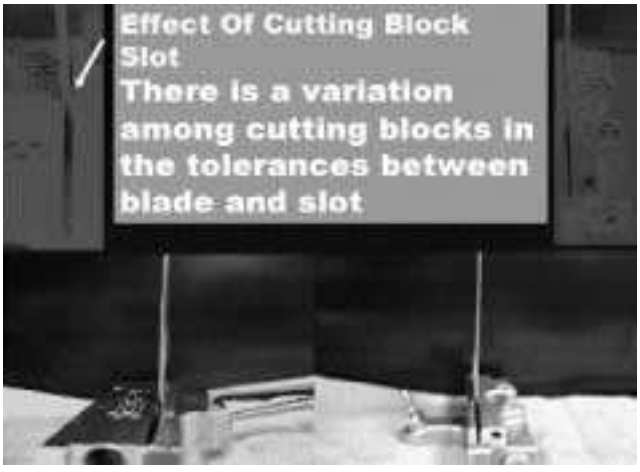
Effect of placing pins on position of cutting blocks

- Placing pins by hand is likely to move a cutting block:
  - Oblique pins
  - Osteoporotic bone
- Manual: 1.2 (0-3)
- Power: .04 (0-1)

Placing Pin With Power

Effect Of Carrying Out Cut On Position Of Blocks

- Cutting through a slotted, well-fixed block does not change its position:
- Femur: .43 (0-2)
- Tibia: .48 (0-1)



Effect Of Saw Blade Stiffness: Close Saw Blade-Cutting Slot Tolerances

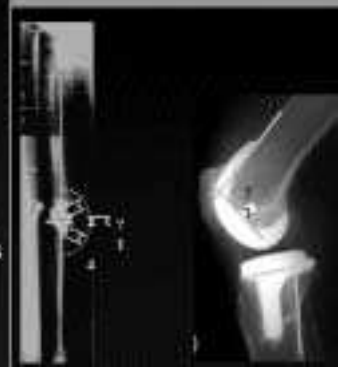
- The distal femoral cut becomes more hyper- extended:
  - 1.83 degrees (0 -3)
- The proximal tibial cut becomes more anteriorly sloped:
  - 0.75 degrees (0 -2)

Effect Of Placing Implants

- **There is a small, but consistent tendency to implant the tibial component into valgus in a knee with a varus deformity**

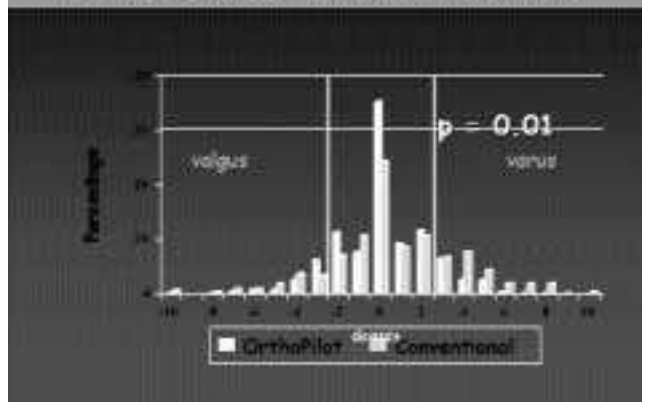
- Prospective, open study
  - 555 cases of navigated implantations
- Historical control group
  - 266 cases of conventional implantations
- No difference between both cohorts
- X-Ray analysis
  - AP and lateral

Methods



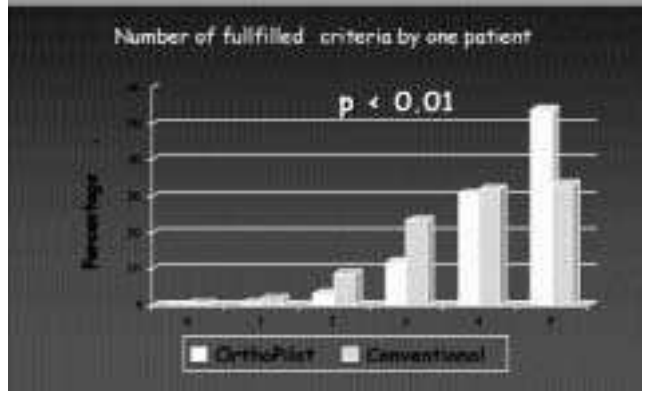
3: Increase Accuracy With Which Manual TKA Performed

Femoro-Tibial Mechanical Axis



4: Increase Accuracy And Reduce Variability Using Navigated Instrumentation

Global quality of implantation



Total Knee Prosthesis Implantation With a Non Image Based Navigation System

A Multi-Center Analysis

J.Y. Jenny
R. Miehlke
St. Kohler
H. Kiefer
W. Konermann
C. Boeri
U. Clemens
B. Ratayski

5: Decrease Need For Soft Tissue Releases and Balancing

75 patients underwent TKR in which the bone preparation of the femur and tibia in the frontal and sagittal planes was guided by an image-free computer assisted navigation system.

Soft tissue releases were performed in 8 of the 75 patients. All of these soft tissue releases were lateral. The average pre -surgical deformity in patients on whom a release was not performed was 1.0 degrees varus (range: 5 degrees varus - 14 degrees valgus). The average pre -surgical deformity in patients on whom a release was performed was 15.6 degrees of valgus (range: 11 -19 degrees valgus). Two lateral retinacular releases were performed in patients with 16 and 19 degrees of pre - operative valgus.

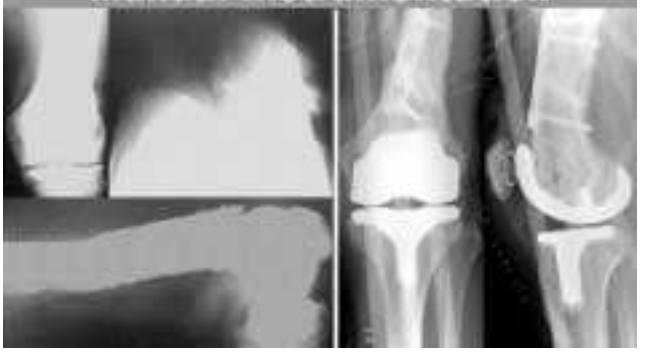
Conclusion

The performance of TKR's in which femoral and tibial bone cuts are accurately made, as measured with an image-free computer assisted navigation system, is associated with a very low incidence of soft-tissue releases. Only patients with severe pre-operative valgus deformities (greater than 10 degrees) appear to require soft tissue releases after the accurate performance of a TKR. **These finding suggest that the incidence of soft tissue balancing procedures can be markedly reduced in most patients undergoing TKR by improving the accuracy with which bone cuts are made.**

6: Improve Judgment Of Correct Positions Of Implants And Extremities In TKA

Become A Better Knee Surgeon

8: Perform Procedures Easily That Would Be Difficult With Manual Instrumentation



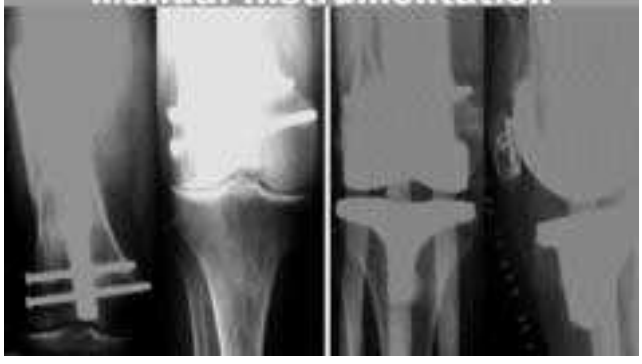
7: Assure Accuracy Of MIS Joint Reconstructions

The Rationale For CAS & MIS-JR

- Increase accuracy of Joint Reconstruction
- Reduce the need for direct visualization of surgical anatomy
- Reduce the dependency on fluoroscopy in the 2 Incision MIS -THA technique

9: Become A Hero To Your Operating Room Staff

8: Perform Procedures Easily That Would Be Difficult With Manual Instrumentation



APPLICATIONS TO HIP ARTHROPLASTY AND MIS

Anthony M. DiGioia, III, MD

I. Overview

A. The development of less and minimally invasive surgery (L/MIS) for partial and total joint replacements holds the promise to change adult reconstructive surgery and dramatically improve patient outcomes. Recent developments in new surgical techniques, navigation and computer-assisted tools and tool redesign now enable MIS techniques for total and partial joint replacements.

B. Identify clinical and technical challenges to overcome in order to perform truly minimally invasive joint reconstructive surgery.

II. The Opportunities When CAOS Meets MIS

A. More accurate and precise preoperative planning coupled with simulations of their actions before the actual patient's surgery.

B. Develop high fidelity and accurate preoperative planners and surgical simulators, less invasive surgical tools and more powerful intraoperative visualization devices that can provide updated images of the bone surfaces and soft tissues being manipulated in a less invasive way.

C. Eventually, miniature sensors and actuators will need to be incorporated into a trial implant or the actual replaced artificial or natural joint surface in order to give feedback to surgeons.

D. A "Complete" Clinical Systems Approach: various enabling technologies will need to be integrated into a complete MIS system. This next generation of tools will include surgical planners and simulators, image guided navigation systems, image overlay visualization, microelectromechanical systems (MEMS) sensors and actuators, micromanipulators and other robotic assistive devices.

E. Training and Development of Surgical Techniques
To educate the practicing orthopaedic surgeon on the next generation of surgical tools and techniques– the MIS "tool box" of the future. This next generation of "smart" tools are necessary to enable surgeons to achieve the surgical goal through smaller and smaller incisions while improving accuracy and precision, reducing complications and speeding patients' recoveries.

III. The Surgical Toolbox for L/MIS: Navigation, Robotics and Computer Assisted Devices

A. Improve patient outcomes through:
1. Improved accuracy and precision while minimizing variation from optimal clinical practice thereby reducing complications
2. Measure and quantify surgical techniques to directly relate patient outcomes to surgical practice
3. Minimally or less invasive techniques

B. Clinical Impact and Pathway for Adoption
1. Initially use these enabling technologies and sensors as measurement tools to gauge current practice and provide timely feedback for surgeons to act upon and improve practice
2. Improve the accuracy and precision of procedures currently performed while reducing "outliers"
3. Develop new surgical techniques that will permit current procedures to be minimally or less invasive
4. Permit the development of a whole new generation of surgical procedures that we are not capable of performing today

C. "Enabling" Tools
1. Surgical Navigation
   a. Image based with CT or MRI
   b. Fluoroscopic Navigation
   c. Non-image based
2. Robotic Assistive Devices
3. Virtual Reality and Hybrid Visualization Systems
4. Planners and Simulators
5. MEMS and Microrobotics

D. Spectrum of Enabling Technologies
1. Clinical functionality determines what you want out of a CAOS system!!
2. No one tool can solve all of our clinical problems!!
3. ??What is necessary?? Only the surgeons know for sure!!
4. The navigation platform of the future will have all the different approaches in order to let the surgeon decide! Plus more. . .

IV. An Example:

A. CT Based Navigation for THR and TKR
1. Gold Standard for Navigation
2. All other navigation tools (i.e. fluoro and non-image systems) need to be validated and tested compared to CT based systems
3. (All) Navigation tools should be able to be used with any implant system or surgical technique

B. CT Based Navigation vs. Fluoro or Non-Image Based
1. Complete 3D information (orientation especially rotations, leg lengths)
2. No need for intra-op imaging
3. Enable new MIS techniques
4. ??Is it necessary all the time?? Only the surgeon knows for sure!!

C. Navigational Tools Cover the Spectrum of Clinical Challenges in THR/TKR
1. Any implant system
2. Real time orientation, rotations, leg lengths, soft tissue balancing, ROM
3. Any surgical approach
4. Cemented or uncemented technique
5. Validate mechanical tools, non-image and fluoro based alignment techniques

D. Spectrum of Navigation Technologies (CT, Fluoro, Non-Image)
1. No one tool can solve all of our clinical problems but…CT based Navigation comes close!!

V. The Future: MIS meets CAOS

A. The next generation of visualization tools utilizing "computer vision" to supplement surgeon's view and videoscopic images.

B. The Future
1. Combined in one tool
   a. Surgeon's view
   b. Navigation
   c. Arthroscopic Images
   d. All in a HMD giving "X-ray Vision"

C. Navigation for Clinicians (and Clinician-Scientists)
1. More accurate, reliable and less invasive surgery

2. Enable new surgical techniques (and biologic replacements)
3. Measure and document patients' outcomes

VI. The Development Process for MIS meets CAOS

A. Opportunities
1. Reduced bone and soft tissue damage
2. Reduced "collateral" damage
3. Quicker recovery and return to earlier function
4. Fewer complications
5. Reduced hospital stays
6. Biologic resurfacing

B. Clinical Challenges and Opportunities
1. Accurately shape and prepare bone surfaces
2. Minimize soft tissue and collateral damage
3. Loss of direct visualization by surgeon
4. Soft tissue balancing
5. Insertion of implants (rigid and fixed geometries)

C. Technical Challenges and Opportunities
1. "Keyhole" tools for bone preparation
2. Redesign mechanical tools
3. Redesign implants
4. New visualization tools
5. Computer assisted surgical (CAS) tools and techniques

D. New Requirements for L/MIS Computer Assistance
1. More accurate pre-op planning with surgical simulators
2. New intra-op visualization devices
   a. Computer vision
   b. "Hybrid" reality
3. New Keyhole Tools
   a. Navigational Tools (image & non-image based)
   b. Robotics
4. Training and Evaluation
5. New Implant Designs
   a. Deployable Implants
   b. Adjustable Implants
   c . Real Time Sensors
   d. Biologic Materials

F. Spectrum of Techniques
1. Traditional
2. "Less" Invasive (LIS)
3. Minimally Invasive (MIS)

G. Spectrum of Implant Options
1. Traditional Total Joint Replacement
2. Partial Joint Replacement
3. Resurfacing
   a. Artificial
   b. Biologic

H. Surgical Training
1. New Techniques
2. New Tools
3. Validation/Evaluation
4. CAOS

CAOS is the L/MIS "Surgical Toolbox of the Future"

Experiences in THR

I. Why Change? Unreliability of Mechanical Acetabular Alignment Guides

A. Introduction: In total hip replacement (THR) surgery, mechanical guides are typically used to align the acetabular component to a preset pair of abduction and version angles. In order to function effectively, the guides require that the patient's pelvis be positioned to –and maintained in- a predetermined orientation. The alignment guides cannot compensate for any deviation from this specified pelvic orientation. However, despite traditional patient alignment and stabilization techniques, pelvic motion does occur during THR thereby introducing error into the acetabular component placement. This study examines the nature of the alignment problem, demonstrates the magnitude of the error and suggests ways to improve acetabular cup alignment.

B. Methods: For a series of 81 patients undergoing THR, optical targets were attached to the pelvis and to the cup placement tool. An image guided tracking system capable of sub-millimeter and sub-degree accuracy was used to monitor both tool and pelvic angles. Pelvic motion (roll, pitch, and yaw) was measured and recorded at various points in the THR procedure. After acetabular preparation, the mechanical guide was aligned in accordance with the manufacturer's guidelines, and the actual cup abduction and version angles were measured and recorded.

C. Results: Data points were not available in 8 cases. The summary presented here represents the data from the remaining 73 cases using the mechanical guides, measured alignment ranged from 35° to 59° (mean 44° + 4°) for abduction, and from 26° of retroversion to 33° of flexion (mean + 1° + 12°) for version, with a strong trend toward neutral alignment and retroversion in _ of the cases. Using the t-test for paired samples, the mean difference from the desired goal of 45° abduction and 20° flexion was -1° for abduction and -19° for flexion both significantly different ($p<.05$). Pelvic orientation measures showed that with the patient in the lateral decubital position, the pelvis was significantly flexed and tilted anteriorly which would lead to improper acetabular alignment especially version alignment.

D. Discussion and Conclusion: Traditional patient alignment and stabilization techniques neither achieve nor maintain the rigid pelvic orientation required for use of mechanical acetabular alignment guides. The uncertainty of actual pelvic orientation imparts an error in acetabular component placement. With the patient's pelvis flexed in the lateral decubiti position, cup alignment tended toward retroversion increasing the risk of posterior dislocation. Mechanical alignment guides when used alone are insufficient to ensure precise and safe acetabular component placement. These results demonstrate a clear need to develop more accurate and reliable tools or anatomic based alignment strategies. Two strategies to improve the reliability of cup alignment would be to introduce significantly more additional flexion of the cup at the time of acetabular placement that the mechanical guide would suggest. Alternatively, anatomic based alignment strategies should be developed.

II. CAOS Meets MIS: Mini Incision Technique Utilizing Surgical Navigation Tools for Total Hip Arthroplasty

A. Introduction: Wide surgical exposures in the total hip arthroplasty (THA) provide visualization of the landmarks, and can help in accurate fixation and orientation of the implant, but at the same time requires large soft tissue dissections, which can increase postoperative complications. This prospective study compares patient's short and early term outcomes using a mini-incision technique versus a traditional posterior approach for THA.

B. Methods: Thirty-three patients (35 hips) (Group I) were selected out of 121 patients that had undergone a mini-

incision THA, and matched by diagnosis, sex, average age and preoperative Harris Hip Score (HHS) to thirty-three patients (35 hips) (Group II) of 120 patients that had undergone THA using the traditional posterior approach. Both groups were enrolled in the HipNav clinical trial. In Group I, the average age was 65 years (range: 49-80), and in Group II, the average age was 65 years old (range 49-76) ($p>0.5$). In Group I (mini-incision) the average age was 65 years (range: 49-80), in Group II (traditional incision) the average age was 65 years old (range 49-76) ($p>0.5$). The average preoperative Harris Hip Score (HHS) was 52.3 (range: 24-74) in Group I and in Group II was 53.4 (range: 22-76) ($p>0.5$). The HHS was measured prospectively and by an independent observer prior to surgery and at 3 months, 6 months and one year postoperatively for all patients.

C. Results: The length of the skin incisions for Group II (traditional posterior approach) measured on average 20.2 cm (range: 14.8-26.0). The length of the skin incisions for Group I (mini-incision) averaged 11.7 cm (range: 7.3-13.0) ($p<0.001$). At the 3 months follow-up, patients in the mini incision group had significant improvement in limp ($p<0.05$) and ability to climb stairs ($p<0.01$) compared to the traditional group. At the 6 month follow-up, the mini-incision group was significantly better in terms of limp ($p<0.05$), distance walked ($p<0.001$), and stairs ($p<0.001$). There was no significant difference between groups in pain, function and range of motion at the 1 year follow-up.

D. Conclusion: Access to surgical navigation technologies and computer assisted tools has created opportunities to develop less invasive surgical techniques for THA. Less invasive surgery will improve clinical outcomes by speeding a patient's recovery to a more functional status earlier and with fewer complications.

REFERENCES

1. Amin DV, Kanade T, DiGioia AM III, Jaramaz B: "Biomedical Paper-Ultrasound registration of the bone surface for surgical navigation," Computer Aided Surgery, Vol. 8, No. 1, pp: 1- 16, 2003.
2. Blackwell M, Morgan F, DiGioia AM: "Augmented reality and its future in orthopaedics," Clinical Orthopaedics and Related Research, No. 354, pp. 111-122, September 1998.
3. DiGioia AM, Jaramaz B, Colgan B: "Computer assisted orthopaedic surgery: Image guided and robotic assistive technologies," Clinical Orthopaedics and Related Research , No. 354, pp.8-16, September 1998.
4. DiGioia AM, Jaramaz B, Blackwell M, et al.: "Image guided navigation system to measure intraoperatively acetabular implant alignment – The Otto Aufranc Award," Clinical Orthopaedics and Related Research, No. 355, 8-22, October 1998.
5. DiGioia AM III, Jaramaz B, Plakseychuk AY, Moody JE, Nikou C, LaBarca RS, Levison TJ, Picard F: "Comparison of a mechanical acetabular alignment guide with computer placement of the socket," The Journal of Arthroplasty, Vol. 17, No. 3, 2002.
6. DiGioia AM III, Plakseychuk AY, Levison TJ, Jaramaz B: "Mini-incision technique for total hip arthroplasty with navigation," The Journal of Arthroplasty, Vol. 18, No. 2, pp: 123-128, 2003.
7. Jaramaz B, DiGioia AM, Blackwell M, Nikou C: "Computer assisted measurement of cup placement in total hip replacement," Clinical Orthopaedics and Related Research, No. 354, pp. 70-81,September 1998.
8. Nikou, C, DiGioia AM III, Blackwell M, et al: Augmented reality imaging technology for orthopaedic surgery, Operative Techniques in Orthopaedics, Vol. 10, No. 1, pp. 82-86, January 2000.
9. Paul HA, Bargar WL, Mittlestadt B, Musits B, el al: Development of a surgical robot for cementless total hip arthroplasty, Clinical Orthopaedics and Related Research, 285, pp. 57-66, 1992.
10. Simon D, Hebert M, and Kanade T: Techniques for fast and accurate intrasurgical registration. Journal of Image Guided Surgery, 1:17-29, 1995.
11. Simon DA, Lavallee S: Medical imaging and registration in computer assisted surgery, Clinical Orthopaedics and Related Research, 354:17-27, 1998.

THE DATA ON CAOS IN TKA, THE GERMAN EXPERIENCE

W. Konermann

Introduction
The specific challenges in total knee replacement surgery are sufficiently well known.

Malalignment of the leg axes as well as the prosthesis and the imbalance of the soft tissue reduce the life span of knee implants.

Clemens et al. presented the advantages of navigated surgery compared to the conventional technique in the largest multicenter study worldwide. The results were based on an optimal alignment of the prosthesis in respect to the reconstruction of the mechanical leg axes.

Concept of the VectorVision CT-free knee Navigation System
The VectorVision CT-free knee navigation system (BrainLAB AG, Germany) assists in achieving a correct alignment of the prosthesis, the reconstruction of the joint line as well as in implementing an optimal balance of the ligaments and an equal extension and flexion gap.

The camera arm and computer workstation are integrated into the VectorVision compact navigation system. The navigated instruments are tracked passively via reflective marker spheres. The spheres reflect the infrared-light, emitted by the cameras, which enable the tracking of surgical instruments in the operating room. There are no bothersome cables in the surgical field. The system is controlled by the surgeon via the touch screen monitor. Reference arrays are attached to both the femur and tibia using a bicortical Schanz pin.

4 Steps in a navigated Procedure

1. Registration
The points, acquired through pivoting of the hip joint and with the pointer, are utilized for the patient registration and are at the same time the basis for the planning of the implant position. After the acquisition of the registration points, a generic model from the database is morphed to the acquired points. This model then has to be verified using relevant points on the tibia as well as the femur. The correct planning of the implant position is based on the collected points and clouds of points, which are acquired by dragging the tip of the pointer along defined areas of the bone surface.

2. Planning
Based on the data acquired intra-operatively, the system automatically calculates an initial optimal implant position. The implant position is displayed on the monitor in a comprehensive planning overview. After the implant size and position are calculated by the system, the implant components can be fine-tuned by the surgeon.

3. Navigation and Verification
The ligament balancing function as well as the navigation and verification of the bone cuts enable a continuous adaption and optimization of the LCS implant position. Tibia and femur are not adapted one after the other, but alternating step by step. Adhering to the conventional surgical technique, the distal femur cut and the tibia resection level have to be parallel when the knee joint is in full extension.

The VectorVision software determines the tibia slope based on the antecurvature of the anterior femoral cortex and therewith against the femur implant position. The limits of the slope range from a maximal 10° to a minimal 5°.

3.1. Calculation of the lateral angle between the femoral anatomical axis and the mechanical axis

3.2. Calculation and verification of the tibia slope

3.3. Navigation of the tibia resection and verification

3.4. Ligament balancing in extension with a specific spreader tool

3.5. Ligament balancing in flexion with a specific spreader tool

3.6. Calculation of the femoral LCS position stored from the ligament balancing

3.7. Navigation of the anterior and posterior femur cut and verification

3.8. Navigation of the distal femoral cut and verification

3.9. Final preparation of the femur and the tibia using the conventional cutting template

4. Documentation of the navigated surgery
During navigation every phase of the surgical procedure can be documented with screenshots. All performed cuts are automatically documented by the VectorVision system.

After the implantation the achieved leg axis can be checked with support of the navigation system. The stability of the leg can be controlled by bringing the leg in full flexion and extension as well as positions in-between.

Implantation
After performing the cuts, assisted by the navigation system, the components of the prosthesis are implanted in the same way as during a conventional surgery. In this step a correct rotational alignment of the tibial component in respect to the tibial resection level is essential.

Results
We present the results of the first 50 TKR. Measurements were made two weeks after surgery based on a lateral fluoroscopy with the patient lying supine (slope of the femoral and tibial component). The mechanical leg axis and the frontal orientation of the femoral and tibial component were measured using an strictly standardized AP long leg x-ray.

The values determined using the X-ray images contain a human error of 1° and a positioning error of 2° for the radiological measurements. It should be taken into consideration that a more accurate method, the navigation system, is currently being evaluated with the X-ray measurement technique, which has a total inaccuracy of 3°.

Mechanical Leg Axis
If a deviation of £3° varus / valgus for the mechanical leg axis is defined as a very good result and the potential radiological measurement error is taken into consideration, then 94% of the navigated prostheses were placed with good results.

Femoral A-P Axis
92% of the cases achieved a good result when considering a deviation of £ 2° varus/valgus.

Lateral Femoral Axis
90% of the measured prostheses were within a range of £ 2° anterior / posterior slope.

Tibial A-P Axis
Good results were achieved for 92% of all navigated knee joints accepting a £ 2° deviation in varus / valgus alignment.

Lateral Tibial Axis
A good result with a deviation of £ 2° anterior / posterior slope can be seen on 80% of all cases.

Comprehensive overview on 5 axes
Summing up the result for all 5 axes and by defining a £5° deviation of the mechanical axis and £4° for the other 4 axes (frontal and sagittal orientation of the femoral and tibial implant component) as a good result, then 93% of the navigated prostheses meet this goal. An optimal result, defined as £3° deviation from the mechanical axis and £2° deviation to all other axes, was achieved in 45% of all cases.

Conclusions and Visions
Based on our actual experiences the VectorVision CT-free knee navigation system in conjunction with the LCS prosthesis enables an optimization of:

1. the reconstruction of the mechanical leg axis
2. the implant position
3. the ligament balancing
4. the flexion and extension gap
5. the reconstruction of the joint line

Another advantage is the user-friendly workflow of the VectorVision software, that can be considered as easy to use as well for surgeons who are not enthusiastic on new technologies. The navigation system is adapted to the surgical technique and the surgeon does not have to change his conventional handling for example with the spacer or cutting blocks. The disadvantage of all navigated methods is the extension of the surgery (10 min.).

The inaccuracy of the cuts, e.g. caused by the bending of the saw plates treating scerotic bones, initially are not taken into account by navigation. The verification of the bone cuts after sawing with navigation now provides relevant data on the accuarcy of the cuts and they can be intra-operatively corrected by resawing. However surgeons need new sawing and milling systems or possibly new minimally-invasive robots.

For the future the integration of pressure sensors has to be demanded, which should be inserted during different surgical steps and being integrated in the trial prosthesis as well as the imlanted inlay as well. Utilizing the data further optimization of the ligament balancing can be achieved. Pressure on the medial and lateral implant components can be measured in full extension and different flexion levels. The surgeon would be able to create a navigated fine tuning release to achieve perfect ligament balancing in any stage of the surgery.

Navigation opened new horizons and ways to go in the last five years. Constant and worldwide interchange of ideas on both the surgeons and engineers side will enable the development of minimally-invasive surgical techniques in the nearest future providing innovative approaches and new designs of the prosthesis. Thanks to the navigation we are stepping into a new age of total knee replacement surgery. Primarily this will bring decisive advantages for our patients.

REFERENCE

1. Buechel FF (2004) Total Knee Arthroplasty. In Stiehl JB, Konermann WH, Haaker RG (Eds.) Navigation and Robotics in Total Joint and Spine Surgery, Springer, Berlin Heidelberg, New York, Tokyo, 175-179
2. Buechel FF, Pappas MJ (1986) The New Jersey low-contact-stress knee replacement system: biomechanical rationale and review of the first 123 cemented cases. Arch Orthop Traum Surg 105: 197-204
3. Clemens U, Konermann WH, Kohler S, Kiefer H, Jenny JY, Miehlke RK (2004) Computer-Assisted Navigation with the OrthoPilot System Using the Search Evolution TKA Prosthesis. In Stiehl JB, Konermann WH, Haaker RG (Eds.) Navigation and Robotics in Total Joint and Spine Surgery, Springer, Berlin Heidelberg, New York, Tokyo, 234-241
4. Jeffrey RS, Morris RW, Denham RA (1991) Coronal Alignement after total knee replacement. J Bone Joint Surg 73 B: 709 – 714
5. Konermann WH, Saur MA (2004) Postoperative Alignment of Conventional and Navigated Total Knee Arthroplasty. In Stiehl JB, Konermann WH, Haaker RG (Eds.) Navigation and Robotics in Total Joint and Spine Surgery, Springer, Berlin Heidelberg, New York, Tokyo, 219-225
6. Rand JA, Coventry MB (1988) Evaluation of Geometric total knee athroplasty. Clin Orthop 232: 168 – 173

EMERGING TECHNOLOGIES: WHERE ARE WE GOING?

Eric Stindel, MD, PhD

I. Introduction

"I can assure you that data processing is a fad that won't past the year" said the chief editor in charge of business book at Prentice Hall in 1957. In 1876, one can find in a memo of the Western Union the following idea : "The telephone is of no inherent value". And closer to our subject, in 1943 Thomas Watson, the CEO of IBM said : "I think there is a world market for maybe five computers". The history of technology is full of great leaders with bad visions of the future…Actually seeing in the future is a game that can lead to science fiction. It will not be our goal in this paper in which we will discuss of emerging technologies that are already in the nest and will become adult soon and usable on a daily routine. Do we really need more technology in orthopaedics surgery? Probably yes. Why?

CAOS (Computer Assisted Orthopedic Surgery) is a new field in our domain. The number of surgeons convinced of its interest is increasing from day to day. However, this technology is following a very fast evolution. In the past, there have been a lot of CAOS systems and prototypes that created some disillusion and frustration, because of poor ergonomics, unclear functionalities, poor accuracy and poor concepts. The most advanced CAOS systems have solved most of those issues and offer solutions that can be used in clinical routine with satisfaction. In the future, there is a huge amount of promises in research labs and industry that will offer solutions to most of clinical problems in orthopaedics surgery for the best benefits of the patient.

II. Where are we : advanced technologies and applications for daily clinical use

In this section, examples of advanced image-free CAOS applications are given. Most of them use the Bone Morphing technology that was introduced in 2000: from a cloud of points digitized with a navigated probe, a 3D model of the bone is reconstructed within a few seconds with no CT, nor fluoroscopy [1]. Therefore, all instruments, drilling guides, cutting blocks can be navigated using an optical localizer and compared to the optimal planning defined intra-operatively.

1. Total Knee Arthroplasty: An image free application is used. By combining kinematics data and 3D morphological data acquired very easily in a few minutes during the surgery, it is very easy to plan and achieve an optimal position of the implants that meets a trade-off between strict alignment (HKA = 180°) and perfect balancing in flexion and extension. This is for instance of particular importance for the LCS implant [2]. This application reduces the occurrence of misaligned and unstable knees and hopefully will increase time of survival of TKA.
2. High Tibial Osteotomy: a simple and fast tool is now available for alignment in both frontal and sagital planes. Hip, knee, and ankle centers are defined accurately using a combination of morphologic and kinematics data. When opening osteotomy is performed, the application automatically compensates for the varus/valgus of the proximal tibia during the correction. This application reduces the rate of postoperative misalignments and helps control the posterior slope of the tibia.
3. Total Hip Arthroplasty: for primary coxarthrosis: It is believed that an image free application makes sense (no CT, no fluoroscopy). The anteversion and inclination angles of the cup are aligned in the Lewinneck pelvis frame. The lateral offset and leg length are monitored and compared to the initial values. Bone Morphing of the acetabulum makes it possible to monitor the depth and direction of the milling, to avoid intra-pelvic protrusion and to control the location of the rotation center of the cup. This application reduces the risk of dislocation, and help to control length leg and lateralization.

III. Where are we going : emerging technologies for future clinical applications

In order to extend the possibilities, to provide more complete patient information, to make it faster and faster as well as more easy to use, and to improve the clinical results, new technologies are being developed in research labs and in the industry. A few examples are cited:

1. The combination of MIS with CAOS certainly makes a lot of sense provided that high quality CAOS systems and applications are used. Three new technologies are just appearing to provide access to 3D morphology percutaneously in the Operating Room: echo- matching, echo- morphing, fluo - morphing.
2. Robotics using big automated systems is certainly obsolete, but mini robotics using compact systems dedicated to orthopaedics and fixed to the bone is appearing. It offers universal instrumentation for accurate cutting or milling. In addition, work is on going to facilitate MIS solutions using such compact robotics systems.
3. Many innovative sensing technologies are emerging: physiological imaging (e.g. 3D spine imaging in standing position) and kinematics measurements (e.g. tracking of the patella during knee surgery), dynamic intra-operative measurements (e;g. intra-articular motorized distractor for knee surgery including force sensors) [3], easy-to-use 3D sensors (e.g. magnetic trackers in combination with optical sensors), 3D intra-operative digital x-ray imaging [4]. All these sensors and imaging devices will benefit from the recent improvement in image processing algorithm providing faster and more accurate 3D images in real time.
4. Integration of patient information, pre, intra and post-operative is also a key technology necessary for patient follow-up and evaluation of performances. In current systems, for each patient, data is stored on a file including all steps of the surgery, but the future one can expect to link CAOS to patient-driven information systems.
5. In addition to these emerging technologies, the new trend of CAOS is to develop many Computer Assisted Surgical Protocols (CASP) in order to implement specific solutions dedicated to a given philosophy, approach, implant, and instrumentation.

IV. Conclusion

Using the most advanced CAOS technologies, it is now possible to improve the quality of surgery with reasonable effort. A wide range of new technology will be available soon to acquire multimodal data, build specific models of the patient and fine tune the planning. High quality sensors and ergonomics are being reinforced. Using CAOS to make MIS easy-to-use is a challenge

very close to being reached. New robots will help to perform accurate gestures. The field is so wide that a need for standardization and integration will appear, meaning that the platform should be open to technologies coming from different partners. In conclusion, technology will no longer be an obstacle to the development of CAOS. But technology does not only mean clinical success. To assure the success of the field, surgeons need to work with developers to impact the field, introduce the surgical expertise in the technology in order to develop powerful and efficient CASP inspired by the idea of quality of surgery, and based on tremendous international practical experience.

REFERENCES

1. Stindel, E., et Al. Bone morphing: 3D morphological data for total knee arthroplasty. Computer Aided Surgery, 2002. 7(3): p. 156-168.
2. J.L. Briard, Stindel E, et Al. CT-Free navigation with the LCS Surgetics station:A new way of balancing the soft tissues in TKA based on bone morphing. In Navigation and robotics in total joint and spine surgery. J.B. Stiehl, W.H. Konermann, RG. Haaker Editors, Springer, Berlin 2003, p. 274-280.
3. Marmignon C., Leimnei A., Cinquin P. Robotized distraction device for ligament balance monitoring in total knee arthroplasty – CAOS International meeting, Marbella Spain, June 2003.
4. L.Desbat, M.Fleute, M.Defrise, X.Liu, C.Huberson, R.Laouar, R.Martin, J.H. Guillou, and S.Lavallée. Minimally Invasive Interventional Imaging for Computer Assisted Orthopedic Surgery. In SURGETICA'2002, pages 288-295. Sauramps médical, 2002. Best conference paper award.

THE GERMAN EXPERIENCE WITH CAOS, THE DATA OF HTO

Joachim Hassenpflug

Summary: High tibial osteotomy has been reported as a beneficial surgical technique for medial compartment osteoarthrosis in young active patients. A recently developed computer-assisted method for precisely guiding the surgical instruments was used in order to improve the accuracy of the procedure and to reduce the rate of complications. The computer-system enables the alignment of the cuts with a theoretical accuracy of less than one degree. The system uses a PC-controlled 3D-infrared camera which detects infrared transmitters fixed to bones and instruments in real-time. The relative position of bones, kinematic joint-axes and instruments are shown on a graphical interface. This provides an intraoperative interface guidance for determining of the leg-axis and subtractive or additive osteotomy angle. In preliminary investigations the reliability and safety of the system for high tibial osteotomies was evaluated in cadaver studies and first clinical trials.

Rationale: In young active Patients suffering from gonarthrosis, limited to the medial aspect of the knee joint, high tibial valgisation osteotomy appears to be an appropriate alternative to knee-arthroplasty (4,9). Over the last years the numbers of high tibial osteotomies has decreased and seems being replaced by uni- or bicondylar knee-arthroplasty. Taking into account biomechanical basics and the positive long-time results (3,9), this change of treatment does not seem to be justified. The procedure for axis correction of the proximal tibia (6) was described by Jackson in 1958 for the first time and modified by Coventry 1965 (2). Depending on the localisation of the deformity, in some cases distal femur osteotomy may be recommended (1,5) in order to achive a horizontal baseline postoperatively. The aims of a high tibial osteotomy are: - correction of the deformity to release the loading of the medial joint compartment, - pain-reduction and improvement of joint-function, - enabling of a biological healing process and supporting additional intraarticular procedures to enhance regeneration of the joint-surfaces. Correction of the deformity reduces weight-bearing of the affected medial part of the joint significantly. Even partial regeneration of the cartilage is possible (7,10). In cases with localized full thickness cartilage defects an additional intraarticular cartilage reconstruction could perhaps even improve the biological joint-resurfacing, so that perhaps one day one can apply the procedure as a kind of "bio-prosthesis". With preserved function and reduced pain over a long period of time, the need for implantation of a prosthesis might be postponed. Long-term follow-ups of several authors have shown a wide range of results concerning pain relief pain and improvement of joint function presenting a wide range from 95 % after 5 years to 60 % after 15 years (3,8,9). Nevertheless there is a progressive deterioration of the results within time.

The principle of the high tibial osteotomy seems to be easy, but precise planning and carrying out the operation exactly according to the planning are required. Therefore, this operation is not an operation for beginners. The failure analysis leads to the assumption, that the results of high tibial osteotomies could be predicted better, if the intraoperative repositions were done by means of a navigation-system in order to decrease major and minor surgical inaccuracies and to achieve the intended correction more precisely.

Method: The 3-dimensional position of bones and instruments is detected in their spatial location through an infra-red optical navigation system. A software-program was specially adapted to perform high tibial osteotomies. The navigation-system is used for determination of the tibial axis, for the orientation of the saw-jigs, for localisation and sizing of the osteotomy-wedge and to navigate the sawing-procedure itself.

Application of the navigation system: The desired correction angle as well as the width and depth of the tibial plateau are measured on long standing weight bearing x-rays and loaded into the system. A first reference marker (rigid body) is fixed about 10 centimeters below the joint line, a second one to the distal medial femur. The markers have to be fixed firmly to the bone so that they do not move during the whole operation. Moving the hip, knee and ankle-joint enables the joint-centers and the leg-axes to be determined exactly by the system. Palpation of additional anatomical reference points is performed to calibrate the geometry of the lower leg with the system. After that, infra-red markers are attached to the surgical instruments.

Closing wedge (subtractive technique, lateral approach): The surgical procedure starts in the usual way with exposition of the peroneal nerve and a shortening osteotomy of the fibula. Then the lateral tibial metaphysis is exposed for the osteotomy. The horizontal osteotomy is positioned first according to the preoperative planning by means of a cutting jig. The surgeon can control the direction on the monitor with the help of two virtual horizons for the a.p. and sagittal view. During the cutting procedure itself, the positioning of the saw-blade and the distance between the tip of the saw-blade and the medial cortex of the tibia can be controlled on the monitor. The pivoting point of the osteotomy is determined with a check-blade. The 2nd saw-jig is pivoted around the check-blade up to the desired degree of correction, guided by the navigation-system. The 2nd osteotomy is performed and the lateral based bone-wedge removed. An osteosynthesis with angular stability allows early weight bearing, a minimal osteosynthesis with Coventry-clamps needs restricted weight bearing.

Opening wedge (additive technique, medial approach): The medial tibial metaphysis is exposed detatching the distal periosteum together with the medial collateral ligament partially. After the calibration the saw-blade is navigated directly in the desired direction, leaving the lateral cortex intact. The wedge is opened medially under direct navigation control of the leg axis, taking care not to loosen the lateral cortex too much. The wedge is interposed and stabilized by osteosynthesis.

Perspective: The first early results are very promising with no severe complications or adverse effects. Use of a navigation-system in high tibial osteotomy ensures exact intraoperative orientation without x-ray control. Intraoperative surveillance of the leg axis garanties the exact degree of correction. The size of the wedge and its postition can be chosen optimally. Smoother osteotomy surfaces could lead to enhanced healing and rehabilitation. We expect a decrease in the operation associated complication-rate.

REFERENCES

1. Blauth W., Stünitz B., Hassenpflug J. (1993): Die interligamentäre valgisierende Tibiakopfosteotomie bei Varusgonarthrose. Operative Orthopädie und Traumato-logie 5: 1-15
2. Coventry M. (1965): Osteotomy of the upper portion of the for degenerative arthritis of the knee. J. Bone Joint Surg. 47A: 984-990
3. Hassenpflug J., Haugwitz V., Hahne A. (1998): Langfristige Ergebnisse nach Tibia-kopfosteotomie. Z. Orthop. 136: 154-161
4. Hassenpflug J., Plötz G.M.J. (2000): Alternativen zur Endoprothetik. In J. Eulert, J. Hassenpflug: Praxis der Knieendoprothetik, Springer, Berlin, Heidelberg, New York,2000: S.7-18
5. Healy W.L., Anglen J.O., Wasilewski S.A., Krackow K.A. (1988): Distal femoral varus osteotomy. J. Bone Joint Surg. 70A: 102
6. Jackson J.P. (1958): Osteotomy for osteoarthritis of the knee. J. Bone Joint Surg. 40B: 826
7. Maquet P.G.J. (1984): Biomechanics of the knee. Springer , Berlin-Heidelberg-New York, 9-74
8. Naudie D., Bourne R.B., Rorabeck C.H., Bourne T.J. (1999): Survivorship of high tibial valgus osteotomy – a 10 to 22 year follow up study. Clin. Orthop. 367: 18-27
9. Rinonapoli E., Mancini G.B., Corvaglia A., Musiello S. (1998): Tibial osteotomy for varus gonarthrosis. Clin. Orthop. 353: 185-193
10. Schultz W, Gobel D (1999): Articular cartilage regeneration of the knee joint after proximal tibial valgus osteotomy: a prospective study of different intra- and extra-articular operative techniques. Knee Surg Sports Traumatolog Arthrosc 7: 29-36.

NAVIGATION AND ROBOTICS IN ACL RECONSTRUCTION EXPERIENCE WITH THE NAVITRACK SYSTEM

Andree Ellermann, MD

Introduction

Decisive for successful surgical stabilisation of the knee-joint following rupture of the anterior cruciate ligament is the correct anatomical positioning of the cruciate-ligament graft. Even though anatomically the differentiation is made between an anteromedial and a posterolateral fascicle and there is thus a spreaded insertion onto the femur and the tibia, there is however a general consensus regarding the position of the tibial and femoral insertion points and of the drilled tunnels for the reconstruction of the anterior cruciate ligament [4,7,13].

The arthroscopic identification of the insertion points often presents difficulties however, even for the experienced surgeon. Sati et al., for example, were able to show that in a group of patients studied by them after anterior cruciate ligament reconstruction surgery there was incorrect placement of the insertion points in about 40% of the cases. Other authors describe poor results after anterior cruciate ligament replacement in between 10 and 29% of the cases [1].

In 2002 we operated over 1000 cases of anterior cruciate ligament injuries. Almost 30% of these were revision cases in whom a second operation was carried out due to incorrect placement of the tibial tunnels.

With the increase in the surgical treatment of ruptures of the anterior cruciate ligament, worldwide, various computer-assisted surgical systems were developed (Medivision, Aesculap, CASurgery, Praxim, Caspar, etc.) , also for the field of anterior cruciate ligament replacement [5,6,10,11,13].

Our own experience is based on the Navitrack system (Centerpulse Orthopedics/Zimmer, Switzerland), which is well known in the field of spinal surgery. It became available to us for the computer-assisted reconstruction of the anterior cruciate ligament for the first time in October 1999.

Description of the system and surgical procedure

The first software version is based on an electromagnetic application. On the day of the operation, firstly a nuclear-spin tomography of the injured knee-joint with a layer-thickness of 1.5 mm is carried out. The data in Dicom-3 format that are obtained in this way are transferred by means of a CD-ROM to an external calculation unit of the Navitrack system and, within a segmentation module, by separation of the individual grey values of the bone and soft-tissue contours, they are converted into an accurate 3D model of the injured knee-joint.

The accuracy obtained with the 3D model of the electromagnetic application was checked by means of cadaver-bone and artificial-bone tests by the firm Orthosoft in Montreal, Canada. The surfaces of the dissected knee-joints were measured with a laser and compared with the reconstructed 3D model of the Navitrack system. By this procedure, with a nuclear-spin- tomographic layer thickness of 1.5 mm a femoral and tibial 3D inaccuracy of less than 1 mm could be demonstrated [2,9].

The representation of the notch roof (Blumensaat line) which is necessary for correct identification of the tibial tunnels is made possible by integration of the whole 3D data set and is represented by a transparency effect of the 3D model. In the electromagnetic application, the instruments usually used in arthroscopy (probe hooks, screwdrivers, arthroscopic aiming device) are provided with sensors in order for them to be recognised in the electromagnetic field that is created by the 3D coil which is positioned close to the knee-joint. By means of a calibrating block an alignment is made by the surgeon between the instrument being used and the magnetic field, whereby the length and axis of the instrument are calculated as a function of a reference sensor on the calibrating block.

In order to create a real-time synchronisation between the knee that is to be operated and the 3D model, before the operation five points each have to be defined on the femoral and tibial surfaces of the model and then identified in the patient's knee by arthroscopy, using the probe hook (so-called "matching").

After successful matching, the femoral and tibial insertion points are defined, with simultaneous arthroscopic control and by use of the Blumensaat line represented in the 3D model. For this, methods of identification for the tibia according to Howell [7] and Stäubli [13] and for the femur according to Bernhard and Hertel [4] are used, in the sense of intraoperative planning. Then the insertion points in the 3D model are linked with a virtual graft, the diameter of which corresponds to that of the original graft (Fig. 39.4).

The patient's knee, on which up till now no drilling or fixation has been carried out, is now flexed and the virtually reconstructed anterior cruciate ligament on the 3D model is subjected to dynamic isometry testing and impingement testing. The system calculates the isometry as the difference between the longest and the shortest extension of the graft and signals an impingement both acoustically and visually on the screen.

Although it is known that the anatomical anterior cruciate ligament is not an absolutely isometric structure, this test nevertheless helps to detect fluctuations.

The same applies for the impingement testing at the cranial and lateral limits of the notch: even if the test is carried out on a patient's knee with a defective anterior cruciate ligament, the acoustic signal given by the system helps to prevent a disturbing impingement on the roof or the lateral wall of the notch.

Nevertheless it may not be forgotten that the system is testing a virtual ligament in an unstable knee.

If the positioning is correct, the operation is continued with placement of the tibial tunnel. Its position and length and its position in relation to the tibial plateau are fixed by means of the navigating positioning device in such a way that it is possible for the surgeon, if necessary, to place the femoral tunnel transtibially (Fig. 39.5).

Besides the conventional drilling procedures, the use of the Navitrack system also allows manual impaction of the tunnels (in contrast to the robot-assisted systems). With pure ligament grafts this ensures an improved healing process [14]. An intraoperative image- converter control to take into account the very great variation in the notch-roof angle then becomes superfluous.

Clinical experience

Between October 1999 and March 2001 sixteen anterior cruciate ligament reconstructions were carried out with the electromagnetic first version, whereby ten operations were performed successfully with the navigation procedure.

In one case there was a complete breakdown of the system, and in the other five cases we did not succeed in achieving a match between the 3D model and the patient's knee (five-point method) which would have ensured sufficient accuracy. In our opinion the reason for this was an insufficiently accurate reconstruction of the surfaces in the 3D model, based on insufficiently accurate nuclear-spin tomographic data. However, all six cruciate-ligament reconstructions could be operated, in good time and without further problems, by the conventional method.

The ten patients who were operated completely by the navigation method underwent a full postoperative examination, with an extensive previous history, a clinical examination, manual measurement of the maximum KT-1000 and standardised radiograms to assess the placement of the tunnels in the operated knee-joint. The clinical examination showed stable knee-joints with unrestricted mobility. Measured on the IKDC score, all the knee-joints could be classified as good to very good. Radiologically, all the patients also showed correct placement of the tunnels, measured according to the above mentioned radiological parameters.

No perioperative complications appeared. Thus in no case were there postoperative infections or problems of wound healing, vascular or neural damage or deep-vein thrombosis in the legs.

Taking an average of 90 minutes, the preoperative reconstruction of the nuclear-spin tomographic data is very time-consuming. However, this is largely responsible for the picture quality obtained with nuclear-spin tomography. In the patients successfully operated by the navigation procedure, the time taken to perform the operation was prolonged by about 30 minutes, but this time lag decreased with the increasing number of operations performed. However, it will not be possible, in the medium term, to achieve an operation time as short as that which is customary for operations carried out by the conventional method.

The intraoperative procedure was not significantly impaired by the additional sensor cables on the surgical instruments. All the operations performed by the navigation procedure were minimally invasive, i.e. they were carried out by arthroscopy. An arthroscopic check of various steps in the navigation procedure was possible at any time.

Consequences and modifications

Since December 2001 a second revised software version, with optoelectronic navigation, has been available. Improved with this new version were especially the reconstruction of the 3D model and the synchronisation (matching) between the patient's knee and the 3D model. While with the first version, supported by nuclear-spin tomography, the surface of the cartilage was completely reconstructed, with the second, CT-supported version the developers concentrated on the cartilage-free area of the notch and the tibial plateau. It is exclusively these areas that are decisive for identification of the insertion points.

The reconstruction of the other parts of the joint is however continued, in order to make orientation over the whole three-dimensional model of the knee-joint easier for the user.

The thickness of the CT layer in the area of the condyles is 1 mm. As in the first version, the reference sensors are fixed to the tibia and the femur during the operation with so-called passively reflecting markers. The procedure is made significantly easier by the universal handle, which can be calibrated in a few seconds and on which the different surgical instruments can be fixed as required. Using a probe-hook, surface matching is now also possible within a matter of minutes, whereby 15 points can be callipered anywhere in the region of the notch and the intercondylar eminence. The time-consuming identification of previously defined points (five-point method) is no longer necessary with the present version. In addition, for the clear identification of the different insertion points, graphic aids can be blended in on the screen. These correspond, for the femur, to the "quadrant method" described by Bernard and Hertel [4], and, for the tibia, to the "43% method" according to Stäubli et al. [13] (Fig. 39.8). In each stage of the operation, the diagrams for the intraoperative planning can be blended in or faded out on the screen as required. Also, the arthroscopic picture can be displayed on the monitor situated in the lower left window of the screen.

This second version, which greatly facilitates the procedure, was also first tested on cadavers and on artificial bone. It was first used clinically in our hospital in February 2002.

Discussion and summary

The basis for the physiological biomechanical functioning and the correct remodelling of the anterior cruciate ligament graft is the approximately anatomical placement of the femoral and tibial tunnels. Wrongly placed tunnels, with relevant anisometry or an impingement in the region of the notch are the main reasons for the failure of anterior cruciate ligament reconstruction surgery.

As the number of anterior cruciate ligament reconstructions is constantly increasing, the question of the intraoperative checking of the placement of the tunnels arises. An intraoperative image-converter method for checking of the placement of the tunnels was therefore promoted by experienced surgeons [3].

The largest number of operations with an excellent clinical and radiological documentation is available for the robotic system Caspar. This system showed high accuracy in planning and drilling the tibial and femoral tunnels, but at the the same time was a time consuming procedure with an extensive preoperative management including CT scans of both legs. This and the fact that the clinical outcome was not better in comparison to conventional ACL surgery made the application disappear [10].

The Navitrack system in its first versions has proved to be a promising instrument for the future. This system creates a virtual 3D model of the bone surface of the injured knee-joint with a possible 3D error of less than 1 mm. The handling of the navigated surgical instruments is comparable to that of conventional instruments. This allows accurate, arthroscopically controlled placement of the tunnels.

However, the routine use of any navigation aid in ACL surgery is still a questionable procedure since the operation itself is time consuming in comparison to conventional surgery. The second version of the Navitrack system leads to a considerable saving of time both before and during the operation. With this version the bone reconstruction of the of the limits of the notch and the eminence is carried out with CT support, which is sufficient for the navigation of the insertion points. However, a 3D model of the whole knee-joint is deliberately created in order to provide the user with support in his orientation within the system.

To summarise, navigation systems represent a step that is aimed at reducing the variability of the placement of the tunnels, with minimally invasive methods. The accurate preoperative and intraoperative virtual reconstruction of the anterior cruciate ligament with dynamic isometry and impingement testing allows active but controlled placement of the tunnels. According to our experience with Navigation up till now, it can be hoped that in the future this method will lead to greater reliability and accuracy in regard to the positioning of the tunnels. The preoperative 3D reconstruction of the knee-joint takes time and the quality of the reconstruction determines the success of the navigation procedure. In the ideal case, the duration of the anaesthesia and the time taken to perform the operation are not significantly prolonged. The graft and the fixation technique can be chosen freely. In the case of a successful navigation procedure, the intraoperative image-converter check becomes superfluous. The system needs further improvement and the pre- or perioperative imaging has to be modified to provide a more user-friendly environment and make the system a routine tool.

Critical analysis of present ACL navigation and visions

Looking at different navigation and robotic techniques it seems an advantage that we are not only able to identify anatomic insertion points correctly, but also restore proper knee kinematics by using impingement- and isometry-tests.

But until now all available navigation systems are testing kinematic parameters of a virtual ligament in an ACL-insufficient knee.

Until further investigation has been made it seems doubtful that this data is valid enough especially in cases with increasing instability which we see in revision situations.

As a consequence we should for the moment focuse on the correct identification of the insertion points alone which we will determine with the help of our virtual models. These models should ideally represent patients anatomy with millimetric accuracy.

This leads to another question: What is the ideal tool to create a valid model of the patients knee?

MRI data might not be accurate enough since it is quite difficult to differentiate between bony and soft tissue structures. CT scans provide high accuracy, but similar to MRI it is a time consuming procedure at the moment. Furthermore there is a rather high radiation exposure to the patient. It has to further proved that procedures based on plain x-rays or image-less information will provide an acceptable accuracy of the model since the combination with kinematic information might not be valid. "Surface-painting"-techniques seem promising, but only in areas with solid structures like cartilage or bone. Other than in open knee surgery we have very limited access to bony structures in arthroscopic surgery to correctly identify the dimensions of the knee joint. Especially the a.p. dimensions will be hard to determine and a "matching" of the model with the patients knee will be very difficult because it cannot be desirable to remove important soft tissue structures: if we focuse on the intercondylar area alone a "painting" of the interesting femoral part with the lateral notch area seems possible, but to correctly identify the tibial dimensions one would have to remove parts of the fat pad and most of the tibial stump of the former ACL (which can be considered a biologically important structure for the ACL graft) not to mention the distal insertion area of the PCL.

High quality fluoroscopy based on three dimensional data could be a promising tool if it proves to be accurate enough. This might even allow the surgeon to rather easily obtain kinematic data from the uninjured knee which then could be converted to the injured one. Ultrasound features combined with arthroscopic instruments could be another option for future minimal-invasive data acquisition.

Performing rather high numbers of conventional ACL surgeries we believe that, despite all problems that occur at the moment and the fact that navigation or robotics in ACL surgery have not proven to be superior to conventional procedures, navigation will help to improve the outcome of cruciate ligament surgery in the future. This will hopefully be true for primary reconstructions but certainly for revision and PCL surgery.

References

1. Almekinders LC, Chiavetta JB, Clarke JP (1998) Radiographic evaluation of anterior cruciate ligament graft failure with special reference to tibial tunnel placement. Arthroscopy14(2):206-11.
2. Amiot LP (1999) Computer Assisted ACL-Reconstruction: A Feasibility Study. Presentation 2nd ACL-Symposium: State of the Art 2000, March 25-27, Heidelberg, Germany
3. Amis AA, Jakob RP (1998) Anterior cruciate ligamnet graft positioning, tensioning and twisting. Knee Surg Sports Traumatol Arthrosc; 6 Suppl 1: S2-12
4. Bernard M, Hertel P, Hornung H, Cierpinski T (1997) Femoral insertion of the ACL. Radiographic quadrant method. Am J Knee Surg ;10(1):14-21
5. Bernsmann K, Rosenthal A, Sati M (1999) Use of CAS System for "Standard" Patellar-Tendon ACL Reconstruction. Presentation 4th Int Symposium on Computer Assisted Orthop Surg, March 17-19, Davos, Switzerland
6. Fleute M, Lavallee S, Julliard R (1999) Computer assisted ACL Reconstruction: Incorporating a Statistical Shape Model of the Femur for 3D Visualization. Presentation 4th Int Symposium on Computer Assisted Orthop Surg, March 17-19, Davos, Switzerland
7. Howell SM, Barad SJ (1995) Knee extension and ist relationship to the slope of the intercondylar roof. Implications for positioning the tibial tunnel in anterior cruciate ligament reconstructions. Am J Sports Med 23: 288-294
8. Lyle Cain E, Phillips BB, Charlebois SJ, Daniels AU, Azar FM (1999) Effect of Tibial Tunnel Dilatation on Pullout Strenght of Quadrupled Semitendinosus/Gracilis Autograft in ACL Reconstruction Secured with Bioabsorbable Interference Screws. Unpuplished datas, University of Ta.-Camphell Clinic, Dep. Orthop Surg, Memphis, Tennessee
9. Milne AD, Chess DG, Johnson JA, and King GJW (1996) Accuracy of an electromagnetic tracking device: A study of the optimal operating range and metal interference. J Biomech 29(6), 791-793
10. Petermann J, Schierl M, Pashimeh-Azar A, Gotzen L (2000) Computer and Roboter Assisted ACL Reconstruction with Caspar System. Presentation 9th Congress of the European Society of Sports Traumatology, Knee Surgery and Arthroscopy, London, GB
11. Rosenthal A, Bernsmann K, ansari B, Sati M (2000) Navigierte Ersatzplastik des vorderen Kreuzbandes (VKB). Z Orthop Suppl Band 138:63
12. Sati M, Bourquin Y, Stäubli HU, Müller ME (1999) Flexible Technology to consider both Anatomical and Functional Factors in ACL Replacement Surgery. Presentation 4 th Int Symposium on Computer Assisted Orthop Surg, March 17-19, Davos, Switzerland
13. Stäubli HU, Käsermann S, Sati M (1999) Inter-Operator Variance of Ligament Placement: Endoscopic versus CAS. Presentation 4th Int Symposium on Computer Assisted Orthop Surg, March 17-19, Davos, Switzerland
14. Weiler A, Windhagen HJ, Raschke MJ, Laumeyer A, Hoffmann RFG (1998) Biodegradable Interference Screw Fixation Exhibits Pull-Out Force and Stiffness Similar to Titanium Screws. Am J Sports Med 26: 119-128

◆ THROMBOEMBOLISM AFTER TOTAL HIP AND KNEE ARTHROPLASTY: WHAT'S BEST FOR MY PATIENT? (EE)

Moderator: Paul F. Lachiewicz, MD, Chapel Hill, NC (a, e – Zimmer, a – Aircast)

Thromboembolism is considered the most frequent complication following primary and revision total hip and knee arthroplasty. The optimum prophylaxis remains controversial. Recent data supporting the use of: mechanical prophylaxis; warfarin; low molecular weight heparin; new pharmacologic agents will be presented. This symposium will present information concerning anesthesia techniques to lower the prevalence of thromboembolism and the utility of genetic markers to determine high risk patients.

I. Coumadin Prophylaxis
Jay R. Lieberman, MD, Los Angeles, CA (n)

II. Low Molecular Weight Heparins
Clifford W. Colwell, Jr., MD, La Jolla, CA (a – AstraZeneca, Pharamacia, Wyeth-Ayerst, Aventis, Sanofi-Synthelabo)

III. Mechanical Prophylaxis
Paul F. Lachiewicz, MD, Chapel Hill, NC (a, e – Zimmer, a – Aircast)

IV. Oral Thrombin Inhibitors
Richard J. Friedman, Jr., MD, Charleston, SC (b – Aventis Pharmaceuticals, AstraZeneca)

V. Multi-modal Approach to Prophylaxis
Eduardo A. Salvati, MD, New York, NY (n)

OPTIMAL VTE PROPHYLAXIS IN LOWER EXTREMITY ORTHOPAEDIC SURGERY PROPHYLAXIS WITH LOW MOLECULAR WEIGHT HEPARINS

Clifford W. Colwell, Jr., MD

- Prevalence of DVT Without Prophylaxis

	Hip	Knee
DVT	45 - 57%	40 - 84%
Proximal DVT	23 - 36%	9 - 20%

- Prevalence of PE Without Prophylaxis

	Hip	Knee
Symptomatic	0.7 - 30%	1.8 - 7%
Fatal	0.3 - 6%	0.2 - 0.7%

- Ideal Prophylactic Methods
  - Effective (clinically proven)
  - Low risk of side effects
  - Practical for use
  - Easy to administer and no monitoring
  - Cost effective
- No single modality meets ideal requirements or is appropriate for every patient condition
  - Orthopaedists have single and additive mechanical and pharmacological protocols, with different time frames of patient exposure
- LMWH Has Multiple Uses
  - Cardiology
  - Chest Medicine
  - General Medicine
  - Neurology
  - Orthopaedics
- What is LMWH?
  - Fragments of unfractionated heparin produced by either chemical or enzymatic depolymerization
  - Mean molecular weights from 4,000 to 6,500 daltons
  - 6 - 8 different agents
- LMWH approved by FDA

	Manufacturer	Approved for
Enoxaparin (Lovenox®)	Aventis (France & US)	TJA
Dalteparin (Fragmin®)	Pharmacia & Upjohn, Inc. (Sweden & US)	THA

- Efficacy and Safety of Enoxaparin to Prevent Deep Vein Thrombosis After Hip Arthroplasty: Results of Four North American Clinical Trials. Clin Ortho. 319:215-222, 1995.

–Total/Proximal DVT's & PE's in Last Placebo Trial

	Placebo	Enoxaparin	UFH
Total DVT	43%	12%	16%
Proximal DVT	22%	4%	5%
PE	2%	0.1%	1%

– Major Bleeding Events in Last Placebo Trial

Major bleeding	4%	4%	6%

- Efficacy and Safety of Enoxaparin Versus Unfractionated Heparin for Prevention of Deep Venous Thrombosis after Elective Hip Arthroplasty. JBJS, 1994

– Incidence of VTED in Total Hip Arthroplasty Enoxaparin vs. UFH

	Enoxaparin 30 mg bid	Enoxaparin 40 mg qd	UFH
Total DVT	5%	15%	12%
Proximal DVT	2%	4%	5%

– Clinically Important Bleeding Events in Total Hip Arthroplasty

Enoxaparin vs. UFH	Enoxaparin 30 mg bid	Enoxaparin 40 mg qd	UFH
Bleeding	4.1%	1.5%	6.3%

- Efficacy and Safety of Enoxaparin Versus Unfractionated Heparin for Prevention of Deep Venous Thrombosis After Elective Knee Arthroplasty. Clin Ortho, 1995

– Deep Venous Thrombosis in Total Knee Arthroplasty

	Enoxaparin 30 mg bid	UFH
Total DVT	25%	34%
Proximal DVT	2%	10%
PE	0	0.8%

–Bleeding Results in Total Knee Arthroplasty

Total bleeding	20%	24%

- A Double-blind, Randomized Comparison of Low-molecular-weight Heparin Prophylaxis using Dalteparin in Close Proximity to Surgery Versus Warfarin in Hip Arthroplasty Patients. Arch Intern Med. 160:2199-2207, 2000.

–Dalteparin vs. warfarin: Venographic Thrombosis on Day 6±2

	Preop Dalteparin	Postop Dalteparin	Warfarin
Total DVT	11%	13%	24%
Proximal DVT	0.8%	0.8%	3%

–Dalteparin vs. warfarin: Bleeding Complications

Major bleeding	9%	6%	4%
Minor bleeding	2%	2%	2%

- Ideal Length of Prophylaxis?
- The Incidence of Symptomatic Venous Thromboembolism During and After Prophylaxis with Enoxaparin: A Multi-institutional Cohort Study of Patients Who Underwent Hip or Knee Arthroplasty. Arch Intern Med. 158:873-5, 1998.

– Venous Thromboembolic Events During Prophylaxis (9 days)

	THA	TKA
Total DVT	1.3%	1.8%
Proximal DVT	1.2%	1.0%
PE	0.5%	0.3%

–Venous Thromboembolic Events After Prophylaxis (84 days)

Total DVT	1.4%	1.0%
Proximal DVT	1.0%	0.6%
PE	0.7%	0.8%

- A Double Blind, Randomized Comparison of Dalteparin and Warfarin for Acute Prophylaxis and of Dalteparin and Placebo for Extended Prophylaxis After Total Hip Arthroplasty. Arch Intern Med. 160:2208-15, 2000

– Frequency of DVT by Venography

	Dalteparin or Warfarin 0-6 days		Dalteparin or Warfarin 6-35 days	
Total DVT	12%	24%	5%	10%
Proximal DVT	0.8%	3%	1%	5%

– Bleeding with Prophylaxis

Major bleeding during acute treatment phase
- Dalteparin 7.7%
- Warfarin 4.5%

Major bleeding during extended treatment phase 0 in both groups
Minor bleeding during extended treatment phase
- Dalteparin 1.8%
- Placebo 2.8%

- The Consortium Study: Comparison of Enoxaparin and Warfarin for Prevention of Venous Thromboembolic Disease After Total Hip Arthroplasty: Evaluation During Hospitalization and Three Months After Discharge. JBJS. 81A:932-40, 1999.

  – Incidence of Symptomatic VTED

	Hospital Period	Post Hospital Period	Cumulative
Enoxaparin	0.3%	3.3%	3.6%
Warfarin	1.1%	2.7%	3.8%

  – Incidence of Major or Minor Bleeding

	Enoxaparin	Warfarin
Major	1.2% (18)	0.6% (8)*
Minor	134	102

- Summary: Benefits of Low Molecular Weight Heparin
  - Predictable dose response
  - High bioavailability at low doses
  - Limited individual variability
  - Linear pharmacokinetics
  - No significant influence of PT or APTT
  - Half-life = 4 1/2 hours
  - Effective q12/24 hr dosing
  - Rapid antithrombotic action
- Summary: Requirements of Low Molecular Weight Heparin
  - Initiation 6-12 hours postop; dosing schedule q12/24hr
  - Periodic platelet counts, discontinue if below 100,000
  - Avoid combining low-molecular-weight heparin with nonsteroidals, i.e. Toradol
  - Can be used with safety and efficacy with same dosing schedule in total knee replacement and total hip replacement
- LMWH and Spinal/Epidural
  - Twice daily dosing
    - Remove catheter 6 hours after last dose and next dose may be given 2-6 hours post removal
    - Half life - 4_ hours
  - Once daily dosing
    - Remove catheter at least 6 hours after last dose and not closer than 6 hours before next dose
  - Monitor patients closely for S/S of neurological impairment
  - Risk of bleeding increased with traumatic or multiple punctures

"In the field of observation, chance favors only the mind that is prepared"
Louis Pasteur

MECHANICAL PROPHYLAXIS: EFFECTIVE FOR TOTAL HIP AND TOTAL KNEE ARTHROPLASTY

Paul F. Lachiewicz, MD

- **Venous Thromboembolism**
  - Virchow's Triad
    venous stasis
    intimal injury
    hypercoagulable state
  - Genetic predisposition?
  - Relationship between deep vein thrombosis and pulmonary embolism with joint arthroplasty patients is controversial

- **Virchow's Triad**
  Activation in THR
  - Hip dislocation → kinking femoral vein
  - Femoral canal preparation → kinking femoral vein
  - Decrease antithrombin III levels
  - Activation clotting cascade during femoral canal preparation

- **Thromboembolism after THR**
  - Specific localized disorder in most THR patients
  - So-called classic risk factors for DVT do not correlate with DVT-PE in these patients
  - Perhaps, "localized" rather than system prophylaxis should be strongly considered

- **Goals of Prophylaxis**
  - Decrease prevalence of
    symptomatic DVT
    symptomatic PE
    fatal PE
  - Avoid bleeding complications
  - Easy for patient and surgeon

- **Pulmonary Embolism-THR**
  Historical Controls

Johnson et al (Charnley)	7,959 hips P.E. 7.9% Fatal P.E. 1.04%	Coventry et al (Mayo)	2,012 hips Fatal P.E. 3.4% (no prophylaxis) Delayed warfarin P.E. 2.2%

- **THR**

	Then	Now
Bed rest	1 week	<1 day
Hospital stay	2-3 weeks	1-4 days
EBL (mean)	1650 ml	300-600 ml
Blood	Homologous	Autologous
Transfusion	1144 ml	0-500 ml
Anesthesia	General	Regional

  – These changes suggest that our older ideas about chemoprophylaxis should be reconsidered in 2004.

- **THR Contemporary Techniques**
  No DVT Prophylaxis
  - U.K. data – Fatal P.E.
  Warwick0.34% (1162 hips)
  Murray 0.12% (130,000)
  Fender 0.19% (2111)
  - Perhaps, the routine use of pharmacologic prophylaxis to prevent death after THR should be reconsidered

- **Thromboembolism THR**
  Anesthesia
  - Spinal or epidural anesthesia reduces risk by 40-50%
  - Thrombi begin during surgery
  - Regional anesthesia increased blood flow in lower extremities during and after the procedure

- **Risk Factors DVT-THR**
  - Duration of operation
  - Genetics - Factor V Leiden; other (?)
  - Prior history DVT-PE (?)
  - History of cancer (?)
  - Classic risk factors (?)
  - Autologous donation reduces risk ?

- **Autologous Donation**
  - Retrospective study 2043 patients
  - Donation 1037; not 1006
  - DVT Donation 9% (p=0.003)
    (venogram) Not 13.5%
  - P.E. Donation 0.3% (ns)
    (clinical) Not 0.7%
  Bae et al JBJS (B) 2001

- **With contemporary techniques, mechanical prophylaxis is sufficient for primary and revision total hip arthroplasty**

- **Mechanical Prophylaxis THR**
  - Intermittent calf & thigh pneumatic compression
  - Begin use intra-op when thrombi begin!
  - Postop - RR and until discharge

- **Mechanical Prophylaxis THR**
  - Intraop use
  - Does not interfere with positioning, exposure, etc.

- **Mechanical Prophylaxis THR**
  - Intra-op and post-op IPC is specific localized prophylaxis:
  - Decreased venous stasis
    increase venous velocity
    increase venous volume

- **Mechanical Prophylaxis THR**
  - Intra-op and post-op IPC is specific localized prophylaxis:
    Inhibits coagulation cascade
    increase tissue factor pathway inhibitor
    decline factor VIIa
    increase nitric oxide and endogenous NO synthase

- **Mechanical Prophylaxis THR**
  - Wide variety of devices
    thigh-calf
    calf
    foot pump
  - Each device has its own mechanics and resultant change in peak venous velocity and venous volume
  - Optimal characteristics of pneumatic compression are not known

- **Venous Hemodynamics after THR**
  - Devices that provide for rapid inflation time produced the greatest increase in peak venous velocity
  - Devices that compress calf and thigh showed the greatest increase in venous volume

- **Mechanical Prophylaxis THR**
  Efficacy
  Woolson & Watt JBJS 1991
  - Prospective, randomized
  - 3 Groups IPC alone
    IPC + aspirin
    IPC + warfarin
  - 70 hips per group
  - No difference in prevalence of DVT in 3 groups

- **Mechanical Prophylaxis THR**
  Efficacy
  Woolson JBJS 1996
  - Prospective, consecutive
  - 322 hips
  - Ultrasonography
  - 6% proximal DVT
    4% regional
    11% general (p=.02)
  - Excluded "high risk" patients

- **Mechanical Prophylaxis THR**
  Efficacy
  Hooker, Lachiewicz, Kelley JBJS 1999
  - Prospective, consecutive
  - 502 hips
  - Ultrasonography
  - Risk factors 54% at least 1, 13% 2 or more
  - Regional anesthesia 88%
  - Hybrid hip 70%

- **Mechanical Prophylaxis THR**
  Efficacy
  Hooker, Lachiewicz, Kelley JBJS 1999
  - Symptomatic DVT 0
  - Asymptomatic DVT 4.6%
  - Pulmonary embolism 0.6%
  - Late DVT 0.6%
  - No correlation between DVT and gender, age, risk factors

- **Mechanical Prophylaxis THR**
  Efficacy
  New data from UNC 2003
  - Prospective, consecutive
  - 1074 hips
  - 35 thrombi (3.3%)
  - 4 P.E. (0.4%)
  - Late DVT 0.8%

- **Symposium**
  Thromboembolism Prophylaxis
  Mechanical Prophylaxis
  - 8 studies
  - 48-502 patients IPC
  - Overall DVT 5-27%
  - Proximal DVT 0-17%
  - Pulmonary embolism 0-1%
  Salvati et al JBJS 2000

- **Mechanical vs Chemoprophylaxis**
  - Warfarin vs IPC
  - 201 patients: venography
  - Proximal thrombi 3% warfarin
    12% IPC
  - Calf thrombi 21% warfarin
    12% IPC
  *However, thigh cuff folded down and not used intraop!
  Francis et al JAMA 1992

- **DVT Surveillance**
  - Duplex ultrasonography screening has a role in prophylaxis
  - Variable institutional sensitivity and specificity
  - Proximal, asymptomatic thrombi are treated
  - Others, aspirin is recommended after discharge for 6 weeks

- **Personal THR Mortality**
  Nunley and Lachiewicz J Arthro 2003
  - 1108 hips
  - 30 day mortality 0.27%
  - 90 day mortality 0.36%
  - No fatal P.E.
  - Symptomatic P.E. 0.7%

- **Future of Mechanical Prophylaxis THR**
  - Pre-op genetic screening to defect highest risk patients
  - Definition of most effective pumping pressure and duration for total hip patient
  - Improved devices

- **Conclusion**
  - Mechanical prophylaxis is safe, effective and acceptable for total hip patients
  - Begin use intraoperatively!
  - Use regional anesthesia
  - Aspirin after discharge (?)
  - Reasonable alternative to any chemoprophylaxis

REFERENCES

1. Antiplatelet Trialists' Collaboration: Collaborative overview of randomized trials of antiplatelet therapy.III. Reduction in venous thrombosis and pulmonary embolism by antiplatelet prophylaxis among surgical and medical patients. British Med J 308:235-246, 1994.
2. Bae H, Westrich GH, Schulco TP, Salvati E: Effect of preoperative donation of autologous blood on deep venous thrombosis in total hip arthroplasty. In abstracts for the Eastern Orthopaedic Association. J Bone Joint Surg 81-A:adv. 10, April 1999.
3. Westrich GH, Farrell C, Bono JV, Ranawat CS, Salvati EA, Sculco TP: The incidence of venous thromboembolism after total hip arthroplasty. A specific hypotensive epidural anesthesia protocol. J Arthroplasty 14:456-463, 1999.
4. Woolson ST: Intermittent pneumatic compression prophylaxis for proximal deep venous thrombosis after total hip replacement. J Bone Joint Surg 78-A:1735-1740, 1996.
5. Woolson ST, Watt JM: Intermittent pneumatic compression to prevent proximal deep vein thrombosis during and after total hip replacement. J Bone Joint Surg 73-A:507-512, 1991.
6. Nunley RM, Lachiewicz PF: Mortality after total hip and knee arthroplasty in a medium-volume university practice. J Arthroplasty 18(3):278-285, 2003.
7. Westrich GH, Specht LM, Sharrock NE, Sculco TP, Salvati EA, Pellicci PM, Trombley JF, Peterson M: Pneumatic compression hemodynamics in total hip arthroplasty. Clin Orthop 372:180-191, 2000.
8. Fender D: Harper WM, Thompson JR. Gregg PJ: Mortality and fatal pulmonary embolism after primary total hip replacement. Results from a regional hip register. J Bone Joint Surg 79-B(6):896-899, 1997.
9. Francis CW, Pellegrini VD Jr, Marder VJ, Totterman S, Harris CM, Gabriel KR, Azodo MV, Leibert KM: Comparison of warfarin and external pneumatic compression in prevention of venous thrombosis after total hip replacement. J Am Med Assn 267:2911-2915, 1992.
10. Hooker JA, Lachiewicz PF, Kelley SS: Efficacy of prophylaxis against thromboembolism with intermittent pneumatic compression after primary and revision total hip arthroplasty. J Bone Joint Surg 81-A:690-696, 1999.
11. Murray DW, Britton AR, Bulstrode CJK: Thromboprophyalxis and death after total hip replacement. J Bone Joint Surg 78-B(6):863-870, 1996.
12. Sharrock NE, Go G, Harpel PC, Ranawat CS, Sculco TP, Salvati EA: Thrombogenesis during total hip arthroplasty. Clin Orthop, 319:16-27, 1995.
13. Warwick D, Williams MH, Bannister GC: Death and thromboembolic disease after total hip replacement. A series of 1162 cases with no routine chemical prophyalxis. J BoneJoint Surg 77-B(1):6-10, 1995.
14. Salvati EA, Pellegrini VD, Sharrock NE, Lotke PA, Murray DW, Potter H, Westrich GH: Recent advances in venous thromboembolic prophylaxis during and after total hip replacement. J Bone Joint Surg 82-A:252-270, 2000.

DIFFERENT SURGICAL OPTIONS FOR MONOCOMPARTMENTAL OSTEOARTHRITIS OF THE KNEE – UNISPACERS, HIGH TIBIAL OSTEOTOMY VERSUS UNICONDYLAR KNEE ARTHROPLASTY VERSUS TOTAL KNEE ARTHROPLASTY: INDICATIONS, TECHNIQUES, RESULTS AND CONTROVERSIES (C)

Moderator: Michael A Mont, MD, Baltimore, MD (a – Stryker)

This symposium will address the current trends and controversies regarding the surgical treatment of monocompartmental arthritis in patients of all ages. The methods will include the spectrum of results from osteotomies, to unispacers, to unicompartmental as well as tricompartmental knee arthroplasties. The use of mini-invasive approaches will also be highlighted.

I. Standard Total Knee Arthroplasty
Steven A. Stuchin, MD, New York, NY (e – Wright Medical)

II. Complex High Tibial Osteotomies
Dror Paley, MD, Baltimore, MD (Smith & Nephew Ortho)

III. Mini-Invasive Unicompartmental Knee Arthroplasty
Alfred J. Tria, Jr., MD, Princeton, NJ (e – Zimmer, IMP)

IV. Standard Unicompartmental Knee Arthroplasty
Peter F. Sharkey, MD, Philadelphia, PA (a, e - Stryker HowMedica Osteonics)

V. Minimally Invasive Total Knee Arthroplasty
Peter M. Bonutti, MD, Effingham, IL (e – Stryker)

VI. Unispacers
Marc W. Hungerford, MD, Baltimore, MD (a, c – Centerpulse Orthopedics)

INTRODUCTION TO THE TREATMENT OF MONOCOMPARTMENTAL OSTEOARTHRITIS OF THE KNEE

Michael A. Mont, MD

The treatment of monocompartmental osteoarthritis of the knee should start with non-operative treatment methods. Non-operative treatment methods include various oral medications such as analgesics to anti-inflammatories to the use in selected patients of narcotics. Recently, there have been a number of studies using various chondroprotective agents such as chondroitin sulfate or analogs for this treatment. When these methods fail, practitioners will very often use injections of various chondroprotective agents including hyaluronan or analogs. Other methods would be to use a series of injections with corticosteroids. Other treatment modalities for monocompartmental osteoarthritis certainly include methods such as physical therapy, which includes strengthening the knee and various uses of cryotherapy, ultrasound or various other agents. Certainly, there are a number of less defined non-mainstream methods of trying to treat monocompartmental osteoarthritis of the knee as well.

When these treatment methods fail, consideration for operative treatment methods should be entertained. These operative treatment methods include arthroscopic debridement, cartilage transfer procedures (Carticel, Mosaicplasty), osteotomies, unicompartmental knee replacements, and total knee arthroplasties. The rest of this symposium will talk about the use of these operative methods and will compare and contrast the use of osteotomies versus unicompartmental knee arthroplasty versus total knee arthroplasty. Recently there has been a change in the way some of these procedures are done to make them much less invasive which may tilt some of the directions into using certain procedures because of the less invasiveness of what previously has been considered standard. In addition, a discussion of minimally invasive unicompartmental knee arthroplasty and minimally invasive knee arthroplasty will also be discussed.

REFERENCES

1. Attmanspacher, W., Dittrich, V., Stedtfeld, H.S.: Experiences with arthroscopic therapy of chondral and osteochondral defects of the knee joint with OATS (osteochondral autograft transfer system). Zentralbl Chir 2000;125(6):494-9.
2. Specchiulli, F., Laforgia, R., Solarino, G.B.: Tibial osteotomy in the treatment of varus osteoarthritic knee. Ital J Orthop Traumatol 1990 Dec;16(4):507-14.
3. Soccetti A., Giacchetta, A.M., Raffaelli, P.: Domed high tibial osteotomy: the long-term results in tibiofemoral arthritis with and without malalignment of the extensor apparatus. Ital J Orthop Traumatol 1987 Dec;13(4)463-75.
4. Convery, F.R., Botte, M.J., Akeson, W.H., Meyers, M.H.: Chondral defects of the knee. Contemp Orthop 1994 Feb;28(2):101-7.
5. Robertsson, O.: Unicompartmental arthroplasty. Results in Sweden. Orthopade 2000 Jun;29 Suppl 1:S6-8.
6. Chassin, E.P., Mikosz, R.P., Andriacchi, T.P., Rosenberg, A.G.: Functional analysis of cemented medial unicompartmental knee arthroplasty. J Arthroplasty 1996 Aug;11(5):553-9.
7. Laurencin, C.T., Zelicof, S.B., Scott, R.D., Ewald, F.C.: Unicompartmental versus total knee arthroplasty in the same patient. A comparative study. Clin Orthop 1991 Dec;(273):151-6.
8. Lindstrand, A., Stenstrom, A., Ryd, L., Toksvig-Larsen, S.: The introduction period of unicompartmental knee. J Arthroplasty 2000 Aug;15(5):608-16.

TOTAL KNEE ARTHROPLASTY IN PATIENTS < 55 YEARS OLD

Steven A. Stuchin MD

I. Introduction

- Recent improvements in technology have led to a confusing profusion of choices in treating mono articular arthritis of the knee in the middle aged patient
- Options include:
  a. High Tibial Osteotomy opening or closed wedge
  b. Unicondylar Knee Arthroplasty
  c. Total Knee Arthroplasty

II. Choice depends on multiple factors including

- Age
- Patient activity level
- Expected durability of the procedure
- Reliability of the procedure to bring about the expected goal
- Ease of revision in the event of failure

III. Contraindications of HTO and Uni

- Contracture > 10- 20 degrees flexion
- Deformity > 10 degrees varus
- Ligament insufficiency ACL
- Bone deficiency patellofemoral arthritis other compartment arthritis

IV. How many patients really qualify for these two procedures?

- Retrospective review of 300 TKA's revealed only 12% Uni candidates
- Laskin CORR 2001

V. Longevity of HTO and Uni may be limited

- Multiple authors have documented declining results of osteotomy and Uni over time
- 10 year follow of HTO's shows results decline to 50-60% good to excellent
- Uni has similar problems with a 10 year lifespan or less

VI. Revision of HTO and Uni may be problematic

- Bone loss
- Exposure
- Ligament balance (HTO)
- Results after HTO slightly better after Uni
- Results comparable to revision TKA

VII. Long term studies of TKA in active patients < 55 years old

Author	#Knees	Age	Follow-up Yrs	Results Good/Excellent	Survivorship
Diduch	108	51	8	100%	94% @18 yrs
Mont	30	43	7.2	96.7%	
Duffy	26	43	13	Knee score 84	95%@ 15 yrs
Ranawat	17	48.7	6.3	94.1%	90.4-100% @10 yrs
Dalury	13	36	7.2	Knee score 93	

VIII. Results far exceed HTO and TKA

- Opening wedge osteotomies may improve revision results but not survivorship to revision
- Newer techniques and technologies may improve Uni longevity

REFERENCES

1. Dalury DF, Ewald FC, Christie MJ, and Scott, RD: Total knee arthroplasty in a group of patients less than 45 years of age. J Arthroplasty 1995;10:598-602
2. Deshmukh RV, Scott RD: Unicompartmental Knee Arthroplasty Long Term Results. Clin Orthop 2001;392:272-278
3. Diduch DR, Insall JN, Scott, WN, Scuderi GR, and Font-Rodriguez D: Total knee replacement in young active patients. Long-term follow-up and functional outcome. J Bone Joint Surg 1997;79A: 575-582
4. Duffy GP, Trousdale RT, and Stuart MJ: Total knee arthroplasty in patients 55 years old or younger. 10-17 year results. Clin Orthop 1998;356:22-27
5. Gill T, Schemitsch EH, Brick GW and Thornhill TS: Revision total knee arthroplasty after failed unicompartmental knee arthroplasty or high tibial osteotomy. Clin Orthop 1995; 321: 10-18
6. Kitson J, Weale AE, Lee AS, and MacEachern AG: Patellar tendon length following opening wedge high tibial osteotomy using an external fixator with particular reference to later total knee replacement. Injury 2001; Dec 32 Suppl 4:140-143
7. Laskin RS: Unicompartmental knee replacement. Some Unanswered questions. Clin Orthop 2001;392:267-271
8. Mont MA, Chang WL, Sheldon MS, Lennon WC and Hungerford DS: Total knee arthroplasty in patients < 50 years old. J Arthroplasty 2002;17:538-543
9. Nagel A, Insall JN and Scuderi GR: Proximal Tibial Osteotomy. A subjective outcome study. J Bone Joint Surg 1996;78A:1353-8
10. Ranawat CS, Padgett DP and Ohashi Y: Total knee arthroplasty for patients younger than 55 years. Clin Orthop 1998;248:27-33
11. Romanowski MR and Repici JA: Minimally invasive unicondylar arthroplasty. Eight year follow-up. J Knee Surg 2002;15:17-22
12. Weale AE, Lee AS and MacEachern AG: High tibial osteotomy using a dynamic external fixator. Clin Orthop 2001;382: 154-167

NEW CONCEPTS FOR MEDIAL AND LATERAL COMPARTMENT OSTEOARTHRITIS

Dror Paley, MD, FRCSC

Deformities associated with medial compartment osteoarthritis
- Bone deformities
  - *Femur:* varus or valgus, procurvatum, recurvatum, with or without torsion
  - *Tibia:* varus, with or without torsion, with or without recurvatum
- Joint deformities
  - Lateral collateral ligament (LCL) laxity
  - Medial collateral ligament (MCL) laxity
  - Plateau depression
  - Lateral subluxation
  - Patellar maltracking
  - Flexion contracture

Introduction to planning osteotomies
- Chao study of joint reactive forces for different deformities
- Fujisawa point

Osteotomies
- Opening wedge, closing wedge, dome

Coventry contraindications
- LCL instability
- Lateral subluxation
- Medial compartment depression
- Knee flexion <90∞
- Knee fixed flexion deformity >10∞
- Advanced age
- Obesity
- Lateral compartment arthrosis

Problems with proximal tibial osteotomies
- Patella baja
- Truncation
- Incision
- Peroneal nerve palsy
- Tibial valgus
- Fixed flexion deformity

Customized high tibial osteotomy for different pathologic abnormalities
- Varus only
- Varus + flexion deformity
- Varus + recurvatum
- Varus + LCL laxity
- Varus + MCL laxity
  - MCL tightening: dome technique
  - MCL tightening: opening wedge technique
  - Puddu plate technique
- Medial plateau joint depression
  - Medial hemi-plateau elevation
    - Varus + torsion deformity
  - External rotation osteotomy below tuberosity
  - External rotation osteotomy above tuberosity
- Lateral compartment osteoarthritis

REFERENCES

1. Coventry MB: Osteotomy about the knee for degenerative and rheumatoid arthritis. J Bone Joint Surg Am 55:23-48, 1973.
2. Jackson JP, Waugh W: Tibial osteotomy for osteoarthritis of the knee. J Bone Joint Surg Br 43:746, 1961.
3. Jakob RP, Murphy SB: Tibial osteotomy for varus gonarthrosis: indication, planning and operative technique. Instr Course Lect 41:87-93, 1992.
4. Mont MA, Alexander N, Krackow KA, Hungerford DS: Total knee arthroplasty after failed tibial osteotomy. Orthop Clin North Am 25:515-525, 1994.
5. Paley D, Marr DC, Herzenberg JE: New concepts in high tibial osteotomy for medial compartment osteoarthritis. Orthop Clin North Am 25:483-498, 1994.
6 Windsor RE, Insall JN, Vince KG: Techincal considerations of total knee arthroplasty after proximal tibial osteotomy. J Bone Joint Surge Am 70:547-555.

UNICONDYLAR KNEE ARTHROPLASTY – THE MIS TECHNIQUE

Alfred J. Tria, Jr.

Unicompartmental knee arthroplasty (UKA) dates back to the early 1970's with the introduction of the polycentric knee and, then, the Marmor implant.1 The results were not well received initially and many surgeons abandoned the procedure and used total knee arthroplasty (TKA) as their primary replacement procedure for the arthritic knee even when there was unicompartmental disease. In the early 1990's Repicci began to investigate the possibilities of using a minimally invasive surgery (MIS) for UKA.2 His work led to renewed interest in the prosthetic replacements and helped to establish the procedure as a separate technique from TKA. The MIS UKA now represents a valid surgical approach for monocompartmental arthritis of the knee.3

The patient selection for the UKA represents one of the most important factors affecting the final result. The history must clearly indicate a pattern of isolated involvement of one side of the knee. If the pain is increased with stair climbing, the surgeon should clearly confirm that the pain is still isolated to the same area. There should be minimal or no complaints of instability of the knee. If the patient does describe instability, it may be necessary to proceed with magnetic resonance imaging to evaluate the joint for meniscal irregularities, surface defects, or loose bodies that will require arthroscopic type intervention rather than UKA.

The physical examination of the knee should confirm the same findings that have been implied by the history. There should be isolated tenderness on the medial or lateral side of the knee with minimal to no findings in the patellofemoral area. Rotational tests for meniscal tears should be negative. The ligaments should be stable; however, some anterior cruciate ligament laxity is acceptable in the setting of a fixed bearing implant for the medial side of the knee. The range of motion should be at least 10 to 105 degrees.

A standing anteroposterior view is mandatory, but this does not have to include the hip and the ankle. The full length x-ray is, however, ideal because it allows the surgeon to plan the surgery and to measure the difference between the anatomic and mechanical axes. A lateral view helps to evaluate the patellofemoral joint and illustrates the slope of the tibial surface, which will be used as a reference for the tibial cut. A "notch" view will confirm that the opposite condyle has no significant disease, especially along the wall of the condyle where lesions from tibial translocation can be hidden from view. A Merchant view will evaluate the patellofemoral involvement and the alignment. The limits for the UKA are 15 degrees of valgus, 10 degrees of varus, and a 10 degree flexion contracture. Mild to moderate involvement of the opposite and patellofemoral compartments is acceptable if the patient has no symptoms in those areas. Tibial translocation beneath the femur is a contraindication. Magnetic resonance imaging can be used to be sure that the opposite compartment is acceptable. Scintigraphic studies sometimes help in confirming the extent of involvement of each area in the knee. However, the plain x-rays remain the primary imaging study.

Surgical technique is the other major component for UKA success.4 The procedure is not a TKA and should not be performed as one. It is very important to remember that only one side of the knee is undergoing surgery. The distal femoral cut is made first. If the knee has a flexion contracture of 5 to 10 degrees, the bone cuts can be used to correct the deformity. For medial replacement, the author uses the distal femoral valgus to determine the depth of the femoral resection, with 2 mm more resection if the valgus is greater than 5 degrees. The additional cut on the distal femur reduces "excess" valgus, corrects the flexion contracture, and allows a shallower cut on the tibial side where bone should be preserved. Most femoral components for TKA remove a minimum of 9 mm for the distal resection and the 2mm deeper cut removes a total of 8 mm. Thus, the additional resection does not compromise revision to TKA. If the distal femoral valgus is 5 degrees or less, the standard 6 mm distal cut is performed. This cut is replaced with 6 mm of metal for the femoral component and the resulting distal femoral valgus is the same or slightly increased by 1 to 2 degrees because of the cement mantle.

After completing the distal femoral cut, the proximal tibia is resected to allow more room to complete the subsequent femoral sizing and cuts. The slope of the tibial cut is determined by the preoperative slope and is decreased if the knee has a flexion contracture and the distal femoral valgus is 5 degrees or less. If the femoral valgus is greater than 5 degrees, the flexion contracture is corrected on the femoral side; and the tibial slope should be kept the same as the pre operative measurement. Decreasing the tibial slope results in a deeper anterior cut for greater extension space with no significant increase in the flexion gap. The slope change does correct the flexion contracture despite the fact that the surgery is only performed on one side of the knee. The tibial resection should be conservative. The sagittal cut should begin just adjacent to the ACL for the medial replacement to give the most surface for support of the tray. The component should be perpendicular to the long axis of the tibia and not in varus.

After completing the tibial cuts, the final femoral cuts are easier to perform with the greater working space in flexion. The femoral component should be positioned centrally over the tibial insert and should be perpendicular in full extension and in 90 degrees of flexion. The "tilt" angle of the femoral component in full extension can be determined by using the difference between the mechanical axis and the anatomic axis of the knee. In the varus knee this angle is typically 4 degrees. In the valgus knee it is typically 6 degrees. In ninety degrees of flexion the surgeon must make the choice between placing the femoral component on the distal femur to cover the anatomic cut surface or setting the component perpendicular to the tibial surface. The perpendicular position is most important to avoid edge loading and sometimes there will be overhang of the component into the intercondylar notch, which should be accepted. The valgus knee is performed in a similar fashion but the depth of the femoral cut cannot be varied and a fixed bearing implant be chosen to avoid bearing dislocation. At the end of the procedure, the overall anatomic knee alignment should be just slightly corrected; and the laxity in full extension and in 90 degrees of flexion should be 2 mm.

Most of the UKA implants use a femoral component with a dual lug or a single lug with a keel. The design choice does enter into the equation for success or failure. There are fixed and mobile bearing designs and most authors agree that the mobile bearing should not be used for lateral disease.5 The tibial

implant can be all polyethylene or modular. The all poly designs permit greater thickness but exchange must involve bone invasion. The modular designs allow better visualization of the posterior aspect of the knee, with simpler poly exchange; and backside wear does not appear to be a major problem in UKA prostheses. The polyethylene thickness should be greater than 6 mm for general safety.

The recent publications of UKA surgery are very encouraging. Repicci has reported 8 year follow up with 7% failure.2 Revision was only performed in 10 patients (5 for disease progression in the other compartments). Price's report with a minimal incision showed faster recovery and better results than the standard UKA. He also indicated similar accuracy to the open approach.6 Berger reported 98% survival at 10 years using the open technique. There were only three repeat operations: one arthroscopy for posterior retained cement, one manipulation, and one revision for disease progression.3 The author has performed 297 UKA's in the past four years and the first 63 knees are now three years after surgery. Four knees in the entire group of 297 have been revised to a TKA: one for a patellar dislocation, one for femoral loosening due to a slightly large component, and two for progression in the patellofemoral joint. Two knees developed minimally displaced tibial fractures in the first month after surgery and were treated conservatively without ill effects. There are no infections or wound compromises.

MIS UKA represents a viable alternative for monocompartmental disease of the knee when the proper patient, implant, and surgery are combined together. Arthroscopy, osteotomy, other limited implants, and total knee arthroplasty must all be considered in the decision making process in order to give each patient the best individual outcome.

REFERENCES

1. Marmor L. Unicompartmental knee arthroplasty, ten to thirteen year follow up study. Clin Orthop1987; 226:14-20.
2. Romanowski, MR, Repicci JA: Minimally invasive unicondylar arthroplasty. Eight-year-follow-up. J Knee Surg. 2002; 15:17-22.
3. Berger RA, Nedeff DD, Barden RM, Scheinkop MM, Jacobs JJ, Rosenberg RA, Galante JO: Unicompartmental knee arthroplasty. Clinical experience at 6- to 10-year follow-up. Clin Orthop. 1999; 367:50-60.
4. Tria AJ Jr.: Minimally invasive unicondylar knee arthroplasty. Techniques in Knee Surgery 1(1): 60-71, 2002.
5. Murray DW, Goodfellow JW, O'Connor JJ: The Oxford medial unicompartmental arthroplasty: a ten year survival study. J Bone Joint Surg Br 1998; 80:983-989.
6. Price AJ, Web, J, Topf, H. Rapid recovery after Oxford unicompartmental arthroplasty through short incision. J Arthroplasty 2001; 16(8):970-976.

UNICOMPARTMENTAL KNEE ARTHROPLASTY

Peter F. Sharkey, MD

CASE FOR UKA

Results
- Generally good mid-term follow-up results
- Pain relief comparable to TKA
- Rapid recovery
- Durability mid-term 80% survivorship
- Confirmed by numerous authors
- Key to good results
- Proper patient selection
- Precise surgical technique
- Good implant design

Durability
- Significant midterm follow-up literature suggesting approximately 80% implant survival at 8-10 year
- Much less long term follow-up studies compared with TKA
- A few long term follow-up studies available
- Available data suggest maintenance of good results into long term (15-20 years)

Results of UKA Revision
- At least four published studies
- Results good
- Revision with primary components often possible

CASE AGAINST UKA

Results are not universally good
- Good results not completely predictable even with ideal patient
- Poor results with certain implants
- Significant surgical experience needed for routine good results
- Which surgical technique yields best result? (i.e. mini-invasive vs. standard approach)

Implant durability most likely less then with total knee arthroplasty
- Fixation not as secure as with total knee arthroplasty
- Implant design may be a limiting problem
- Metal backing enhances fixation but, leads to accelerated polyethylene wear
- Failure can be related to progressive arthritis or patellar impingement

UKA revision
- Residual defects in bone often prompt grafting or the use of metal augments
- Long term follow-up after UKA revision not available

REFERENCES

1. Berger RA, Nedeff D, Barden RM, Sheinkop MM, Jacobs JJ, Rosenberg AG, Galante JO: Unicompartmental knee arthroplasty: Clinical experience at 6-to 10 year followup. Clin Orthop Rel Research 1999;367:50-60.
2. Dawson J, Fitzpatrick R, Murray D, Carr A. Questionnaire on the perceptions of patients about total knee replacement. J Bone Joint Surg 1998;80B:63-69.
3. Laurencin CT, Zelicof SB, Scott RD, Ewald FC. Unicompartmental versus total knee arthroplasty in the same patient. A comparative study. Clin Orthop Rel Research 1991;273:151-156.
4. Newman JH, Ackroyd CE, Shah NA. Unicompartmental or total knee replacement? Five year results of a prospective, randomized trial of 102 osteoarthritic knees with unicompartmental arthritis. J Bone Joint Surg 1998;80B:862-865.
5. Palmer SH, Morrison PJM, Ross AC. Early catastrophic tibial component wear after unicompartmental knee arthroplasty. Clin Orthop Rel Research 1998;350:143-148.
6. Rees JL, Price AJ, Lynskey TG, Svard UCG, Dodd CAF, Murray DW. Medial unicompartmental arthroplasty after failed high tibial osteotomy. J Bone Joint Surg 2001;83B:1034-1036.
7. Robertsson O, Knutson K, Lewold S, Lidgren L. The routine of surgical management reduces failure after unicompartmental knee arthroplasty. J Bone Joint Surg 2001;83B:45-49.
8. Rougraff BT, Heck DA, Gibson AE. A comparison of tricompartmental and unicompartmental arthroplasty for the treatment of gonarthrosis. Clin Orthop Rel Research 1991;273:157-164.
9. Scott RD, Cobb AG, McQueary FG, Thornhill TS. Unicompartmental knee arthroplasty. Eight to 12 year follow-up evaluation with survivorship analysis. Clin Orthop Rel Research 1991;271:96-100.
10. Squire MW, Callaghan JJ, Goetz DD, Sullivan PM, Johnston RC: Unicompartmental knee replacement: A minimum 15 year followup study. Clin Orthop Rel Research 1999; 367:61-72.
11. Stockelman RE, Pohl KP. The long-term efficacy of unicompartmental arthroplasty of the knee. Clin Orthop Rel Research 1991;271:88-95.
12. Svard UCG, Price AJ. Oxford medial unicompartmental knee arthroplasty: A survival analysis of an independent series. J Bone Joint Surg 2001;83B191-194.

TOTAL KNEE ARTHROPLASTY MINIMALLY INVASIVE APPROACH

Peter M. Bonutti, MD

Monocompartment Knee Arthroplasty Surgical Treatment Options
1. Osteotomy
2. Unicompartmental knee arthroplasty
3. Total knee arthroplasty

Osteotomy Drawbacks
1. Osteotomy has prolonged recovery due to healing and functional recovery.
2. Hardware risks - infection / removal.
3. Conversion to TKA can be difficult.

Unicompartmental Knee Arthroplasty - Drawbacks
1. Limited incision
2. Risk for patellofemoral pain / disease
3. Correction of mechanical alignment
4. Polyethylene wear / thin poly
5. Variable long term results, 67-90% success rate
7. Revision to total knee can be difficult due to significant bone loss

Treatment Options - Total Knee Arthroplasty
- Consistent reproducible results
- Corrects mechanical alignment
- Treats all three knee compartments.
- Reproduced greater than 90% - 10 year survivorship
- High patient satisfaction

Drawbacks
- Extensive exposure with quadriceps disruption.
- Eversion of the patella.
- Postoperative pain, extensive rehabilitation - often greater than 3-6 months

Mahoney, Schmalzried et al identified at three months only 40% of traditional TKA could rise from a chair without the use of the arms and at 6 months only 64% . Suggests significant quadriceps damage and long term quad recovery.

Mont and Ragland identified that 65% of well functioning TKA with knee scores greater than 90 over the age of 65 years old felt that there were significant limitations and only 50% able to squat or kneel.

Is this technique or implant related ?

Minimally Invasive – Possible Concerns, Drawbacks
1. Cosmetic value only
2. Unproven patient benefits
3. Increased operating time
4. Learning curve

Minimally Invasive TKA
1. Project developed over 10 years
2. Over 2.5 years evolvement
3. Over 200 TKA implanted
4. 46 simultaneous bilateral TKA

MIN TKA - driving force is limited soft tissue damage, reduced quadriceps exposure, improved rehab and recovery, not just cosmetics.

Technique - Incision 2 times patellar length, 6-10 cm
- Superior and inferior capsulotomy.- VMO snip.
- Retract patella laterally (avoid eversion of patella
- Retract patella - 8.7% stretch to quad length, eversion of the patella with traditional exposure 16.7% increase in quad length stress
- Progressively flex and extend knee to expose portion of joint
- Downsized / streamlined instrumentation for osteotomies and bone cuts
- Patella resurfacing – avoid everting patella

Surgical time - mean 1 hour

Results - 210 TKA up to 2 year follow up
- No catastrophic failures
- No component loosening
- No component revision
- No progressive radiolucent lines

MIN New Technique - Suspended Leg Technique
- 25 patients, Legs hanging over the edge of table in arthroscopic knee holder
- Soft tissue distraction with gravity, - Identical instrumentation exposure
- Technique similar to traditional leg holder, -gravity distracts joint to allow exposure

Future Enhancements
1. Computer navigation to fine tune rotation alignment
2. Minimally invasive friendly implant
   - Easy to implant
3. Medial versus lateral approach
   - Avoiding all quadriceps releases
   - Patella in situ resurfacing

Minimally Invasive TKA
- Clinical confirmation is essential
- Current ongoing randomized prospect study with independent evaluator
- 240 TKA over 6 sites

Conclusions - Treatment of Monocompartmental Knee Arthroplasty

Clearly TKA offers a most consistent reproducible long term result for knee arthritis. Clearly long term results are superior to osteotomy (buying time) vs. unicompartmental knee arthroplasty - a temporary procedure with limited indications.

REFERENCES

1. Bonutti P, Kester M: Use of suspended leg technique for minimally invasive total knee arthroplasty. Orthopedics - Accepted for Publication - 2003.
2. Mont M, Ragland P: Limits of Total Knee Arthroplasty. Data presentation, manuscript in preparation.
3. Mahoney O, Schmalzried T: Improved Extensor Mechanism Function with Scorpio TKA.
4. Robertsson, O: Unicompartmental arthroplasty. Results in Sweden. Orthopade 2000 June;29 Suppl 1:S6-8.
5. Chassin, EP, Mikosz, RP, Andriacchi, TP, Rosenberg, AG: Functional analysis of cemented medial unicompartmental knee arthroplasty. J Arthroplasty 1996 Aug;11(5):553-9.
6. Laurencin, CT, Zelicof, SB, Scott, RD, Ewald, FC: Unicompartmental versus total knee arthroplasty in the same patient. A comparative study. Clin Orthop 1991, 273:151-6.

OPTIMIZING OUTCOMES FOLLOWING COMPLICATIONS OF PRIMARY TOTAL KNEE ARTHROPLASTY (G)

Moderator: Arlen D. Hanssen MD, Rochester, MN (n)

Complications following total knee arthroplasty as with any procedure are inevitable. This symposium will focus on the treatment of common complications that present following total knee replacement.

I. Introduction
Arlen D. Hanssen, MD, Rochester, MN (n)

II. Treatment of the Stiff Knee
Paul A. Lotke, MD, Philadelphia, PA (e – Stryker, DePuy)

III. Extensor Mechanism Problems
John J. Callaghan, MD, Iowa City, IA (a, b, c, e – DePuy)

IV. Treatment of Instability
Douglas A. Dennis, MD, Denver, CO (n)

V. Treatment of Osteolysis
Mark W. Pagnano, MD, Rochester, MN (c – Zimmer)

VI. Treatment of the Infected Knee
Arlen D. Hanssen, MD, Rochester, MN (n)

EXTENSOR MECHANISM COMPLICATIONS

John J. Callaghan, MD

I. Patella femoral instability

Prevention:
1. Medialization of patellar component
2. Tibial or femoral component malalignment (internal rotation)
3. Assessment of patella tracking

Treatment:
1. Lateral release
2. Medial reefing
3. Tubercle transfer
4. Revise components

II. Patella Fracture

Prevention:
1. Proper rotation of components
2. Preserve blood supply
3. Avoid over resection

Treatment:
1. Non-operative when possible
2. If quad mechanism deficient remove component, consider alignment and bone graft

III. Quadriceps Tendon Rupture

Prevention:
1. Don't devascularize tendon

Treatment:
1. Fix to bone
2. Allograft if necessary
3. Immobilize 6 weeks

IV. Patellar Tendon Rupture

Prevention:
1. Quad snip, tubercle osteotomy
2. Don't dislocate patella in exposure
3. Pin in tendon

Treatment:
1. Semitendinosus gracilis autograft
2. Achilles tendon allograft
3. Extensor mechanism allograft (repair tight wait 6 weeks to move)

V. Patellar Soft Tissue Impingement

Prevention:
1. Better designs
2. Excise peripatellar synovium at surgery
3. Avoid joint line elevation

Treatment:
1. Excision of involved synovium

VI. Patellar Component Wear and Loosening

Prevention:
1. Avoid metal backed patellar components
2. Assure adequate patellar tracking
3. Avoid necrosis

Treatment:
1. Revise
2. Resect
3. Bone graft

TREATMENT OF LIGAMENTOUS INSTABILITY FOLLOWING TOTAL KNEE ARTHROPLASTY

Douglas A. Dennis, MD

I. TKA STABILITY
- A. Component Articular Geometry
- B. Soft Tissue Supporting Structures
  1. Ligaments/Capsule/Muscles
- C. Better obtained BIOLOGICALLY than PROSTHETICALLY
  1. Constraint Creates Increased Fixation Stresses

II. TKA INSTABILITY
- A. Classification
  1. Medial-Lateral
  2. Anterior-Posterior
  3. Global
  4. Symmetric vs. Asymmetric
- B. Incidence 2-22%
- C. Etiologies
  1. Ligament Imbalance
  2. Malalignment
  3. Component Failure
  4. Faulty Prosthetic Design
- D. Symptoms - Variable
  1. None / Pain / Weakness / Giving Way
- E. Diagnosis
  1. Clinical Exam
     a. Measurable Ligamentous Laxity
     b. Hyperextension
     c. Posterior Sag
     d. Effusion
  2. Stress Radiographs
  3. Dynamic Fluoroscopy
- F. Prevention
  1. Balance & Equalize Flexion and Extension Gaps
  2. Restoration of Joint Line (Stiehl, J Arthroplasty, 1995)
     a. 3.08 cm Distal to Medial Epicondyle
     b. 2.53 cm Distal to Lateral Epicondyle
  3. Extension Gap
     a. Determined by Tibial and Distal Femoral Resections
  4. Flexion Gap
     a. Determined by Tibial and Posterior Femoral Resections
- G. Symmetric Extension Instability
  1. Usually Secondary To:
     a. Excessive Bone Resection / Loss
     b. Soft Tissue Laxity (MCL/LCL/PCL/Posterior Capsule)
  2. Results in Varus-Valgus Laxity ± Recurvatum
- H. Asymmetric Extension Instability
  1. Etiologies
     a. Error in Femoral / Tibial Resection
     b. Asymmetric Bone Loss
     c. Collateral Ligamentous Imbalance
        - Under vs. Over-release
        - Attenuation vs. Disruption
     d. Tight PCL
  2. Can Usually Tolerate Mild Laxity
     a. Dynamic Stabilizing Effect of Iliotibial Band
- I. Symmetric Flexion Instability
  1. Etiologies
     a. Undersized Femoral Component
     b. Excessive Posterior Tibial Slope
     c. Attenuated vs. Disrupted PCL
  2. Accentuated with Extensor Mechanism Insufficiency
  3. Can Result in Dislocation
- J. Asymmetric Flexion Instability
  1. Etiologies
     a. Error in Femoral Component Rotation
     b. Collateral Ligamentous Imbalance
     c. Tight PCL
  2. Can Result in Femoral Condylar Lift-Off

III. TKA INSTABILITY: MANAGEMENT
- A. Nonoperative
  1. Mild Instability Often Asymptomatic
  2. Bracing (Problems with Compliance)
  3. Physiotherapy
- B. Operative
  1. Key: Balance and Equalize Flexion/Extension Gaps and Restore Joint Line

	EXTENSION ADEQUATE	EXTENSION LOOSE	EXTENSION TIGHT
FLEXION ADEQUATE	No changes	Augment distal femur	• Resect distal femur • Posterior release • D/C posterior osteophytes
FLEXION LOOSE	Larger femoral component with posterior augmentation	Thicker tibial	• Larger femoral component with posterior augmentation • Resect distal femur
FLEXION TIGHT	• Smaller femoral component • Posterior tibial slant • Consider PS	• Smaller femoral component with distal augmentation • Consider PS	• Thinner tibial component • Resect tibia

  2. Options
     a. Thicker Tibial Insert
     b. Angled Tibial Insert (Shaw, J Arthroplasty, 1992)
        - If Associated Malalignment
     c. Larger Femoral Component
     d. Increased Prosthetic Constraint
     e. Ligamentous Advancement
- C. Flexion Instability: Treatment Options
  1. Thicker Tibial Insert
     a. Often Fails (Waslewski, Benjamin, et al, J. Arthroplasty, 1998; Engh, et al, JBJS, 2000; Babis, Trousdale, et al, JBJS, 2002; Brooks, Fehring, et al, CORR, 2002)
  2. More Congruent Insert
  3. PCL Substituting TKA (Mild Instability)
  4. Constrained TKA (Severe Instability)
- D. Dislocated PCL Substituting TKA
  1. Secondary to Excessive Flexion Laxity
  2. Incidence Low (<1-2%)
  3. Mechanisms
     - Excessive Valgus / Lateral Releases (Dislocates in "Figure Four" Position)
     - Hyperflexion
  4. Treatment

- Closed Reduction / Cast / Physiotherapy in Most
- Thicker PS Insert
- Increase Femoral Component Size
- Constrained TKA
- Ligamentous Advancement

E. Persistent Instability: Options
1. Constrained Condylar TKA
   a. Not All Are the Same!!
   b. Variations in Varus-Valgus Laxity / Rotational Laxity /Post Height
   c. Unlinked Constrained (i.e., Total Condylar III) Vs. Linked (Hinge)
2. Linked Hinge TKA
   a. Rarely Required
   b. Often Associated with Premature Failure
   c. Indications
      - Global Instability
      - Uncontrolled Hyperextension
      - Tumor Resection
      - Comminuted / Osteopenic Supracondylar Femoral Fracture
3. Ligamentous Advancement (Krackow, JBJS-A, 1990)
   a. MCL vs. LCL Advanced at Femoral Origin
   b. Technically Demanding (Krackow Locking Stitch, JBJS-A, 1986)
   c. Protect Repair (Brace vs. Constrained TKA)
   d. Limited Cases Reported

BIBLIOGRAPHY

1. Babis GC, Trousdale RT, Morrey BF: The effectivelness of isolated tibial insert exchange in revision total knee arthroplasty. J Bone Joint Surg Am 84-A(1): 64-68, 2002.
2. Brooks DH, Fehring TK, Griffin WL, Mason JB, McCoy TH: Polyethylene exchange only for prosthetic knee instability. Clin. Orthop. 405: 182-8, 2002.
3. Cohen B, Constant CR: Subluxation of the posterior stabilized total knee arthroplasty. J Arthroplasty 7:161, 1992.
4. Edwards E. Miller J, Chan KH: The effect of postoperative collateral ligament laxity in total knee arthroplasty. Clin Orthop 236:44-51, 1988.
5. Engh GA, Koralewicz LM, Pereles TR: Clinical results of modular polyethylene insert exchange with retention of total knee components. J Bone Joint Surg., 82(4): 516-523, 2000.
6. Fehring TK, Valadie AJ: Knee instability after total knee arthroplasty. Clin Orthop 299:157-62, 1994.
7. Galinat BJ, Vernace JV, Booth RE Jr, Rothman RH: Dislocation of the posterior stabilized total knee arthroplasty: A report of two cases. J Arthroplasty 2:363, 1988.
8. Gebhard JS, Kilgus DJ: Dislocation of a posterior stabilized total knee prosthesis: A report of two cases. Clin Orthop 254:225-9, 1990.
9. Griffin WI, Fehring TK, Valadie A: Revision of the unstable total knee arthroplasty. In Engh GA, Rorabeck CH (eds): Revision Total Knee Arthroplasty (Chapter 18). Baltimore, Williams & Wilkins, 1997, pp. 340-351.
10. Healy WL, Lemos DW: Proximal medial collateral ligament advancement with bone plug recession for treatment of severe valgus deformity in total knee arthroplasty. Presented at the Annual Meeting of the Knee Society, New Orleans LA, March 22, 1998.
11. Hofmann AA, Tkach TK, Evanich CJ, Camargo MP, Scott D: Posterior stabilization using an ultracongruent polyethylene insert in total knee arthroplasty. Presented at the Annual Meeting of the Knee Society, San Francisco CA, February 16, 1997.
12. Kester MA, Cook SD, Harding AF, et al: An evaluation of the mechanical failure modalities of a rotating hinged knee prosthesis. Clin Orthop 228:156, 1988.
13. Kocmond JH, Delp SL, Stern SH: Stability and range of motion of Insall-Burstein condylar prostheses, a computer simulation study. J Arthroplasty 10:388, 1995.
14. Krackow KA, Thomas SC, Jones LC: A new stitch for ligament-tendon fixation: brief note. J Bone Joint Surg 68A:764-6, 1986.
15. Krackow KA, Weiss AP: Recurvatum deformity complicating performance of total knee arthroplasty. A brief note. J Bone Joint Surg 72A:268, 1990.
16. Krackow KA: Deformity. In Krackow KA (ed): The Technique of Total Knee Arthroplasty (Chapter 8). St. Louis, CV Mosby, 1990, pp. 249-372.
17. Lombardi AV, Mallory TH, Vaughn BK, et al: Dislocation following primary posterior-stabilized knee arthroplasty. J Arthroplasty 8:633-9, 1993.
18. McPherson EJ, Vince KG: Breakage of a Total condylar III knee prosthesis. J Arthroplasty 8:561, 1993.
19. Pagnano MW, Hanssen AD, Lewallen DG, Stuart MJ: Flexion instability after primary posterior-cruciate retaining total knee arthroplasty. Presented at the Annual Meeting of the Knee Society, New Orleans LA, March 22, 1998.
20. Pritsch M, Fitzgerald RH Jr, Bryan RS: Surgical treatment of ligamentous instability after total knee arthroplasty. Arch Orthop Trauma Surg 102:154-8, 1984.
21. Rand JA, Chao EY, Stauffer RN: Kinematic rotating-hinge total knee arthroplasty. J Bone Joint Surg 69A:489, 1987.
22. Ritter MA, Meding JB: Anterior displacement. Its effects on instability and radiolucency in total knee replacements. Clin Orthop 208:259-65, 1986.
23. Sculco TP: Total condylar III prosthesis in ligament instability. Orthop Clin North Am 20:221-6, 1989.
24. Sharkey PF, Hozack WJ, Booth RE Jr, Balderston RA, Rothman RH: Posterior dislocation of total knee arthroplasty. Clin Orthop 267:128, 1992.
25. Shaw JA: Angled bearing inserts in total knee arthroplasty. J Arthroplasty 7:211, 1992.
26. Shoemaker SC, Markolf KL, Finerman GA: In vitro stability of the implanted total condylar prosthesis. Effects of joint load and of sectioning the posterior cruciate ligament. J Bone Joint Surg 64A:1201-13, 1982.
27. Stiehl JB, Abbott BD: Morphology of the transepicondylar axis and its application in primary and revision total knee arthroplasty. J Arthroplasty 10:785-9, 1995.
28. Vince KG, Berkowitz R, Spitzer A: collateral ligament reconstruction in difficult primary and revision total knee arthroplasty. Presented at the Annual Meeting of the Knee Society, San Francisco CA, February 16, 1997.
29. Warren PJ, Olanlokun TK, Cobb AG, Walker PS, Iverson BF: Laxity and function in knee replacement. A comparative study of three prosthetic designs. Clin Orthop 305:200-8, 1994.
30. Waslewski GL, Marson BM, Benjamin JB: Early, incapacitating instability of posterior cruciate ligament-retaining total knee arthroplasty. J Arthroplasty 13(7): 763-7, 1998.
31. Whiteside LA, Kasselt MR, Haynes DW: Varus-valgus and rotational stability in rotationally unconstrained total knee arthroplasty. Clin Orthop 219:147-57, 1987.

TREATMENT OF OSTEOLYSIS AFTER TOTAL KNEE ARTHROPLASTY

Mark W. Pagnano, MD

I. Wear debris from the articulation of metal against polyethylene is expected
- A. Articular surface wear is an obvious source
- B. Backside wear increasingly recognized as important
- C. Tibial post wear via impingement may contribute
- D. Tibial tray-poly interface of mobile bearing designs

II. Presentation of osteolysis
- A. Uncommon at less than 5 years
- B. Radiographic detection before clinical symptoms is typical
- C. X-ray appearance of scalloped defects first appearing at margins
- D. Look carefully at AP view of femur to see lesions of femoral condyles
- E. Clinical signs with wear may include effusion, cyst formation
- F. Clinical symptoms can include increase in pain

III. When to intervene
- A. Any symptomatic patient with clear evidence of wear and lysis
- B. Asymptomatic patient who has progressive loss of bone demonstrated on serial x-rays.
- C. How quickly to intervene and how much progression of lysis is necessary before intervention can be individualized but in general would be inversely related to age and activity level. With younger and more active patients being operated upon sooner rather than late.

IV. What to do
- A. Component revision and bone grafting is the treatment of choice in most cases
- B. Carefully remove components to limit iatrogenic bone loss
- C. Thoroughly debride the osteolytic lesion back to healthy bone
- D. Cavitary defects can be managed well with morselized cancellous graft in many cases
- E. Segmental or structural defects that compromise component fixation demand careful attention.
- F. Role of component retention and bone grafting is probably lower in the knee than it is with osteolytic lesion around the hip.
  1. Why ?
  2. Method of fixation is often cement around knee, thus harder to determine if component well fixed.
  3. Thinner metal components do not withstand fatigue as well so if portion of component remains unsupported after isolated grafting it may fail.
  4. Do not leave in place a component with poor track record.
  5. Recognize the relatively poor results reported for isolated tibial liner exchange in revision total knee surgery.

V. How to address larger structural defects
- A. Stemmed components to bypass the deficient proximal tibia or distal femur are typically used.
- B. Reestablish rotational and axial stability of the implant with some combination of bone graft, standard metal augments, metaphyseal filling cone augments of solid metal or trabecular metal.

VI. Trabecular metal augments and cones
- A. Offer a way to obtain immediate stability against host bone – a foundation for the new implant
- B. Biologic fixation against host
- C. No risk of resorption and collapse as occurs with large stuctural allograft
- D. Efficient, effective reconstitution of missing segmental or large cavitary defects

REFERENCES

1. Engh GA et al: In vivo deterioration of tibial baseplate locking mechanisms in contemporary modular total knee components. JBJS 83-A 1660-65, 2001.
2. Rodriguez JA et al: Metal backed and all polyethylene tibial components in total knee replacement. Clin Orthop 392:174-83, 2001.
3. O'Rourke MR et al: Osteolysis associated with a cemented modular posterior cruciate substituting total knee design:5-8 year followup. JBJS 84-A:1362-71, 2002.
4. Huang CH et al: Osteolysis in failed TKA a comparison of mobile bearing and fixed bearing knees. JBJS 84-A:2224-9, 2002.
5. Keating EM et al: Long term followup of nonmodular total knee replacements. Clin Orthop 404:34-39, 2002.
6. Weber AB et al: A study of polyethylene and modularity issues in 1000 cruciate retaining knees at 5-11 years. J Arthroplasty 17:987-91, 2002.
7. Pagnano MW, Scuderi GR, Insall JN. Tibial osteolysis associated with the modular tibial tray of a cemented posterior stabilized total knee replacement: a case report. J Bone Joint Surg Am. 2001 Oct;83-A(10):1545-8.
8. Babis GC, Trousdale RT, Pagnano MW, Morrey BF. Poor outcomes of isolated tibial insert exchange and arthrolysis for the management of stiffness following total knee arthroplasty.J Bone Joint Surg Am. 2001 Oct;83-A(10):1534-6.

INFECTION: DIAGNOSIS AND MANAGEMENT IN THE EARLY POSTOPERATIVE PERIOD

Arlen D. Hanssen, MD

I. Prevention: Prophylactic antibiotics are single most effective method.[7]

	Host	Wound	Bacteria
Preop	Immunosuppression	Vascular disease	Oral cavity/ GU tract/
	Diabetes mellitus	Prior surgery	Pulmonary
	Rheumatoid arthritis	Extensive scarring	Skin lesions/Venous
	Obesity	Prior radiation	stasis ulcers
	Advanced age	Psoriatic plaques	Infected ingrown toenails
	Malnourishment	Thin atrophic skin	Skin breaks (web spaces)
	Prior Surgery		Follicular infection
	Anesthetic risk		Preop shaving
			Prolonged hospitalization
			Prior septic arthritis/
			osteomyelitits
Intra-op	Allogeneic transfusion	Wound irrigation	Prophylactic antibiotics
		Surgical technique	Instrument sterilization
		Structural bone graft	Operating- room traffic/
		Hemostasis	"Dispersers"
		Drains	Face masks or hoods
		Suture selection	Body-exhaust suits
		Wound closure	Skin preps/Double gloves
			Splash basins/Sucker tips
			Laminar airflow/
			Ultraviolet light
Postop	Allogeneic transfusion	Wound hematoma	Urinary tract management
	Patients at risk	Draining wounds	Remote infections
	Rheumatoid arthritis	**Prostheses at risk**	Intravenous catheters
	Prior infection	Metal synovitis	**Procedures of risk**
	Immunusuppressed	Loose prostheses	dental
	Malnutrition	Hinged prostheses	gastrointestinal
			urologic

Surgical technique and patient's severity of illness the primary determinants of surgical wound infection after total knee arthroplasty.[5]

II. Classification[18]

Type 1: Positive intraoperative culture (PIOC): 4-6 weeks of antibiotics

Type II: Early postoperative infection (EPOI): prosthesis salvage possible

Type III: Late chronic infection (LCI): prosthesis removal required

Type IV: Acute hematogenous infection (AHI): prosthesis salvage possible

III. Diagnosis

1. Requires high index of suspicion and avoidance of certain practice patterns[6,22]
   a. Indiscriminate use of antibiotics for fever, pain, or wound drainage
   b. Fever:[8,19]
      92 TKR: all had temp > 37 degrees C at some time in 1st 5 days
      16 (17%) had fever of more than 39 degrees C
      Risk 2X for each unit drop in Hg; 4X for each unit of blood transfusion
      laboratory investigations only in the presence of positive physical findings
2. Examination
3. Laboratory Tests
   a. Erythrocyte sedimentation rate- not useful in early postop period [4,13]
      Peak occurs on 5th day (101.3 mm/h) and remains elevated for 6-9 months [2]
   b. C-reactive protein: peak occurs on 2nd postop day (26.02 mg/dl),[2, 13,14,26]
      Rising levels after 3rd postop day may indicate infection
      Requires preop CRP in patients with rheumatoid arthritis [9]
   c. Other Inflammatory Parameters [27]
      Interleukin-6: IL-6 serum concentration peaked 6 h postoperatively at maximum levels (399+/-140 pg/ml)with a mean half-life of 15 h with rapid return to normal. In comparison, postoperative CRP rose more slowly with maximum levels (138+/-54 mg/l) on 2nd day with a slow descent (mean half-life of 62 h).
4. Arthrocentesis: Culture and confirmation of diagnosis
5. Imaging studies: Not helpful in early postoperative period

IV. Treatment

1. Persistent Wound Drainage: Rest and immobilization. Avoid indiscriminate antibiotics as this predisposes toward multi-drug resistant infections, affects subsequent cultures, and may mask the symptoms for long enough that the window of opportunity is lost for debridement and prosthesis salvage.
   1) - 41 TKR and 37 THR followed mean 50 months 1 - 8 (10%) developed deep infection: all diagnosed within 6 months after surgery
   2) - 597 TKR: 8 with persistent drainage followed 4.3 years [25]
      - Wound debridement, arthrotomy, and irrigation at average of 12.5 days
      - 25% had positive joint culture but no subsequent deep infections
2. Debridement with Prosthesis Retention
   Treatment should be prompt and considered emergent once the diagnosis has been confirmed.20 Traditionally it has been believed that gram (+) organisms are a prerequisite for success however, at our clinic this has not been the case as many gram (-) organisms have been associated with a higher success rate than gram (+) organisms. Furthermore, the time spent with identification of the specific organism by culture techniques only delays appropriate surgical treatment. Debridement in less than 48 hours appears to be an important determinate of success with Staphylococcus aureus. [3]
   A. Open Debridement
      - Success possible in 50-75% of Type II and 50% of Type IV infections [15-18]
      - Success related to duration of symptoms (eg. S. aureus < 48 hours) [3]
      - Irrigation and debridement less successful for treatment of infections when used more than 2 weeks after the initial arthroplasty (20% vs. 60%). [21]
   B. Arthroscopic Debridement [23,24]
      - The primary problem is that when arthroscopic debridement fails (several weeks or months later), the

window of opportunity for a successful open debridement has been lost and the patient must undergo implant removal and reimplantation for cure.
- Associated with a much lower rate of success when compared with open debridement. [12,24]
16 TKR (4 EPOI / 12 AHI) with < or = 7 days of knee symptoms were treated by arthroscopic debridement. Only 6 of the 16 (38%) did not require prosthesis removal at 64 months follow-up. Two (13%) ultimately required an arthrodesis for persistent infection. Arthroscopic irrigation and debridement is indicated only under selected circumstances (medically unstable or anticoagulated patients).

VI. Future Directions
- Identification of more specific inflammatory parameters [27]
- Improved imaging studies and bacterial genetic detection technology for diagnosis [10]
- Staging systems for patient outcome with various treatment options [11]

REFERENCES

1. Abudu A, Sivardeen KA, Grimer RJ, et al: The outcome of perioperative wound infection after total hip and knee arthroplasty. Int Orthop 26:40-43, 2002.
2. Bilgen O, Atici T, Durak K, et al: C-reactive protein values and erythrocyte sedimentation rates after total hip and total knee arthroplasty. J Int Med Res 29:7-12, 2001.
3. Brandt CM, Sistrunk WW, Duffy MC, et al: Staphylococcus aureus prosthetic joint infection treated with debridement and prosthesis retention. Clin Infect Dis 24(5):914-919, 1997
4. Choudhry RR, Rice RP, Triffitt PD, Harper WM, Gregg PJ. Plasma viscosity and C-reactive protein after total hip and knee arthroplasty. J Bone Joint Surg, 74(B):523-524, 1992
5. Gordon SM, Culver DH, Simmons BP, Jarvis WR. Risk factors for wound infections after total knee arthroplasty. Am J Epidemiol 131:905-916, 1990
6. Hanssen AD. Managing the infected knee: as good as it gets. J Arthroplasty,17(4 Suppl 1):98-101, 2002
7. Hanssen AD, Osmon DR, Nelson CL: Prevention of deep periprosthetic infection. Instr Course Lect; 46:555-567, 1997
8. Kennedy JG, Rodgers WB, Zurakowski D, et al: Pyrexia after total knee replacement. A cause for concern? Am J Orthop 26:549-552, 1997
9. Laiho K, Maenpaa H, Kautiainen H, et al: Rise in serum C reactive protein after hip and knee arthroplasties in patients with rheumatoid arthritis. Ann Rheum Dis 60:275-277, 2001
10. Mariani BD, Martin DS, Levine MJ, Booth RE, Jr., et al.: The Coventry Award. Polymerase chain reaction detection of bacterial infection in total knee arthroplasty. Clin Orthop 331:11-22, 1996.
11. McPherson EJ, Tontz W Jr, Patzakis M, et al: Outcome of infected total knee utilizing a staging system for prosthetic joint infection. Am J Orthop 28:161-5, 1999
12. Mont MA, Waldman B, Banerjee C, et al: Multiple irrigation, debridement, and retention of components in infected total knee arthroplasty. J Arthroplasty 12:426-33,1997
13. Moreschini O, Greggi G, Giordano MC, et al: Postoperative physiopathological analysis of inflammatory parameters in patients undergoing hip or knee arthroplasty. Int J Tissue React 23:151-154, 2001
14. Niskanen RO, Korkala O, Pammo H. Serum C-reactive protein levels after total hip and knee arthroplasty. J Bone Joint Surg Br 78(3):431-433, 1996
15. Perry CR, Hulsey RE, Mann FA, et al: Treatment of acutely infected arthroplasies with incision, drainage, and local antibiotics delivered via an implantable pump. Clin Orthop 281:216-223, 1992
16. Rasul AT, Jr., Tsukayama D, Gustilo RB: Effect of time of onset and depth of infection on the outcome of total knee arthroplasty infections. Clin Orthop 273:98-104, 1991.
17. Schoifet SD, Morrey BF. Treatment of infection after total knee arthroplasty by debridement with retention of the components. J Bone Joint Surg Am 72(A):1383-1390, 1990
18. Segawa H, Tsukayama DT, Kyle RF, et al: Infection after total knee arthroplasty. A retrospective study of the treatment of eighty-one infections. J Bone Joint Surg Am 81(10):1434-1445, 1999
19. Shaw JA, Chung R. Febrile response after knee and hip arthroplasty. Clin Orthop 367:181-189, 1999
20. Tattevin P, Cremieux AC, Pottier P, et al: Prosthetic joint infection: when can prosthesis salvage be considered? Clin Infect Dis 29:292-295, 1999
21. Teeny SM, Dorr L, Murata G, Conaty P. Treatment of infected total knee arthroplasty. Irrigation and debridement versus two-stage reimplantation. J Arthroplasty 5:35-39, 1990
22. Trousdale RT, Hanssen AD. Infection after total knee arthroplasty. Instr Course Lect 50:409-414, 2001
23. Vidil A, Beaufils P. Arthroscopic treatment of hematogenous infected total knee arthroplasty: 5 cases. Rev Chir Orthop Reparatrice Appar Mot 88:493-500, 2002
24. Waldman BJ, Hostin E, Mont MA, Hungerford DS. Infected total knee arthroplasty treated by arthroscopic irrigation and debridement. J Arthroplasty 15:430-436, 2000
25. Weiss AP, Krackow KA. Persistent wound drainage after primary total knee arthroplasty. J Arthroplasty 8:285-289, 1993
26. White J, Kelly M, Dunsmuir R. C-reactive protein level after total hip and total knee replacement. J Bone Joint Surg 80(B):909-911, 1998
27. Wirtz DC, Heller KD, Miltner O, et al: Interleukin-6: a potential inflammatory marker after total joint replacement. Int Orthop 24:194-196, 2000

◆ CONTROVERSIAL ISSUES AND HOT TOPICS IN PRIMARY TOTAL KNEE REPLACEMENT (W)

Moderator: William J. Maloney, MD, St. Louis, MO (n)

The symposium will highlight the on the ongoing controversies as it related to the performance of primary total knee arthroplasty. With increasing frequency, patients are being educated as to the choices the surgeons have to make including the type of fixation, bearing surface, modularity of implants and surgical technique. This symposium will focus on those issues providing the attednee with up-to-date opinions on relative technical and material related issues.

I. Fixation for Primary Total Knee Replacement
   a. I Prefer Cemented Fixation – John J. Callaghan, MD, Iowa City, IA (a, b, c, e – DePuy)
   b. I Prefer Cementless Fixation – Leo A. Whiteside, MD, St. Louis, MO (a, b, c – Smith & Nephew)
   c. Panel Discussion

II. The Role of Posterior Cruciate Ligament in Total Knee Arthroplasty: Retain or Substitute
   a. Retain and Balance the Posterior Cruciate Ligament - Aaron G. Rosenberg, MD, Chicago, IL (a, c, d, e – Zimmer)
   b. Sacrifice and Substitute - Robert E. Booth, Jr., MD, Philadelphia, PA (a, c – Zimmer)
   c. Panel Discussion

III. Highly Cross-linked Polyethylene in the Knee: Pros and Cons
   a. Pros – Aaron A. Hofmann, MD, Salt Lake City, UT (e – Centerpulse, Zimmer)
   b. Cons – Daniel J. Berry, MD, Rochester, MN (a, c – DePuy)
   c. Panel Discussion

IV. Modular Tibial Base Plates
   a. Modularity on the Tibial Side is the Gold Standard – Aaron Rosenberg, MD, Chicago, IL (a, c, d, e – Zimmer)
   b. Considerations for Non-modular Base Plates – Arlen D. Hanssen, MD, Rochester, MN (a – Implex Corp., c – Zimmer)

V. The Patella in Knee Replacement
   a. Support for Patella Resurfacing – Paul F. Lachiewicz, MD, Chapel Hill, NC (a – Zimmer, Aircast, e – Zimmer)
   b. Support for the Unresurfaced Patella – Leo A. Whiteside, MD, St. Louis, MO (a, b, c – Smith & Nephew)
   c. Panel Discussion

VI. Mobile Bearing Tibial Platforms: Is There a Role?
   a. Why I use Fixed Bearing Tibias - J. David Blaha, MD, Ann Arbor, MI (a, b – DePuy, J&J, Zimmer, Smith & Nephew, Wright Medical Technology, Centerpulse, c – Wright Medical Technology, d – DePuy, J&J, Zimmer, Medtronic, Wright Medical Technology, e – Wright Medical Technology,)
   b. Why I Use Mobile Bearing Tibias – Douglas A. Dennis, MD, Denver, CO (a, c – DePuy, Zimmer)
   c. Panel Discussion

VII. Mini-Incisions for Total Knee Arthroplasty
   a. Why I Use Mini-Incision in Some Patients - Luke M. Vaughan, MD, Del Mar, CA (a, b, c, e – Zimmer)
   b. Why I Prefer a Convention Incision – Robert E. Booth, Jr., MD, Philadelphia, PA (a, c – Zimmer)
   c. Panel Discussion

CEMENTED FIXATION IN PRIMARY TKR

John J. Callaghan, MD

Benefits of cemented fixation in total knee replacement:
1. Stop in system (no need for "perfect" cuts).
2. Seal to particulate debris.
3. Less concern for early failure.
4. Long track record:

A. Total Condylar Knee
Rodriquez, Ranawat; Clin Orthop 388
20 yr f-u
220 knees
14 revisions:
– 7 aseptic loose
– 4 sepsis
– 3 fx
Survival 24 yr: 80%, 88%

B. Total Condylar Knee
Sulco, Clin Orthop 388
120 knees
– 8.3% revision
91% survival, 23 yr

C. Kinematic I TKR
Sextra, Berry, Rand; Clin Orthop 388
168 knees
15 yr f-u
13 rev:
– 1 fx
– 1 instab
– 3 asep loose
– 4 poly wear
– 4 pat loose
88% survival
106° flexion

D. AGC TKR
Ritter, Clin Orthop 388
4583 knees
Survivorship 15 yr 98%
– .18% fem, .46% tib, 4.2% patella
110° flexion

E. Mobile Bearing TKR (LCS)
Buechel et al, Clin Orthop 388
373 knees (10 to 20 yr)
97% 10 yr survival
83% 16 yr survival
1.8% osteolysis

F. LCS Rotating Platform
Callaghan et al, JBJS 82A
119 knees
9-12 yr f-u
No revisions
102° flexion

G. PFC CR
Fetzer, Callaghan et al; J Arthroplasty 2002
101 knees
9-12 yr f-u
110° flexion
No revision loosening
2% osteolysis

H. IB II
O'Rourke, Callaghan; JBJS 84A
145 mod, 31 all poly
Knee flexion 113°
5-8 yr f-u
No revision asep loose
Osteolysis 16%, no all poly

Cemented total knee works: Why change?

UNCEMENTED FIXATION IN TOTAL KNEE REPLACEMENT

Leo A. Whiteside, MD

Basic Principles of Cementless Fixation

Alignment was identified early in the history of total knee arthroplasty as an important issue in longevity. Moderate malalignment resulted in a severe increase in early and midterm failure rates. Although extramedullary alignment systems improved the quality of implant alignment, intramedullary alignment instruments were the first to virtually ensure correct alignment of femoral and tibial implants every time.

After alignment, rigidity of initial fixation is the most important feature to ensure pain-free function after arthroplasty. Several reported clinical series and laboratory studies suggest that rigid fixation can be achieved with press-fit techniques in total knee arthroplasty, but some bone-ingrowth total knee arthroplasty designs have not adequately addressed rigid fixation of the tibial component. Several early reports of bone-ingrowth total knee arthroplasty had inferior results because the tibial component had no stem, peg, or screw fixation, leading to implant migration and failure attributable to loosening.

An effective stem has been shown to greatly improve tibial component fixation. The cut upper surface of the prepared tibia has areas that are too weak to withstand the forces that are applied to the surface, and failure in compression is likely unless fixation is augmented. The upper tibial metaphysis does not have a peripheral cortex, so the tibial bone depends on the tibial stem to prevent the implant from sinking. An effective stem also reduces the shear and tensile loads at the bone-prosthesis interface. The effectiveness of compression or compaction of the tibial cancellous bone with an appropriately sized tibial metaphyseal stem has been shown, and probably was a major factor in the long-term success of fixation in our series.

Studies by Ryd et al. have shown initial migration within the first few months after total knee replacement that diminishes rapidly after the first 6 months with virtually no additional movement for years after. Ryd et al. also suggested that cemented components do not remain rigidly fixed to bone long-term. In a study of 27 cemented tibial components with a radiographically intact bone-cement interface, each was loose enough to move 0.2 to 1 mm at the bone-cement interface with provocative testing. Although bone-ingrowth tibial components migrate slightly more than cemented ones do initially, they also stabilize and do not sink progressively. Recent roentgen stereophotogrammetry analysis studies are finding progressive migration of cemented tibial components, whereas the bone-ingrowth components stabilize and cease migration.

Cementless Technique

The sequence of procedures is very important in any total knee replacement:

- First, the femoral surfaces are cut, followed by the tibial surfaces.
- Second, the osteophytes are removed.
- Third, the trials or spacers are inserted.
- Fourth, the ligaments are balanced.
- Fifth, the final components are inserted.

Intramedullary alignment instrumentation is used both on the femur and the tibia and the femoral cutting guides are applied to a single point of reference, set, and then not moved until all of the surfaces are prepared. Special effort is made to diverge the anterior and posterior flange surface cuts to achieve anterior and posterior press-fit. An important design feature of the femoral implant is that the anterior and posterior surfaces are parallel so that press-fit is achieved, but these surfaces do not bear axial load.

All femoral surface cuts are made first and then the tibial surface is exposed, the alignment rod is inserted, and the initial rough cut is made. The osteophytes then are removed, and the secondary tibial cutting guide is applied, so that a fine surface finish can be made on the upper surface of the tibia. After the surface has been cleaned of debris, the tibial trial is inserted and evaluated carefully for toggle without a stem. Surface pressure is applied in four quadrants and any visible motion is a sign of inadequate preparation of the tibial surface. Repeat surface cut is made if necessary to ensure perfectly flush fit of the tibial tray on the upper tibial surface. Any soft bone areas are bone grafted.

After the surfaces all have been prepared, the osteophytes are completely removed and the trials then are inserted. Ligament balancing is finished with the trials in place and then the trials are removed and the final components are inserted.

The tibial component always has a stem. The metaphyseal, grit blasted, titanium stem is used in most cases. It is press-fit into the tibial bone and the pegs finally are driven in until the tibial component fits tightly against the upper tibial surface. An important design feature of the tibial component is full porous coating on the under surface. This seals the under surface and prevents joint fluid access to the stem of the tibial component and down into the medullary canal of the tibia. The four screw holes are evaluated carefully to make sure that the implant is firmly seated in all four quadrants. Screws are then placed through the screw holes out to the diaphyseal cortical bone in all four quadrants.

The polyethylene component is inserted next. An important design feature is peripheral capture of the polyethylene component so that it is press-fit into the locking mechanism. As this implant bears load and imbibes water, it expands and achieves tighter fixation in the peripheral capture.

Finally, the femoral component is applied. The knee is flexed to approximately 110 degrees and the femoral component is hooked on so that the posterior flange engages the posterior surface of the bone. The anterior surface of the implant is tapped with a soft surface mallet, the component is guided into the correct position, and finally driven into place. A final check is made to ensure that the femoral component is firmly fixed and cannot be pulled off with manual pressure.

The patella usually is not resurfaced in this procedure, but that is dependent on the femoral component design. If the anterior femur is "patella friendly", then trimming the osteophytes and leaving the patella unresurfaced is good technique.

The Future

Sealing the interface between the metal and bone is an important part of porous-coating technology. A full porous coating that allows no ingress under the edges of the prosthesis is important to prevent cyst formation even in the face of low wear.

Screws still are important for holding the tibial component, although a tightly-fit stem also is an effective adjunct to fixation. A well-fixed polyethylene component locked with a circumferential locking mechanism helps prevent pressurization of the screw holes and late cyst formation. The next step in this technology will be to seal the interface between the polyethylene and metal so that the screw holes are not bathed in joint fluid, and the fluid pressure remains very low. Press-fit technique for the femoral component remains highly effective, with few failures reported in well designed total knee systems. Sintered titanium or cobalt chromium beads have been reliable in arthroplasty surgery.

Technique continues to be an extremely important issue in cementless fixation. The upper surface of the tibia requires a precise, secondary cut such that no detectable toggle is visible when a flat plate is applied. Central stem and peripheral screws also are necessary to control toggle, but only early in the healing process.

With current techniques and implant technology, a surgeon who is expert with cementless fixation can achieve high survivorship and excellent results for greater than 90 percent of cases.

BIBLIOGRAPHY

1. Bargren JH, Blaha JD, Freeman MA: Alignment in total knee arthroplasty. Correlated biomechanical and clinical observations. Clin Orthop 173:178-83, 1983
2. Bartel DL, Burstein AH, Santavicca EA, Insall JN: Performance of the tibial component in total knee replacement. J Bone Joint Surg 64A:1026-1033, 1982.
3. Buechel FF, Pappas MJ: New Jersey low contact stress knee replacement system. Ten-year evaluation of meniscal bearings. Orthop Clin North Am 20(2):147-177, 1989.
4. Hofmann AA, Wyatt RWB, Beck SW, Alpert J: Cementless total knee arthroplasty in patients over 65 years old. Clin Orthop 271:28-34, 1991.
5. Hungerford DS, Krackow KA: Total joint arthroplasty of the knee. Clin Orthop 192:23-33, 1985.
6. Insall JN, Binazzi R, Soudry M, Mestriner LA: Total knee arthroplasty. Clin Orthop 192:13-22, 1985.
7. Insall J, Scott WN, Ranawat CS: The total condylar knee prosthesis: A report of 220 cases. J Bone Joint Surg 61A:173-180, 1979.
8. Insall J, Tria AJ, Scott WN: The total condylar knee prosthesis: The first 5 years. Clin Orthop 145:68-77, 1979.
9. Li MG, Nilsson KG: The effect of the preoperative bone quality on the fixation of the tibial component in total knee arthroplasty. J Arthroplasty 15:744-53, 2000.
10. Lotke P, Ecker M: Influence of positioning of prosthesis in total knee replacement. J Bone Joint Surg 59A:77-79, 1977.
11. Miura H, Whiteside LA, Easley JC, Amador DD: Effects of screws and a sleeve on initial fixation in uncemented total knee tibial components. Clin Orthop 259:160-168, 1990.
12. Nelissen RGHH, Brand R, Rozing PM: Survivorship analysis in total condylar knee arthroplasty. J Bone Joint Surg 74A:383-389, 1992.
13. Ranawat CS, Flynn WF, Saddler S, Hansraj KK, Maynard MJ: Long-term results of the total condylar knee arthroplasty: a 15-year survivorship study. Clin Orthop 286:94-102, 1993.
14. Rand JA, Bryan RS, Chai EYS, Ilstrup DM: A Comparison of Cemented Versus Cementless Porous-Coated Anatomic Total Knee Arthroplasty. In Rand JA, Dorr, LD (eds) Total Arthroplasty of the Knee: Proceedings of the Knee Society, 1985-1986. Rockville, MD, Aspen Publishers 195-212, 1987.
15. Rorabeck C, Bourne R, Nott L: The cemented Kinematic-II and the non-cemented Porous-Coated Anatomic prostheses for total knee replacement. J Bone Joint Surg 70A:483-490, 1988.
16. Ryd L, Albrektsson B, Herberts P, Lindstrand A, Selvik G: Micromotion of noncemented Freeman-Samuelson knee prostheses in gonarthrosis. Clin Orthop 229:205-212, 1988.
17. Ryd L, Lindstrand A, Rosenquist R, Selvik G: Micromotion of conventionally cemented all-polyethylene tibial components in total knee replacements. Arch Orthop Traum Surg 106:82-88, 1987.
18. Ryd L, Lindstrand A, Stenstrom A, Selvik G: Porous coated anatomic tricompartmental tibial components. The relationship between prosthetic position and micromotion. Clin Orthop 251:189-97, 1990.
19. Volz RG, Nisbet J, Lee R, McMurtry M: The mechanical stability of various noncemented tibial components. Clin Orthop 226:38-42, 1988.
20. Whiteside LA: Long-term followup of the bone-ingrowth Ortholoc knee system without a metal-backed patella. Clin Orthop 388:77-84, 2001
21. Whiteside LA: Use of four screws for fixation of the tibial tray in cementless total knee arthroplasty. Clin Orthop 299:72-76, 1994.
22. Whiteside LA, Pafford J: Load transfer characteristics of non-cemented total knee replacement. Clin Orthop 239:168-177, 1989.
23. Yoshii I, Whiteside LA, Easley JC, Amador DD: The effect of central stem and stem length on micromovement of the tibial tray. J Arthroplasty 7(Suppl):433-438, 1992.

RETAIN AND BALANCE THE POSTERIOR CRUCIATE LIGAMENT

Aaron G. Rosenberg, MD

The controversy over PCL retention versus substitution is a long and hallowed one. The debate continues because no side has the bulk of evidence in its favor.

Kinematics

By preserving the posterior cruciate ligament (PCL), femoral rollback may be preserved and guided.. Using 3-D kinematic assessment during step-up with fluoroscopic measurement, Banks et. al. found that a group of total knee replacements with intact posterior cruciate ligaments had essentially a normal axial rotation and condylar translation while those with a post-cam substitution and no posterior cruciate ligament had the smallest kinematic range of rotation and translation.

More recent work by Komistek, Dennis and Steihl evaluated rollback of the femur on the tibia in PS and CR knees using digital analysis of video fluoroscopy of in vivo knee performance in flexion. The earliest studies showed a consistent pattern of paradoxical anterior translation of the femur on the tibia in all of the PCL retained knees studied. Specifics of patient function and CR retaining knee design were not described. More recently the same group studied an unselected group of CR TKA patients using a specific design of implant, specific instrumentation and specific technique to adjust PCL tension performed by a single experienced PCL retaining TKA surgeon. Remarkably, in this group of 20 patients all but 1 demonstrated essentially normal roll back patterns! Indeed recent review of patients with the AMK implant- a matched group of PS and CR knees with a similar design, in responding to a detailed questionnaire regarding functional activities, demonstrated a large (and highly significant) difference with the CR patients having more comfort with activities requiring deeper flexion motions

Additional benefits of PCL preservation are that when the posterior cruciate ligament is preserved, it resists posterior subluxation forces and serves as a secondary stabilizer, resisting varus /valgus instability. The absorption of these forces into the ligament will protect the fixation interface from additional stress and prolong long-term fixation.

Another advantage of posterior cruciate ligament conserving knees is that this design of prosthesis tends to conserve more bone. The femoral bone is conserved because there is no notch necessary for the spine-cam articulation. Tibial bone is conserved because no central stem is needed for cruciate retaining knees in a manner similar to the stem needed for posterior cruciate ligament substituting knees.

One problem that has existed with posterior cruciate ligament substituting knees is an elevation of the joint line. This is found to be as much as 12mm in posterior cruciate ligament substituting condylar knee replacements. This elevated joint line significantly changes knee kinematics and has been correlated with patello-femoral symptoms and need for revision. Retention of the PCL requires strict maintenance of the joint line and so rarely is joint line elevation a problem in the PCL retaining TKA.

Prosthesis design is extremely important for success with total knee arthroplasty. In posterior cruciate ligament preserving designs, it is clear that the femoral component contours provide for optimal kinematic restoration. This requires not only an anatomic shape of the femoral component, but also a significant number of sizes so that the anterior/posterior dimension of the femur is not changed from what the ligaments are normally used to seeing. For a system to be successful in preserving the posterior cruciate ligament, at least six and preferably eight sizes of femoral components should exist. This size range allows for accurate reconstitution of the size of the distal femur.

To reproduce the normal femoral rollback, the geometry of the femoral component needs to reproduce that of the normal femur. To accomplish this in the most satisfactory method, the medial and lateral condyles should have a different radius of curvature. In the normal unreplaced knee, the lateral femoral condyle has a larger radius of curvature than the media side. This difference in radius of curvatures alone causes a differential rollback and this is very desirable in maintaining the quadriceps lever arm and the function of the knee after replacement. Thus, femoral component design should optimally contain a different radius of curvature for the lateral condyle than the medial condyle and be available in multiple sizes. This has been born out in the recent Gait studies of Bertin, Dennis and Komistek.

Tibial component design and posterior slope also affect the function and success of posterior cruciate ligament preserving knee replacement. The tibial articulation must be designed to be compatible with normal femoral rollback. Thus in the saggital plane, a minimally conforming shape should exist to allow the femur to roll back on the tibia. This slightly flattened design in the sagittal plane takes advantage of the retained ligament and allows the kinematics (rollback and rotation) to be as close to normal as possible. At the same time, significant congruence in the frontal plane allows the stresses in the polyethylene to be minimized and long-term wear to be less of an issue. In the process of implanting a tibial component, the posterior slope of the articulation must be considered. If the prosthesis is designed to be inserted with a posterior inclination to the plane of resection, this must be surgically performed. Most tibial components are designed in this fashion. If this posterior slope is not reestablished, the posterior aspect of the tibial component will be placed too far proximal. This will result in excessive tightness in the posterior cruciate ligament during flexion. This causes excessive rollback and high pressure in the posterior part of the tibial articulation. Polyethylene wear may be increased and range of motion can also be limited. Both of these situations are undesirable and can be eliminated by reproducing the normal tibial slope.

Soft Tissue Balancing

During posterior cruciate ligament preservation It's important to achieve appropriate tension in the P.C.L. Therefore during the trial reduction, after preparing the femur and tibia with preservation of the posterior cruciate ligament, the surgeon must look for signs of the ligament either being too loose or too tight. If the ligament is too loose, a thicker tibial articulating surface may be necessary.

Some severe deformities may require a release of the posterior cruciate ligament. In these situations, the posterior cruciate ligament can be recessed from its tibial insertion and the patient's subjective and objective results not compromised. Worland found that even the KT-1000 results with posterior cruciate ligament recession were acceptable at follow up. The advantage of

this approach is that the patient's joint line is not changed and the rest of the knee kinematics are preserved. Excessive tightness of the posterior cruciate ligament can be determined during the trial reduction if the knee is excessively tight in flexion and the knee has appropriate tightness in extension, the PCL is too tight. This tightness in flexion is evidenced by either the anterior trial base plate lifting off from the tibial cut or from the tibio-femoral articulation occurring too far posteriorly with flexion. This hinging appearance to the tibio-femoral articulation indicates excessive tightness of the PCL. The PCL can also be palpated directly during the trial reduction and it's tension assessed. If with these methods of evaluation the posterior cruciate ligament is found to be too tight, the tibia can be subluxated in front of the femur and the posterior cruciate ligament insertion released subperiosteally off from the tibia. If a complete release of the posterior cruciate ligament is necessary, the surgeon has three options. The surgeon could use a standard cruciate retaining articulation, but this would probably be less desirable. The second option is to use a prosthesis that is more congruent in the sagittal plane. This would be an anterior constrained or ultra congruent plastic. The third option is to convert to a posterior stabilized prosthesis. The surgeon should assess the anterior-posterior stability thoroughly at this point and select the most appropriate prosthesis.

The concept of simply resurfacing the joint and maintaining as much of the native (healthy?) structure as possible is a philosophically appealing one. However, retention of the PCL requires understanding of the differences required in patient selection, surgical technique and component design required for succesful performance of this procedure.

In cases where the ligament is a part of the ligament contracture pathology (generally moderate or severe sagittal plane alignment abnormalities combined with flexion contracture) and in the revision setting, PCL substitution seems the most reasonable alternative. Additional settings in which PS substitution are appropriate include the patellectomized knee, and the knee with severe inflammatory changes which have affected the integrity of the ligament itself.

In situations where the surgeons wishes to convert to PS substituting during the operation several considerations must be kept in mind. The most serious potential complication in cconverting to a PS knee is instability. This may occur from a combination of factors that produce a well functioning CR knee but may sabotage the surgeon converting to a PS. These factors include the posterior tibial slope and the general principle of downsizing the femoral component when between sizes. Combined with a relative flexion collateral ligament instability this may result in an underfilled flexion gap and with flexion and varus or valgus stress (depending on the side of collateral instability) the psot may slip under the cam. In converting midstream between the CR to the PS the surgeon must keep this in mind.

REFERENCES

1. Aglietti P, Buzzi R, Gandenzi A: Patello-femoral functional results and complications with PS total condylar knee prosthesis. J Arthroplasty 3:17, 1988.
2. Andriacchi, T.R. and Galante, J.O.: Retention of the posterior cruciate in TKA. J Arthroplasty Vol. 3, Supplement:S13-S19, 1988.
3. Andriacchi, T.R., Galante, J.O. and Fermier, R.W.: The influence of TKR design on walking and stairclimbing. J Bone Joint Surg 64A:1328, 1982.
4. Banks SA, Markovich GD, Hodge WA: In vivo Kinematics of cruciate-retaining and substituting knee arthroplasties. J Arthroplasty 12:297-304, 1997.
5. Bertin KC, Komistek RD, Dennis DA, Hoff WA, Anderson DT, Langer T. "In vivo determination of posterior femoral rollback for subjects having a NexGen posterior cruciate - retaining total knee arthroplasty". JoA 2002
6. Dorr L, Gronley J, Perry J: Functional comparison of posterior cruciate retained versus cruciate-sacrificed TKA. CORR 236:36, 1988.
7. Heck DA, Reuben JD, Stiehl JB, et al: Knee prosthetic design and reoperation. AAOS 65th Annual Meeting, March 19-23, 1998.
8. Kleinbart FA, Bryk E, Scott WN et al: Histologic comparison of PCLs from arthritic and age-matched knee specimens. J Arthroplasty 11:726-731, 1996.
9. Li E and Ritter MA: Total knee arthroplasty, point-counter point. J Arthroplasty 10:560, 1995.
10. Rand JA, Illstrup DM: Survivorship analysis of TKA -- cumulative rates of survival of 9200 total knee arthroplasties. J Bone Joint Surg 73A (3):397-409, 1991.
11. Scott RD, Volatile TB: Twelve years experience with posterior cruciate-retaining TKA. CORR 205: 100, 1986.
12. Shoji H et al: Cruciate retaining and excised TKA. Clin Orthop 305:218, 1994.
13. Sondry M., Walker PS, Reilly DT et al: The effects of TKR design on femoral-tibial contact conditions. J Arthroplasty 1:35, 1986.
14. Sorger, Grood, et al: The posterior cruciate ligament in TKR. J Arthroplasty 12:869-879, 1997.
15. Sorrell R, Fennign J, Davenport J: Comparison of the clinical results & survivorship of non-cemented cruciate sacrificing versus cruciate sparing TKR. AAOS Annual Meeting, San Francisco 1993.
16. Soudry J, Walker P, Reilly D, et al: Effort of TKR design on femoral-tibial contact conditions. J Arthroplasty 1:35, 1986.
17. Warren PS et al: Proprioception after knee arthroplasty. Clin Orthop 297:182, 1993.
18. Worland RL, Jessup DE, Johnson J: Posterior cruciate recession in TKA. J Arthroplasty 12:70-73, 1997.

THE ROLE OF POSTERIOR CRUCIATE…SACRIFICE AND SUBSTITUTE

Robert E. Booth, Jr., MD

FACT : PS TKA ROM greater than CR in majority of studies, internal and external to industry.

FACT: PS TKA stability greater – PS dislocation rate 0.15% vs. 100% subluxation with CR.

FACT: PS TKA survival rates equal or greater in all series. Best long-term survival.

FACT: PS TKA success rates greater in combined deformities over 20∞. Handles a wider and more difficult range of problems.

FACT: PCL preservation does not provide better proprioception in CR TKA's.

FACT: Shallow trochlear box minimizes femoral bone loss in PS TKA, while CR design mandates greater tibial bone resection.

FACT: CR & PS designs now both accommodate patellar non-resurfacing.

FACT: PS TKA has 3 times greater (3mm. vs. 9mm) accommodation of joint line alteration than CR.

FACT: PS TKA has greater simplicity and success, especially for lower volume surgeons.

FACT: PS TKA has superior and consistent kinematic design, not altered annually in response to instability and osteolysis like CR TKA.

FACT: PS TKA has consistent and predictable rollback, unlike CR TKA, which minimizes poly wear.

FACT: PS TKA, despite early reports, now confirmed to have equal gait and stair climbing results.

FACT: PS TKA mid-range laxity is less troublesome than CR mid-range stiffness.

FACT: PS TKA now fastest-rising design, soon to overtake CR nationally and worldwide.

CONCLUSION:

PS TKA is easier, more reliable, longer lasting, more stable, and more mobile than CR-TKA fixed bearing designs. Why would you not use a PS-TKA???

CROSSLINKED VS CONVENTIONAL PE IN TOTAL KNEE ARTHROPLASTY

Daniel J. Berry, MD

I. Introduction
- A. All agree that as TKA use has increased in younger more active patients that the interconnected problems of PE wear and lysis have become much bigger problems.
- B. Therefore, gaining a better bearing surface is desirable.

II. Conventional PE (Gamma radiated, inert/barrier packaged)
- A. Pros: Modest crosslinking level
  No shelf oxidation
  Favorable track record to date
  Intact mechanical properties at implantation
- B. Cons: Not cross linked enough to maximize wear characteristics
  Potential for oxidation in the body after implantation (likely a fairly slow process)

III. Cross Linked PE (Intermediate Radiation Dose)
- A. Pros: 1. Potential for better wear characteristics
  2. No potential for oxidation (if fully quenched product), ie. melt annealed
- B. Cons: 1. No clinical track record at all
  2. Knee simulator data though encouraging are very rudimentary at present. We don't know if they will accurately predict wear.
  3. Mechanical properties of cross-linked PE are reduced (due to crosslinking)
  4. Reduced mechanical properties create several potential problems that are especially important in the knee, because due to knee kinematics, bearing surface loads are much higher in the knee than the hip.
     - potential for fracture of PE
     - potential for PE wear due to subsurface mechanical failure leading to pitting/delamination. This is different wear mode than that which is protected by crosslinked PE (i.e. adhesive/abrasive wear).
     - potential for locking mechanism failure of modular tibial PE if mechanical PE strength poorer

IV. Bottom Line
- A. Cross-linked PE does have potential in the knee
- B. But it is unproven and risks are probably higher than in the hip
- C. Await data before widespread unrestrained use.

MODULAR TIBIAL BASE PLATES: MODULARITY ON THE TIBIAL SIDE IS THE GOLD STANDARD

Aaron Rosenberg, MD

Modularity in tibial base plates serves 3 basic purposes. The first purpose is to help control inventory. 2,3 If all of the possible tibial components in a knee system came in all of the sizes and potential configurations as separate mono-block components (particularly if metal backed) inventory costs would be substantially higher than they currently are. This might prohibit the manufacturer from providing the range of options available to the reconstructive surgeon or would increase the cost substantially. It might also lead to increased shelf life for the plastic as larger inventory would be expected to cycle over larger periods of time.

This second is surgeon convenience and improved intra-operative flexibility. Modularity allows the surgeon to change course in mid-stream. If the knee exam changes after the tibial base plate is inserted the surgeon still retains the ability to modify the tibial aspect of the articulation. Modularity also allows access to the posterior aspects of the knee following component cementing and makes cement removal simpler.

Third is the ability of the surgeon to replace a worn bearing with a new bearing without removal of a well fixed tibial component. Every experienced knee surgeon has some cases where this modularity has allowed simple revision without the need to remove an otherwise well functioning implant. While not always effectivem in the right circumstance this ability can be helpful .6,3

Of course modularity also adds the potential for serious complications and many of these have been the source of catastrophic early failures in multiple different knee systems. 7,8,9, 10, 11 Problems with modularity include inadequate polyethylene locking mechanisms with back-surface micro-motion, and locking mechanisms which generated substantial wear particles apart from the specific interactions with the polyethylene.1,4,5,12 Fortunately most manufacturers are well aware of the isues involved and modern modular components are generally engineered so as to minimize these problems.

REFERENCES

1. Ash HE, Scholes SC, Parkin R, Unsworth A. Relative movements between Kinemax Plus tibial inserts and the tibial base-plates. Proc Inst Mech Eng [H].;217(2):99-104, 2003
2. Barrack RL. Modularity of Prosthetic Implants.J Am Acad Orthop Surg. Jan;2(1):16-25, 1994
3. Berend, M, Ritter, MA, Engh, GA, Rao AR,Collier, MB, Morrey BF, Babis, GC and Trousdale, RTThe Pros and Cons of Modularity in Total Knee Replacements J Bone and Joint Surg 84(A):1480-1481, 2002
4. Brassard MF, Insall JN, Scuderi GR, Colizza W.Does modularity affect clinical success? A comparison with a minimum 10-year followup. Clin Orthop. Jul;(388):26-32, 2001
5. Engh, GA, Lounice S, Rao AR, Colliuer MB. In Vivo Deterioration of Tibial Baseplate Locking Mechansim in Contemporary Modular Total Knee Components J Bone and Joint Surg :83A:11 1660 – 1665, 2001
6. George C. Babis, MD, Robert T. Trousdale, MD and Bernard F. Morrey, MD The Effectiveness of Isolated Tibial Insert Exchange in Revision Total Knee Arthroplasty J Bone and Joint Surg 84(A):64-68, 2001
7. Minntz L, Tsao AK, McCrae CR, Stulberg SD, Wright T.The arthroscopic evaluation and characteristics of severe polyethylene wear in total knee arthroplasty.Clin Orthop. Dec;(273):215-22, 1991
8. Peters PC Jr, Engh GA, Dwyer KA, Vinh TN.Osteolysis after total knee arthroplasty without cement. J Bone Joint Surg Am. Jul;74(6):864-76, 1992
9. Shirazi-Adl A, Ahmed AM. A parametric axisymmetric model study on the interface motions in porous-surfaced tibial implants.Ann Biomed Eng. 17(4):411-21, 1989
10. Wasielewski RC, Parks N, Williams I, Surprenant H, Collier JP, Engh G.Tibial insert undersurface as a contributing source of polyethylene wear debris. Clin Orthop. Dec;(345):53-9, 1997
11. Weber AB, Worland RL, Keenan J, Van Bowen J.A study of polyethylene and modularity issues in >1000 posterior cruciate-retaining knees at 5 to 11 years. : J ArthroplastyDec;17(8):987-91, 2002
12. Yoshiya S, Kurosaka M, Akisue T, Yamaguchi M, Bauer TW, Takikawa S, Schils JP,. "Backside" polyethylene deformation in total knee arthroplasty J Arthroplasty. 2003 Sep;18(6):784-91.

MONOBLOCK TIBIAL COMPONENTS

Arlen D. Hanssen, MD

Total knee replacement (TKR) is one of the most successful reconstructive procedures in orthopedic surgery. Although TKR was originally reserved for more elderly and sedentary individuals, the inclusion criteria for TKR have progressively widened. Currently, wear debris related osteolysis and associated prosthetic loosening are predominant concerns of TKR.[7,12] Initially, tibial components were all polyethylene monoblock constructs. During this time frame, currently accepted principles and surgical techniques were not routinely accomplished. Long-term follow-up studies of these implants have demonstrated excellent durability in survivorship studies. Aseptic loosening of the tibial component was one of the causes of failure in these implants. Polyethylene wear and osteolysis were rarely observed.

Metal-backed nonmodular tibial components were subsequently introduced to allow for improved tibial load distribution and to protect osteoporotic bone. Long-term studies have established that the one-piece nonmodular tibial component maintains excellent durability. Eventually, modularity between the polyethylene tibial component and the metal-backed tray was introduced in the mid-80s to facilitate intraoperative versatility by interchange of various polyethylene thicknesses, and to add stems or wedges. Other advantages included the reduction of inventory, use of screw augmentation for cementless implants, and the potential of isolated tibial polyethylene exchanges as a subsequent revision procedure. At the same time of modularity introduction, the interest in cementless fixation of prosthetic components was intensified. Since the late 1980's, the phenomena of polyethylene wear and osteolysis has been observed much more frequently when compared with earlier observations. The reasons for this increased prevalence of synovitis, progressive osteolysis, and severe polyethylene wear remain unclear.

Some of the etiologies of increased polyethylene wear and osteolysis include:

- the young age, gender, weight and activity level of patients
- polyethylene quality (resin, manufacturing, sterilization, and shelf-life)
- articular geometry and conformity of tibial surface (CR vs. PS)
- thickness of the polyethylene insert
- modularity (type and quality of locking mechanism) [7]

Based on the literature, it is difficult to separate out the independent effect of these variables.

For example, many early cementless designs with high failure rates were plagued by the associated variables of thin polyethylene, variation in polyethylene manufacturing processes, preferential insertion of cementless implants in younger and more active patients, and the eventual failures of metal-backed patellar components. Currently, the issues of polyethylene manufacturing and sterilization, minimum polyethylene thickness, and articular surface geometry have been addressed intensively in modern TKR prosthetic designs. Despite these changes, it is a commonly held perception that wear and osteolysis are significant concerns. [7,12,20,26]

All Polyethylene Monoblock

Author	# Knees	Implant	Age	FU(yr)	Survival	Revision	Loosening	Osteolysis
Font-Rodriguez [9]	265	IB1			94.1-16yr			
Pagnano [17]	81	TC	79 (75-89)	14	98%-14yr		100%-14 yr	none
Pavone [18]	34	TC	78 (53-94)	23	91%-23yr			none
O'Rourke [16]	31	IB2	76 (69-85)	6.4		100%-7yr		none
Rodriguez [23]	54	TC	65 (31-88)	20	77%-21yr		85%-21yr	none
Rodriguez [22]	130	PFC	70 (27-88)	5.5	99%-7yr			none

Metal-Backed Monoblock

Author	# Knees	Implant	Age	FU(yr)	Survival	Revision	Loosening	Osteolysis
Ansari [1]	445	KC			96%-10yr	2.5%		
Brassard [4]	159	IB2			96.4-11yr			
Diduch [5]	114	IB1	51 (21-55)		87%-18yr	94%-18yr		
Font-Rodriguez [9]	2036	IB1&2			98.1-14yr			
Keating [13,21]	4583	AGC	70.4 (19-83)		98%-15yr			
Sextro [25]	168	KC	65.2 (21-88)	15.7	88.7%-15yr			
Weber [27]	698	AGC	71.1	6.3		1.4%		0.1%

Metal-Backed Modular

Author	# Knees	Implant	Age	FU(yr)	Survival	Revision	Loosening	Osteolysis
Berger [3]	172	MG1	70 (31-88)	11	84%-10yr			
Berger [3]	109	MG2	72 (54-90)	7.5	100%-10yr			
Brassard [4]	154	IB2			98.1%-11yr			
Fetzer [8]	101	PFC	71 (52-89)	10.5	93%-12yr			
Font-Rodriguez [9]	49	IB1 &2			93.6%-10yr			
Hoffman [11]	176	Natural	65		93.4%-10yr			
Li [10]	94	IB2		10	92.3%-10yr			
Mikulak [15]	557	PFC		5	96%-5yr			
O'Rourke [16]	145	IB2	69 (49-84)	6.4	94.3%-7yr			16%
Rodriguez [22]	113	PFC	70 (27-88)	5.5	75%-7yr			5%
Schai [24]	235	PFC	68 (22-89)	10.5	90%-10yr	92%-10yr		
Weber [27]	353	AGC	67.9	5.5		3.1%		1.7%

Mayo Clinic Series [19]
11,606 primary TKR (Jan 1978-Dec 2000)
10-yr Survivorship
All-polyethylene tibial component
97% (95% CI, 94% -99%)

Nonmodular metal-backed tibial component
92% (95% CI, 90% -93%)
Modular metal-backed tibial component
90% (95% CI, 89% -91%)

There was a significant difference in survivorship between the prostheses with a nonmodular metal-backed tibial component and those with a modular metal-backed tibial component ($p < 0.0001$) but not between the implants with either nonmodular metal-backed tibial design and those with the all-polyethylene tibial component.

Modularity at Revision TKR

Recently, several studies have revealed that the effectiveness of isolated tibial insert exchange in revision TKR is of limited value. Isolated tibial insert exchange led to a surprisingly high rate of early failure. Tibial insert exchange as an isolated method of total knee revision should therefore be undertaken with caution even in circumstances for which the modular insert was designed and believed to be of greatest value.2 An isolated revision of the tibial polyethylene insert should not be performed when there is accelerated wear of the insert with severe delamination and grade-3 or 4 undersurface wear within ten years after the primary procedure. Because a variety of patient-related, implant-related, and technical factors influence polyethylene wear, the orthopaedist must consider multiple variables whenever contemplating a limited revision. [2,6]

REFERENCES

1. Ansari S, Ackroyd CE, Newman JH. Kinematic posterior cruciate ligament-retaining total knee replacements. A 10-year survivorship study of 445 arthroplasties. Am J Knee Surg. 1998 Winter;11(1):9-14.
2. Babis GC, Trousdale RT, Morrey BF.The effectiveness of isolated tibial insert exchange in revision total knee arthroplasty. J Bone Joint Surg Am. 2002 Jan;84-A(1):64-8
3. Berger RA, Rosenberg AG, Barden RM, Sheinkop MB, Jacobs JJ, Galante JO.Long-term followup of the Miller-Galante total knee replacement. Clin Orthop. 2001 Jul;(388):58-67.
4. Brassard MF, Insall JN, Scuderi GR, Colizza W.Does modularity affect clinical success? A comparison with a minimum 10-year followup. Clin Orthop. 2001 Jul;(388):26-32.
5. Diduch DR, Insall JN, Scott WN, Scuderi GR, Font-Rodriguez D.Total knee replacement in young, active patients. Long-term follow-up and functional outcome. J Bone Joint Surg Am. 1997 Apr;79(4):575-82.
6. Engh GA, Koralewicz LM, Pereles TR.Clinical results of modular polyethylene insert exchange with retention of total knee arthroplasty components. J Bone Joint Surg Am. 2000 Apr;82(4):516-23.
7. Engh GA, Lounici S, Rao AR, Collier MB.In vivo deterioration of tibial baseplate locking mechanisms in contemporary modular total knee components. J Bone Joint Surg Am. 2001 Nov;83-A(11):1660-5.
8. Fetzer GB, Callaghan JJ, Templeton JE, Goetz DD, Sullivan PM, Kelley SS.Posterior cruciate-retaining modular total knee arthroplasty: a 9- to 12-year follow-up investigation. J Arthroplasty. 2002 Dec;17(8):961-6.
9. Font-Rodriguez DE, Scuderi GR, Insall JN.Survivorship of cemented total knee arthroplasty. Clin Orthop. 1997 Dec;(345):79-86.
10. Forster MC.Survival analysis of primary cemented total knee arthroplasty: which designs last? J Arthroplasty. 2003 Apr;18(3):265-70
11. Hofmann AA, Evanich JD, Ferguson RP, Camargo MP.Ten- to 14-year clinical followup of the cementless Natural Knee system. Clin Orthop. 2001 Jul;(388):85-94.
12. Huang CH, Ma HM, Liau JJ, Ho FY, Cheng CK.Osteolysis in failed total knee arthroplasty: a comparison of mobile-bearing and fixed-bearing knees. J Bone Joint Surg Am. 2002 Dec;84-A(12):2224-9.
13. Keating EM, Meding JB, Faris PM, Ritter MA.Long-term followup of nonmodular total knee replacements. Clin Orthop. 2002 Nov;(404):34-9.
14. Li PL, Zamora J, Bentley G.The results at ten years of the Insall-Burstein II total knee replacement. Clinical, radiological and survivorship studies. J Bone Joint Surg Br. 1999 Jul;81(4):647-53.
15. Mikulak SA, Mahoney OM, dela Rosa MA, Schmalzried TP. Loosening and osteolysis with the press-fit condylar posterior-cruciate-substituting total knee replacement. J Bone Joint Surg Am. 2001 Mar;83-A(3):398-403.
16. O'Rourke MR, Callaghan JJ, Goetz DD, Sullivan PM, Johnston RC. Osteolysis associated with a cemented modular posterior-cruciate-substituting total knee design : five to eight-year follow-up. J Bone Joint Surg Am. 2002 Aug;84-A(8):1362-71.
17. Pagnano MW, Levy BA, Berry DJ. Cemented all polyethylene tibial components in patients age 75 years and older. Clin Orthop. 1999 Oct;(367):73-80.
18. Pavone V, Boettner F, Fickert S, Sculco TP. Total condylar knee arthroplasty: a long-term followup. Clin Orthop. 2001 Jul;(388):18-25.
19. Rand JA, Trousdale RT, Ilstrup DM, Harmsen WS. Factors affecting the durability of primary total knee prostheses. J Bone Joint Surg Am. 2003 Feb;85-A(2):259-65.
20. Rao AR, Engh GA, Collier MB, Lounici S. Tibial interface wear in retrieved total knee components and correlations with modular insert motion. J Bone Joint Surg Am. 2002 Oct;84-A(10):1849-55.
21. Ritter MA, Berend ME, Meding JB, Keating EM, Faris PM, Crites BM. Long-term followup of anatomic graduated components posterior cruciate-retaining total knee replacement. Clin Orthop. 2001 Jul;(388):51-7.
22. Rodriguez JA, Baez N, Rasquinha V, Ranawat CS. Metal-backed and all-polyethylene tibial components in total knee replacement. Clin Orthop. 2001 Nov;(392):174-83.
23. Rodriguez JA, Bhende H, Ranawat CS: Total Condylar Knee Replacement: A Twenty Year Follow-up. Clin Orthop. 2001 Nov;(388): 10-17.
24. Schai PA, Thornhill TS, Scott RD. Total knee arthroplasty with the PFC system. Results at a minimum of ten years and survivorship analysis. J Bone Joint Surg Br. 1998 Sep;80(5):850-8.
25. Sextro GS, Berry DJ, Rand JA.Total knee arthroplasty using cruciate-retaining kinematic condylar prosthesis. Clin Orthop. 2001 Jul;(388):33-40.
26. Surace MF, Berzins A, Urban RM, Jacobs JJ, Berger RA, Natarajan RN, Andriacchi TP, Galante JO.Coventry Award paper. Backsurface wear and deformation in polyethylene tibial inserts retrieved postmortem. Clin Orthop. 2002 Nov;(404):14-23.
27. Weber AB, Worland RL, Keenan J, Van Bowen J. A study of polyethylene and modularity issues in >1000 posterior cruciate-retaining knees at 5 to 11 years. J Arthroplasty. 2002 Dec;17(8):987-91

SUPPORT FOR ROUTINE PATELLA RESURFACING

Paul F. Lachiewicz, MD

Routine Patella Resurfacing?
Why are we asking the question again in 2004?
- Too many complications after resurfacing ?
  fracture, pain, clunk, etc.
- High rate of failure and reoperation with metal-backed patella in late 1980's - early 1990's
- Increasing frequency of patients "demanding" uni's and MIS
- Faster procedure without resurfacing?
- Are the results of knees without resurfacing really as good as with resurfacing ?

Data for Resurfacing
- Selective resurfacing studies
- Bilateral knee studies
- Randomized clinical studies
- National registry

Analysis of Studies
- Type of components
- Technique of resurfacing
- Follow-up time

No Resurfacing
Picetti et al JBJS 1990
- 100 total condylar knees
- 29% patellofemoral pain at 4.5 yr mean f/u
  *Resurface: all rheumatoid knees;
  Osteoarthritic knees: with preop patella pain, weight > 60 kg, height > 5'3", advanced changes of patella

Selective Resurfacing
Kim, Scott Clin Orthop 1999
- 30 selected PFC® knees
- Patella friendly trochlea
- 20% mild-mod. ant. knee pain
- 2.5% resurfacing at 10 years

Complications with or without Resurfacing
Boyd et al JBJS 1993
- 396 knees with resurfacing
  495 without resurfacing
- Retrospective
- PCL retaining, single-peg dome
- 6.4 year mean follow-up

Patella Complications
Boyd et al JBJS 1993
- Resurfacing 4% (loosening 1%)
- No resurfacing 12% (revision to resurface 10%)
- Higher rate of post-op pain in nonresurfaced knees

Bilateral TKR Studies
- Ennis Townley
  resurfacing better
- Shoji TCP, rheumatoid
  no difference
- Keblish LCS
  no difference at 5 yrs
- Barrack MG-II
  excluded knees with deformity
  no difference pain, function
  10% reoperation-resurfacing

Randomized Clinical Trials
Barrack et al JBJS 2001
- MG-II knee
- 102 knees; 5-7 yr f/u
- No difference in pain, function
- 12% reoperation-resurfacing

Randomized Clinical Trials
Wood et al JBJS 2002
- MG-II knee
- 220 knees; 4 yr f/u
- No difference in revision
- Higher prevalence of anterior pain without resurfacing

Randomized Clinical Trials
Bourne et al 1995, 2003
- AMK knee
- 100 patients; all DJD
- Mean 6.3 yr f/u
- More patients satisfied with (80%) than without resurfacing (48%)
- More revisions without resurfacing (12% vs 4%)

Summary
Randomized Clinical Trials
- 471 knees; 5 studies
- Revisions (all) nonresurfaced 24%, resurfaced 11%
- Revisions (p-f) nonresurfaced 11%, resurfaced 5%

National Registry
Swedish TKR Registry
- 27,372 knees 1981-1995
- Higher rate of high patient satisfaction with resurfacing ($p<.001$)
- Females; both DJD and RA

U.S.A. – TKR Registry
Does not yet exist
- Large numbers of patients, wide variety of designs
- Could possibly determine the "ideal" patient and implant for non-resurfacing

Summary – Literature Review
Without Resurfacing
- 10-12% reoperation to resurface the patella by 5-7 yrs
- Higher rate of patient dissatisfaction

Patella Resurfacing
Techniques
- Rotation of femoral component
- Insall type exposure and resection of patella
- Proper thickness, coverage of patella
- Cement a single or 3-peg design
- Resect peripatella tissue

Patella Resurfacing
Personal Results
- 228 I-B II knees single or 3-peg dome
- Mean 7 yr f/u
- No reoperations for patella
- Fracture 3%
- 97% patient satisfaction, 1% mod. ant. knee pain

Algorithm for Patella Resurfacing
- Patellofemoral arthritis
- Inflammatory arthritis
- Age ≥60 years
- Women
- Varus, valgus deformity; flexion contracture

When all aspects are considered, resurface the patella in all TKR patients.

SUPPORT FOR THE UNRESURFACED PATELLA

Leo A. Whiteside, MD

Resurfacing the patella in total knee arthroplasty is commonly recommended as the preferred treatment, but other studies report superior results of not resurfacing the patella especially in qualities of the knee related to quadriceps function such as stair climbing. One reason for this discrepancy in the literature may be design of the femoral component.

Design features of the patellofemoral surface have a distinct effect on kinematics of the knee, patellar stability, and shear stresses, so it would be likely that design features of the femoral surface that articulates with the patella also would affect postoperative anterior knee pain and revision rates.

Various femoral component designs have been available during the past two decades, and the contact stresses on the unresurfaced patella vary greatly among these designs.

- The femoral implants that produced the highest stresses on the unresurfaced patella were those with a shallow patellar groove and wide intercondylar notch.
- The femoral components with deeper patellar grooves and supporting lateral flange surfaces had low contact stress similar to that of the normal patellofemoral joint.
- This suggests that the variation in the reported clinical results of not resurfacing the patella could be explained by the differences in design features of the femoral component.

Clinical Analysis
A clinical and laboratory study was done to test the hypothesis that reported differences in clinical results of unresurfaced patellae in total knee arthroplasty are due to differences in design of the femoral component.

- Thirty-eight knees had an Ortholoc II femoral component (shallow patellar groove, wide intercondylar notch, and flat femoral surface).
- Thirteen knees had severe and three had moderate anterior knee pain.
- Fifteen knees required patellar resurfacing later.
- Two hundred twenty-two knees had Advantim femoral components (deepened and extended patellar groove, narrow intercondylar notch, and rounded femoral surfaces).
- None of these knees had severe anterior knee pain.
- Eighteen percent had mild anterior knee pain on stairs postoperatively.
- Three hundred thirty knees had Profix femoral components (deepened and extended patellar groove, rounded femoral surfaces, and extended lateral patellar support).
- Ten percent of Profix knees had mild anterior knee pain.
- This rate was statistically significantly less than that of the knees with Advantim femoral components ($p<0.03$).
- None of the Advantim or Profix knees required patellar resurfacing. This was significantly lower than the revision rate of the Ortholoc group ($p<0.002$).

Laboratory Analysis
A pressure sensitive electronic transducer was used in cadaver knees to measure pressure on the patellar surface at various positions of knee flexion.

Peak pressures were much higher with the Ortholoc II femoral component than with the other two designs, and slightly (but significantly) higher with the Advantim than with the Profix femoral component.

The clinical study supports the hypothesis that femoral component design is a significant factor affecting anterior knee pain after total knee arthroplasty. The laboratory study suggests that differences in articular surface pressure are responsible for these differences in clinical performance.

BIBLIOGRAPHY

1. Andriacchi TP, Yoder D, Conley A, et al: Patellofemoral design influences function following total knee arthroplasty. J Arthroplasty 12:243-249, 1997.
2. Barrack RL, Bertot AJ, Wolfe MW, et al: Patellar resurfacing in total knee arthroplasty. J Bone Joint Surg 83A:1376-1381, 2001.
3. Bourne RB, Rorabeck CH, Kramer J, Hardie R, Robertson D: Resurfacing versus not resurfacing the patella during total knee replacement. Clin Orthop 321:156-161, 1995.
4. Boyd AD, Ewald FC, Thomas WH, Poss R, Sledge CB: Long-term complications after total knee arthroplasty with or without resurfacing of the patella. J Bone Joint Surg 75A:674-681, 1993.
5. Enis JE, Gardner R, Robledo MA, Latta L, Smith R: Comparison of patellar resurfacing versus nonresurfacing in bilateral total knee arthroplasty. Clin Orthop 260:38-42, 1990.
6. Ewald FC, Wright RJ, Poss R, et al: Kinematic total knee arthroplasty. J Arthroplasty 14:473-480, 1999.
7. Feller JA, Bartlett RJ, Lang DM: Patellar resurfacing versus retention in total knee arthroplasty. J Bone Joint Surg 78B:226-228, 1996.
8. Kirk PG, Rorabeck CH, Bourne RB: Clinical comparison of the Miller Galante I and AMK total knee systems. J Arthroplasty 9:131-136, 1994.
9. Levai JP, McLeod HC, Freeman MAR: Why not resurface the patella? J Bone Joint Surg 65B:448-451, 1983.
10. Matsuda S, Whiteside LA: Contact stresses with an unresurfaced patella in total knee arthroplasty: the effect of femoral component design. Orthopedics 23:213-218, 2000.
11. Petersilge WJ, Oishi CS, Kaufman KR, Irby SE, Colwell Jr CW: The effect of trochlear design on patellofemoral shear and compressive forces in total knee arthroplasty. Clin Orthop 309:124-130, 1994.
12. Picetti III GD, McGann WA, Welch, RB: The patellofemoral joint after total knee arthroplasty without patellar resurfacing. J Bone Joint Surg 72A:1379-1382, 1990.
13. Soudry M, Mestriner LA, Binazzi R, Insall JN: Total knee arthroplasty without patellar resurfacing. Clin Orthop 205:166-170, 1986.
14. Thompson NW, Ruiz AL, Breslin E, Beverland DE: Total knee arthroplasty without patellar resurfacing in isolated patellofemoral osteoarthritis. J Arthroplasty 16:607-612, 2001.
15. Wood DJ, Smith AJ, White B, et al: Patellar resurfacing in total knee arthroplasty: A prospective randomized trial. J Bone Joint Surg 84A:187-193, 2002.

WHY I USE MOBILE BEARING TIBIAS

Douglas A. Dennis, MD

I. METHODS
- A. In Vivo Weight-Bearing Fluoroscopic Analysis
- B. Automated 3-D Model Fitting Technique
  1. CAD Models Fit (Overlaid) Over Fluoroscopic Images
  2. Femorotibial Contact Points Determined
- C. Various Kinematic Patterns Studied
  1. Anteroposterior Femorotibial Translation
  2. Femoral Condylar Lift-Off
  3. Axial Femorotibial Rotation
  4. Range of Motion

II. ANTEROPOSTEROR FEMOROTIBIAL TRANSLATION
- A. Normal Knee
  1. Contact Anterior In Extension
  2. PFR During Flexion
     a. Lateral Condyle > Medial Condyle
     b. 13–17 mm PFR Laterally In Deep Flexion Activities
     c. PFR 3-4 mm During Gait
- B. Fixed Bearing Posterior Cruciate Retaining (PCR) TKA
  1. Contact Posterior In Extension
  2. Anterior Femoral Slide in Mid-Flexion Commonly Observed
  3. Posterior Femoral Rollback (PFR) Uncommon
  4. High Variability in Contact Pathways
- C. Fixed Bearing Posterior Cruciate Substituting (PS) TKA
  1. Posterior Femoral Rollback Routinely Occurs
     a. Less than in the Normal Knee
  2. Consistent Contact Pathways
- D. Meniscal Bearing TKA
  1. Very Similar To Fixed Bearing PCR TKA
  2. Highly Variable Contact Pathways
- E. Rotating Platform TKA
  1. Minimal Average Anteroposterior Translation
     a. Increased Sagittal Conformity
     b. Contact Midline Throughout Flexion
  2. High Variability Among Subjects
- F. Rotating Platform PS TKA
  1. PFR Routinely Occurs In Deep Flexion
  2. Minimal Anteroposterior Translation In Gait
  3. Minimal Variability
  4. Similar to Fixed Bearing PS TKA

III. FEMORAL CONDYLAR LIFT-OFF
- A. Fixed Bearing PCR TKA – 70% Incidence
  1. Primarily Lateral
- B. Fixed Bearing PS TKA – 80% Incidence
  1. Both Medial and Lateral
- C. Rotating Platform TKA – 85% Incidence
  1. 41% Medial / 59% Lateral

IV. AXIAL FEMOROTIBIAL ROTATION
- A. Normal – Tibial Internal Rotation with Increasing Flexion (Screw-home Mechanism)
- B. Fixed Bearing PCR TKA
  1. Average Rotation (0-90∞) – 1.9∞
  2. Reverse Screw-home Rotation Common @ 60-90∞
  3. Highly Variable Rotational Patterns
- C. Fixed Bearing PS TKA
  1. Average Rotation (0-90∞) – 10.4∞
  2. Highly Variable Rotational Patterns
- D. Rotating Platform TKA
  1. Average Rotation (0-90o) – 2.9∞
  2. Reverse Screw-home Pattern – 65%
  3. Highly Variable Rotational Patterns
     a. Minimum - 0.1∞
     b. Maximum 0 - 9.5∞
  4. Bearing Routinely Rotates

V. RANGE OF MOTION
- A. Abnormal Kinematics Often Observed Only Under Weight-Bearing Conditions
- B. Tested Under Passive / Nonweight-Bearing vs. Active / Weight-Bearing Conditions

TYPE	NONWEIGHT-BEARING	WEIGHT-BEARING
NORMAL	139	135
FIXED PCR TKA	123	103
FIXED PS TKA	127	113
MENISCAL BEARING	121	100
ROTATING PLATFORM*	108	99
ROTATONG PLATFORM**	121	114

*Posterior Cruciate Ligament Sacrificing
**Posterior Cruciate Ligament Substituting

VI. SUMMARY
- A. In Vivo / Weight-Bearing Kinematic Patterns Are Not Dramatically Different
  1. Exception – Rotating Platform TKA Designs In Gait Which Demonstrated Minimal Average Anteroposterior Translation. Minimal Anteroposterior Translation Results In Reduced Polyethylene Stresses and Should Be Favorable For Reduced Polyethylene Wear.
- B. Range of Motion – More Determined By Implant Geometry Than Bearing Mobility

BIBLIOGRAPHY

1. Callaghan J, Squire M, Goetz D, Sullivan P, Johnston R: Cemented rotating platform total knee arthroplasty: A 9-12 year follow-up study. J. Bone Joint Surg. 82A:705-711, 2000.
2. Callaghan J, Insall J, Greenwald AS, Dennis D, Komistek R, Murray DW, Bourne R, Rorabeck C, Dorr L: Selected Instructional Course Lecture, The American Academy of Orthopaedic Surgeons "Mobile-Bearing Knee Replacements", J Bone Joint Surgery 82-A(7):1020-1041, 2000.
3. Dennis DA, Komistek RD, Hoff WA, Gabriel SM: In vivo knee kinematics derived using an inverse perspective technique. Clin. Orthop., 331: 107-117, 1996.
4. Dennis DA, Komistek RD, Stiehl JB, Hoff WA, Cheal E.: An in vivo determination of condylar lift-off using an inverse perspective technique that utilizes fluoroscopy. Orthopaedic Transactions, p.645, 1997.
5. Dennis DA, Komistek RD, Colwell CE, Ranawat SC, Scott RD, Thornhill TS, Lapp MA: In vivo anteroposterior femorotibial translation of total knee arthroplasty: A multicenter analysis. Clin. Orthop., 356: 47-57, 1998.
6. Dennis DA, Komistek RD, Northcut EJ, Anderson DT: In vivo analysis of tibiofemoral rotation: Does screwhome rotation occur after total knee arthroplasty? American Association of Orthopaedic Surgeons, New Orleans, LA, 1998.
7. Dennis DA, Komistek RD, Stiehl JB, Walker SA, Dennis K: Range of motion following total knee arthroplasty: The effect of implant design and weight-bearing conditions. J. Arthroplasty, 13(7): 748-752,1998.
8. Dennis DA, Komistek RD, Stiehl JB, Anderson DT, Shoureshi RA: In vivo determination of total knee arthroplasty kinematics during treadmill gait. Orthopaedic Research Society, Anaheim, CA, 1999

9. Dennis DA, Komistek RD, Cheal EJ, Walker SA, Stiehl, J.B.: In vivo femoral condylar lift-off in total knee arthroplasty. JBJS-B 83:33-39, 2001.

10. Haas BD, Dennis DA, Komistek RD, Brumley JT, Hammill C : Range of motion of posterior-cruciate-substituting total knee replacements : The effect of bearing mobility. J Bone Joint Surgery, 83A, Suppl2, 51-55, 2001.

11. Haas BD, Komistek RD, Stiehl JB, Anderson DT, Northcut JN: Kinematic comparison of posterior cruciate sacrificing versus substituting in a mobile bearing total knee arthroplasty. J Arthroplasty, 17:685-692, 2002.

12. Hoff WA, Komistek RD, Dennis DA, Gabriel SA, Walker SA: A three dimensional determination of femorotibial contact positions under in vivo conditions using fluoroscopy. J. Clin. Biomech., 13: 455-470, 1998.

13. Jonsson J, Karrholm J, Elmquist LG: Kinematics of active knee extension after tear of the anterior cruciate ligament. Amer. J. Sports Med., 17(6): 796-802, 1989.

14. Jordan LR, Olivo JL, Voorhorst RE: Survivorship analysis of cementless meniscal bearing total knee arthroplasty. Clin. Orthop., 338: 119-123, 1997.

15. Komistek RD, Dennis DA, Fluoroscopic Analysis of Total Knee Replacement. In Surgery of the Knee, Ed. 3, vol. 2, pp1695-1704, New York, Churchill Livingston, 2001.

16. Komistek RD, Dennis DA, Surgery of the Knee, 3rd Edition, Insall and Scott, Fluoroscopic Analysis of Total Knee Replacement, Churchill Livingston, New York, 2000, pages 1695-1704.

17. Sarojak M, Hoff WA, Komistek RD, Dennis DA: Utilization of an automated model fitting process to determine kinematics of total knee arthroplasty. Orthopaedic Transactions, 1999.

18. Stiehl JB, Komistek RD, Dennis DA, Paxson RD: Fluoroscopic analysis of kinematics after posterior-cruciate-retaining knee arthroplasty. J. Bone Joint Surg., 77B: 884-889, 1995.

19. Stiehl JB, Dennis DA, Komistek RD, Keblish PA: In vivo kinematic analysis of a mobile bearing total knee prosthesis. Clin. Orthop., 345: 60-66, 1997.

20. Stiehl JB, Dennis DA, Komistek RD, Keblish PA, "In-Vivo Kinematic Analysis of a Mobile Bearing Total Knee Prosthesis", Clin Orthop, 345: 60-66, 1997.

21. Stiehl JB, Dennis DA, Komistek RD, Crane H.: In vivo determination of condylar liftoff and screw home in a mobile bearing total knee arthroplasty. J. Arthroplasty, 14: 293-299, 1999.

22. Stiehl JB, Dennis DA, Komistek RD, Keblish PA: In vivo kinematic comparison of posterior cruciate ligament retention or sacrifice with a mobile bearing total knee arthroplasty. Am J Knee Surg, 13:13-18, 2000.

23. Stiehl JB, Komistek RD, Cloutier JM, Dennis DA: The cruciate ligaments in total knee arthroplasty: a kinematic analysis of 2 total knee arthroplasties. J Arthroplasty 15:545-550, 2000.

24. Stiehl JB, Komistek RD, Dennis DA: A novel approach to knee kinematics. Am J Orthop, 30:287-293, 2001.

25. Stiehl JB, Komistek Rd, Haas B, Dennis DA: Frontal plane kinematics after mobile-bearing total knee arthroplasty. Clin Orthop, 392:56-61, 2001.

26. Walker PS, Komistek RD, Barrett DS, Anderson DT, Dennis DA, Sampson M: Motion of a mobile bearing knee allowing translation and rotation. J Arthroplasty, 17:11-19, 2002.

MINIMAL INCISION TOTAL KNEE ARTHROPLASTY: UP TO 5 YEARS OF FOLLOW-UP

Luke Michael Vaughan, MD

I. Introduction
- Total knee arthroplasty (TKA) pioneered by Insall et al in the 1970s
- Minimal incision unicondylar knee arthroplasty developed in early 1990s
- Minimal incision TKA first reported by Vaughan in 2000

II. Potential Benefits and Risks of Minimal Incision TKA
- Potential benefits
  - Reduced soft tissue (quadriceps) violation
  - Reduced blood loss, tourniquet time, and operating time
  - Reduced pain; decreased narcotic analgesic requirement
  - Earlier rehabilitation, discharge, and return to ADL
  - Improved cosmetic appeal
- Potential risks
  - Suboptimal visualization
  - Compromised soft tissue balancing
  - Potential wound healing issues

III. Current Status of Minimal Incision TKA
- Published study of 120 minimal incision TKAs with up to 2 years of follow-up (Tria 2003)
- Study described herein of 176 consecutive primary TKAs with up to 5 years of follow-up (Vaughan 2004)

IV. Study Design
- Single center, single surgeon, nonrandomized, prospective
- Minimal incision defined as < 15 cm; standard incision defined as ≥ 15 cm
- Surgeries from January 1998 through June 2003

V. Patient Demographics
- Minimal incision/standard incision
- Sex, age, weight, BMI
- Operative side
- Primary diagnosis
- Indications/Contraindications

VI. Operative Information
- Implant: NexGen" LPS
- Surgical technique
- Measured parameters
  - Incision length
  - Tourniquet time; operating time
  - Blood loss
  - Length of hospital stay
  - Disposition (home discharge versus in-patient rehabilitation facility)

VII. Clinical Results
- Minimal incision = 99, standard incision = 77
- Postoperative Days 1 and 2: minimal versus standard incision
  - Visual analog pain score
  - Straight leg raise
- Up to 5 years of follow-up; minimal versus standard incision
  - Range of motion
  - Knee Society Function Score
  - Knee Society Assessment Score
- Complications

VIII. Minimal Incision TKA: a New Paradigm?
- Incision should fit the patient
  - Minimal incision can always be extended
- Instrument design should accommodate minimal incision technique
  - Without compromising consistently reproducible, accurate cuts
- Typical operating times, with experience:
  - Surgical exposure: 10 min
  - Cuts, balancing, and implantation: 40 min
  - Closure: 10 to 15 min
- Patients do better with minimal incision TKA
  - Reduced tourniquet time
  - Reduced pain
  - Improved rehabilitation
  - Improved cosmesis
- Clinical and radiographic outcomes comparable for minimal versus standard incision TKA

IX. Potential Drawbacks of Minimal Incision TKA
- Suboptimal visualization needed to make bone cuts and protect soft tissue
  - No malalignments occurred in present study
  - No soft tissue injuries in present study
- Difficulty with soft tissue balancing
  - No residual instabilities noted in present study
  - Can always extend incision, as needed
- Wound healing issues
  - Two seeping wounds; no deep infections in present study
  - Larger cohort required to determine ? significance

REFERENCES

1. Bonutti P: Limited incision for total knee replacement: new technique in surgical positioning. SICOT XXII. Aug 2002. (Abstract P0828, poster).
2. Ranawat CS: History of total knee replacement. J South Orthop Assoc 2002;11:218-26.
3. Repicci JA, Eberle RW: Minimally invasive surgical technique for unicondylar knee arthroplasty. J South Orthop Assoc 1999;8:20-27.
4. Repicci JA: Mini-invasive knee unicompartmental arthroplasty: bone-sparing technique. Surg Technol Int 2003;11:280-84.
5. Romanowski MR, Repicci JA: Minimally invasive unicondylar arthroplasty: eight-year follow-up. J Knee Surg 2002;15:17-22.
6. Romanowski MR, Repicci JA: Technical aspects of medial versus lateral minimally invasive unicondylar arthroplasty. Orthopedics 2003;26:289-93.
7. Tria AJ Jr: Advancements in minimally invasive total knee arthroplasty. Orthopedics 2003;26:s859-63.
8. Tria AJ Jr, Coon TM: Minimal incision total knee arthroplasty: early experience. Clinical Orthopaedics and Related Research 2003;416:1-6.
9. Vaughan LM, Johnson S: Total knee arthroplasty. A short(er) incision technique. New Technology and Techniques in Total Joint Arthroplasty, Rancho Mirage, Oct 2000 (podium presentation).

MINI INCISIONS FOR TKA-WHY I PREFER A CONVENTIONAL INCISION

Robert E. Booth, JR., MD

I. What is "MIS"?
- Time
- Length
- Quad

II. Has it Arrived?
- Hip
- Knee

III. Concerns!
- A. In Whose Hands?
- B. Economic Issues
- C. Community Pressures
- D. Psychology of Failure
- E. Biologic Issues
- F. Instrumentation
- G. Patient Expectation

FUTURE DIRECTIONS IN TOTAL HIP REPLACEMENT AND TOTAL KNEE REPLACEMENT – LESSONS LEARNED FROM JOINT REPLACEMENT REGISTRIES (DD)

Moderator: Robert B. Bourne, MD, London, ON Canada (n)

National joint replacement registries allow the pooling of large numbers of total hip and knee replacements such that trends can be identified and evidence-based practice promoted. In countries with national joint replacement registries, there has been a step-wise reduction in the need for revision surgery. The purpose of this symposium is to highlight the findings of national joint replacement registries in North America and Scandinavia and to explore the advantages and disadvantages of a national joint replacement registry in the USA.

I. Future Directions in THR and TKR – Lessons Learned from Joint Replacement Registries
Robert B. Bourne, MD, London, ON Canada (n)

II. Outcomes of THR and TKR in the US
Jeffrey N. Katz, MD, Boston, MA (n)

III. Lessons Learned from the Swedish Hip Registry
Henrik Malchau, MD, Goteborg, Sweden (a, e – Centerpulse, Link, Smith & Nephew, Zimmer, a – DePuy, Johnson & Johnson)

IV. Lessons Learned from the Swedish Knee Registry
Otto Robertsson, MD, Lund, Sweden (n)

V. Lessons Learned in Establishing a Joint Replacement Registry in Canada
Robert Bourne, MD, London, ON, Canada (n)

VI. Do We Nee a US National Joint Replacement Registry?
William J. Maloney, MD, St. Louis, MO (n)

LESSONS LEARNED IN ESTABLISHING A JOINT REPLACEMENT REGISTRY IN CANADA

Robert B. Bourne, MD

1. **Rationale for a National Joint Replacement Registry**
   A national joint replacement registry has been proven to be an effective way to reduce the need for revision total hip and knee replacement by providing surgeons with data that would allow them to make evidence-based decisions. When the Swedish Hip Arthroplasty Registry commenced in 1979, the revision burden for total hip replacements was similar to contemporary revision rates in most countries. Today, the total hip replacement revision burden in Sweden is 7% of hip operations as compared to 11 – 18% in countries which do not have a national joint replacement registry.

2. **Development of the Canadian Joint Replacement Registry**
   The Canadian Joint Replacement Registry is conducted by orthopaedic surgeons under the umbrella of the Canadian Orthopaedic Association, funded by Health Canada and administered by the Canadian Institute of Health Information. Inaugurated in 2000, the Canadian Joint Replacement Registry has issued three annual reports which highlight trends in total hip and knee replacement in Canada with particular reference to the trends which have occurred over the past decade. The Canadian Joint Replacement Registry not only provides data for evidence-based surgical practice, but also allows linkages to other national data bases, influences health care providers and provides a vehicle for continuous medical education.

3. **Impediments to Developing a National Joint Replacement Registry in North America**
   Problems which had to be overcome in developing the Canadian Joint Replacement Registry included:
   - who would fund the Registry?
   - who would own the data?
   - would surgeons voluntarily provide data?
   - what were the medicolegal ramifications?
   - could the data be used against an individual surgeon?

4. **Results from the Canadian Joint Registry**
   1. THR and TKR utilization in Canada increased by 34% from 1994-5 to 2000-01.
   2. Total knee replacement utilization exceeded total hip replacement rates in the mid-1990's and increased TKR use continues to grow.
   3. Considerable provincial area variations exist with regards THR and TKR utilization in Canada.
   4. THR and TKR are more commonly performed in female patients with peak utilization being between 65 – 74 years of age. One third of THR's and TKR's are now performed on patients <65 years of age.
   5. Average length of stay has dropped precipitously over the last two decades. Average length of stay is now approximately five days for THR's and TKR's.
   6. In-hospital mortality is higher for THR's (1.51%) as compared to TKR's (0.54%).
   7. Complications leading to readmission are more common in THR's.
   8. Age-standardized rates of THR and TKR/100,000 population have increased from 1994-5 to present, but still are lower than other countries.
   9. Waiting times for surgery remain a problem with most patients waiting more than six months for surgery.
   10. One year post-operatively, 96% of patients would have their primary or revision total hip or knee replacement performed again.
   11. Patients are more satisfied with the outcome of primary procedures as compared to revisions.
   12. THR patients have a higher level of satisfaction than TKR patients.

5. **Conclusion**
   Development of the Canadian Joint Replacement Registry is recognized as a win-win-win situation for patients, surgeons and health care providers in Canada. A national joint replacement registry is an important vehicle to pool large data sets, allow trends to be recognized, influence health care providers and promote evidence-based surgical practice.

REFERENCES

1. Health Care in Canada 2003, Canadian Institute of Health, Ottawa
2. 2002 Report, Total Hip and Knee Replacements in Canada, Canadian Institute of Health, Ottawa
3. 2003 Report, Total Hip and Knee Replacements in Canada, Canadian Institute of Health, Ottawa

THE MEDICARE DATABASE AS A TOTAL JOINT REGISTRY: OPPORTUNITIES, CHALLENGES, WORK FROM THE FIELD

Jeffrey N. Katz, MD

Medicare data base: Major considerations
Virtually all Americans age 65+ are insured by Medicare (N = ~ 40,000)
Providers must submit claims to be paid (except prospective capitation plans)
Medicare is an insurance plan not a research program; claims lack key clinical details.

Coverage:
Part A (free): Hospital Care
Part B (supplementary, costs): Physician, therapist; outpatient facility

Key areas of non-coverage:
Oral medications
Nursing home (Medicare covers rehabilitative but not custodial care)

Medicare Data and Research:
Claims filed using standard forms. Fields include:
- Date of service
- Patient Medicare ID number
- Provider ID number (e.g. hospital ID; physician UPIN)
- Type of service
  - Part A: ICD procedure codes
  - Part B: CPT procedure codes
- Diagnosis
  - ICD-9-CM codes

Identifying Cases
- Develop algorithm
- Combinations of procedure and diagnosis codes
- Guided by data on sensitivity, specificity, positive predictive value

Case Definition of THR:
- Hospital and surgeon claim for primary THR
- Exclude codes for infection, fracture
- Exclude HMO recipients

Pos Predictive Value of our algorithm (1) - Primary THR: 0.99, Revision THR: 0.92

Identifying Outcomes
- Types of outcomes
  - Claims data provide no information on pain, function, satisfaction
  - Perioperative outcomes
    - Mortality, MI, PE, pneumonia
    - Infected prosthesis, dislocation, MUA, return to OR
  - Long term outcomes: revision THR
- Predictor variables
  - Demographics: Age, sex
  - Race coded as Black/White/Other or unknown until last few years;
    - Not useful in identifying Hispanics
  - Medicaid eligibility: identifies bottom 20% of income
  - Diagnosis: accuracy varies by diagnosis.
  - Comorbidity: medical record based systems (e.g. Charlson) have been adopted for claims data.
  - Need to distinguish complications from comorbidities
  - Prosthesis related variables:
    - No data on prosthesis type, company, approach, cement

Merging with other data:
- American Hospital Association (3)
  - Hospital characteristics
- Pharmacy plans for Medicare patients
- Geocoding
  - Zip, tract, block level; Socioeconomic data
- Latino surname data (Census based file that identifies whether a person is Hispanic, based upon surname) (4)

Limitations of Medicare Data:
No data on patients < 65
Data unreliable in HMOs
No data on medications

Ambiguities:
- Left and right limbs are not distinguished
- Left censoring: nothing known about beneficiaries prior to their reaching 65

Unique advantages of Medicare data:
- Near complete enumeration of 65+ population
- Identified cases done in very small hospitals. These would be very inefficient to include in cohort studies, yet may be the most interesting in terms of outcomes.
- Follows patients' care anywhere in the US (very few losses to follow-up).
- Powerful sampling frame:

Challenges for use of Medicare data in TJR Registry:
- Link with information on prosthesis
  (If all prostheses were linked with a patient ID number, it would be theoretically possible to follow outcomes in Medicare claims data)

Our THR and TKR Medicare Studies : Medicare THR cohort (7/95-6/96) (1)

	Primary N=58,521	Revision N=12,956
> 75	40%	47%
Female	64%	62%
Caucasian	94%	94%
Osteoarthritis	94%	--
Rheumatoid arthritis	6%	--
Avascular necrosis	6%	--

Slides to be presented:
Distribution of hospital and surgeon volume of THR

Association between volume and outcome of THR
- Perioperative outcomes
- Short term functional outcomes
- Revision rates in first four years

Association between volume and perioperative outcome of TKR

REFERENCES

1. Katz JN, Losina E, Barrett J, et al. Association between hospital and surgeon procedure volume and outcomes of total hip replacement in the United States medicare population. J Bone Joint Surg Am 2001;83-A(11):1622-9.
2. Losina E, Barrett J, Baron JA, Katz JN. Accuracy of Medicare claims data for rheumatologic diagnoses in total hip replacement recipients. J Clin Epidemiol 2003;56(6):515-9.
3. Katz JN, Phillips CB, Baron JA, et al. Association of hospital and surgeon volume of total hip replacement with functional status and satisfaction three years following surgery. Arthritis Rheum 2003;48(2):560-8.
4. Escalante A, Barrett J, del Rincon I, Cornell JE, Phillips CB, Katz JN. Disparity in total hip replacement affecting Hispanic Medicare beneficiaries. Med Care 2002;40(6):451-60.

LESSONS LEARNED FROM THE SWEDISH HIP REGISTER

Henrik Malchau, MD

Introduction
The Swedish Total Hip Replacement Register was initiated in 1979. The mission of the Register is to improve the outcome of total hip replacement and the hypotheses for the project is that feed back of analysed data stimulates the participating clinics to reflect and improve according to the principle of the good example. The clinical and socio-economic effects of the past 25 years of register work in Sweden has been striking and almost 50 quality registers have been started in different medical fields in Sweden during the last decade.

In the past year the Federation of County Councils and the National Board of Health and Welfare in Sweden have agreed to provide a subsidy for a National Competence Center for Orthopaedics (NKO) (nko.orthop.gu.se) of competence for national orthopaedic registers and contributions have been given for two years in order to establish the center. The center will support the creation of new registers through information practical-wise and technological IT support and develop common guidelines and routines for annual reports. The center will also increase focus on interdisciplinary research, cooperation with biostatistician, epdemiologist and health economist.

Improvement of clinical outcome in Sweden
An analysis of implant survival rates for the individual clinics performing total hip replacement in Sweden show a clear change in the country over time. The national average for 7-year survival has improved from 93.5% (± .15) to 95.8 (±0.15) in the periods observed, 1979-1991 and 1992-2002. Thus a clear improvement has been observed in general in the country and more over the proportion of clinics with a result significantly below the national average has decreased from 24.7% to 12.9%, a very positive development that reflects improved implants in combination with development in cemeting and surgical techniques. Above all the result most be viewed on a national level and comparison between individual clinics is less relevant until it becomes possible by means of regression analysis to compensate for differences in the individual clinics case-mix.

The National Hip Arthroplasty Register has with a high probability contributed to documented quality effects on the activity. We have seen a continuous positive development and for all patients that underwent surgery in 1992 the cumulative reoperation frequency is barely 6% compared to just over 16% for those who had their operations in 1979. This means the revision rate has been reduced to almost a third.

Alternative to the failure end-points used in the register
A general problem in orthopaedic is that serious complications or treatment occurs so long after the surgical intervention. In the Swedish Hip Arthroplasty Register results are mainly reported with revision or extraction of the implant components as the definition of failure. This failure end-point has disadvantage in the form of late documenting of failure and delayed reporting of failure as a result of waiting times for competent treatment and variation in length of waiting list for revision surgery. There is also an unreported number due to indications for further surgery and dissatisfied patients without indication for revision.

A follow-up model with the aim of being able to report in the register patient experience after arthroplasty and to measure the outcome with quality of life instrument was started in 2002 in Western Region. The compliance in this project has been very high and implementation of this instrument nation-wide seems to be a realistic future scenario.

The ultimate aim is to be able to measure outcome after hip prosthesis surgery throughout the country with the same scientifically tested methods in order to be able to compare results from different units in an optimal manner. If a generic instrument is included and used prospectively and the cost of the procedure is known, the cost benefit rate can also be calculated. This type of calculation is being used increasingly for allocation of resources in a shrinking health economy.

Specific cohort studies
Specific areas with problems currently studied in the register are Postoperative Femoral Periprosthetic Fractures, the Primary Infected Hip, Re-revised Patients and Patients below 50 years of age at Index Operation. For the periprosthetic fractures we find a high frequency of unknown loose prostheses. Furthermore, reoperation after fractures are technically difficult and often results in repeated revision operation. Primary deep infections after hip prosthetic surgery also have a poor result and this project confirm that the bacterial spectrum in infections have changed to a smaller proportion of gramnegative as a causative pathogens to an increasing proportion of coagulasenegative staphylococci. We also find an increased risk of revision in men and a significantly lower revision risk for patient treated with antibiotic impregnated cement (Gentamicin) at the primary operation.

Future development of register analysis
The intension for the register to make more use of online regression analysis which will create a more powerful tool for our users and allow an in-depth statistical processing of the units own material as well as creating models that can be used to assist clinical decisions directly affecting patient treatment.

Conclusions
The primary reason to document failures and the need for revision surgery is to improve and redefine indications, surgical technique and implant choice. Too high a variation reflects autonomi in a region and to follow the principles in evidence-based medicine is necessary to standardise around excellence. Register results can provide the information needed in this process. The following conclusions are well founded.

- The most serious complication has declined threefolded over the past two decades in Sweden.
- Aseptic loosening still constitute to the major problem.
- The nation-wide introduction of modern cementing technique have substantially improved the outcome of cemented total hip replacement.
- As a result of the register six implants constitute 70% of the total hip replacement market in Sweden. All have long-term documentation. The revision burden recorded for 1979-2000 was only 7.4% for cemented implants.
- Specific patient cohorts, especially younger patients in all diagnostic groups have increase failure risks.

- The intermedium term survival rate for contemporary uncemented implants are promising
- For the health care provide us in Sweden quality registers have contributed to a substantial cost reduction.
- Two key features have contributed to the success of the Register, the Swedish identification number and the willingness of the Swedish orthopaedic surgeons to cooperate and to work in consensus.

REFERENCES

1. Herberts P, Ahnfelt L, Malchau H, Strömberg C and Andersson G B J. Multicenter clinical trials and their value in assessing total joint arthroplasty. Clin Orthop 1989;289:48-55.
2. Malchau H, Herberts P and Ahnfelt L. Prognosis of total hip replacement in Sweden. Follow-up of 92,675 operations performed 1978-1990. Acta Orthop Scand 1993;64:497-506.
3. Herberts P, Malchau H. How outcome studies have changed THA practices in Sweden. Clin Orthop 1997;344:44-60.
4. Garellick G, Malchau H, Herberts P, Hansson E, Axelsson H, Hansson T. Life expectancy and cost utility after total hip replacement. Clin Orthop 1998;346:141-151.
5. Persson U, Persson M, Malchau H. The economic of preventing revisions in total hip replacement. Acta Orthop Scand 1999;70:163-169.
6. Malchau H. Editorial Comments. Introduction of new technology: A stepwise algorithm. Spine 2000;25:285.
7. Garellick G, Malchau H, Herberts P. Survival of total hip replacements: A comparison of a randomized trial and a registry. Clin Orthop 2000;375:157-167.
8. Söderman P, Malchau H, Herberts P, Johnell O. Are the findings in the Swedish National Total Hip Arthroplasty Register valid? A comparison between the Swedish THA register, the National Discharge Register and the National Death Register. J Arthroplasty 2000;15:84-889.
9. Söderman P, Malchau H, Herberts P. Outcome of total hip replacement. A comparison of different measurement methods. Clin Orthop 2001;390:163-172.
10. Malchau H, Herberts P, Eisler T, Garellick G, Söderman P. The Swedish total hip replacement register. J Bone Joint Surg (Am) 2002:84(Suppl 2

CAN WE TRUST PUBLISHED DATA? THE EXPERIENCE FROM THE OLDEST NATIONAL REGISTRY (KNEE)

Otto Robertsson, MD PhD

I. Introduction

It has become a requirement for doctors and healthcare providers that they base their selection of treatment on the available evidence of quality and effiacy.

Evidence based medicine ranks the importance of evidence by levels.

II Types of Studies

- Cross-sectional – Describe a phenomenon fixed in time
- Longitudinal – Investigate processes over time

Retrospective–subjects grouped by outcome

Prospective–subjects grouped by exposure to a factor

Observational–observation without intervention

Experimental/analytical–observing the effect of deliberate interventions

non-randomized

randomized

III. BIAS

- Selection bias
- Information bias
- Publication bias
- Confounding

IV. Inclusion criteria

Are set to make the groups under investigation as homogenous as possible.

A randomized arthroplasty study would limit the study group with respect to:

Certain diagnoses, age interval, type of fixation ……

V. POWER

The magnitude of the effect to be measured has a great influence on the number of subjects needed in a study. The relatively high survival of implants necessitates a large number of patients to be included in randomized survival studies.

VI. Randomized TKA survival-study in Sweden?

To be able with 80% certainty to detect a difference in revision numbers of 5% and 7.5%, all available Swedish patients (65-75 years of age, having a TKA for OA) would have to be randomized for 1.5 years - and then followed for 8 –10 years

VII. What is there around of randomized studies?

Most deal with thromboembolic prophylaxis, analgesia and physiotherapy.

Relatively few deal with factors directly related to the surgery.

Many are inconclusive regarding the comparisons performed.

We can get no help from present randomized studies when deciding what implants to select.

VIII. Absence of evidence <> evidence of absence

Freedman and colleagues reviewed the 1997 issues of the American and British Journal of Bone and Joint Surgery as well as that of Clinical Orthopedics. They found that of all the studies with negative results only 3% had the power to detect a small difference in effect size (a difference of 0.2 times the standard deviation). And of 25 negative Randomized controlled trials none had the power to detect such difference.

IX. National registers

Being initiated in 1975, the Swedish Knee Arthroplasty Register is the oldest national register

The national registers are a separate type of prospective non-randomized studies that include whole populations. With the large number of patients available they have the possibility of detecting statistical differences, although it should be remembered that the same type of BIAS affects them as other studies.

X. The importance of national registries

- Their results generate impact
- They express the results of the average surgeon
- They are probably less affected by publication bias

XI. Impact

When inferior results are published nationwide the effect is much greater than when individual centers disclose similar results.

XII. The results of the average surgeon

Many published studies come from highly specialized unit and are often based on groups of highly selected patients and it is probable that the surgeons have become acquainted with the use of the specific implant on forehand and have thus avoided the so-called learning curve.

XIII. Less publication bias

The majority of studies published show much better results than what is to be expected from the number of revisions that actually are being performed in that country. It may be that only those studies showing very good or interesting results are being selected for publication.

XIV. How to use the literature for choosing implants

- Be aware if you see articles describing inferior results for an implant!
- Positive results may be dependent on a particular setting and you cannot assume that you will be able to get the same results with a different mix of patients and surgeons.
- Look for information in national registers for the implant to see if they are similar to that published by others.
- If you use an unproven implant with no long-time record, follow up your patients…carefully, preferably as a part of a study .

DO WE NEED A U.S. NATIONAL JOINT REPLACEMENT REGISTRY?

William J. Maloney, MD

To answer that question, one has to first look at outcomes of total hip and total knee arthroplasty in the United States. Hip and knee implants are designed and manufactured with the expectation that they are equivalent or superior to existing products. Surgeons perform total hip and knee replacement operations using techniques that they feel are optimal. However, unexpected outcomes can and do occur. In the United States, the revision burden for hip replacement is approximately 18%. This is in comparison to Sweden where the revision burden runs approximately 6 to 8%.

The reasons for premature failure are multifactorial. There are certainly implant issues including issues related to materials, design and manufacturing. There are also surgeon related issues related to surgical technique and experience. Finally, the patient obviously plays a role. In some cases premature failure is patient related.

The question then to raise is how does one get information out to the orthopaedic community in a timely fashion. It is quite clear that currently dissemination of information as it relates to early implant failure is not done in a timely fashion. Ken Chang wrote an article in the New York Times entitled "When Implants Fail, Patients Suffer Twice" and concluded "no one keeps track of who has what." There are multiple examples of premature implant failure that are related to implant design, implant material or implants that simply are too technically sensitive for general orthopaedic use. In England, the premature failure of the capital hip lead to a national investigation and subsequent mandating of a registry. The inquiry concluded, "As manufacturers strive to improve the design of artifical hips, the possibility of adverse consequences of design changes cannot be ruled out. However, the consequences of such problems would be minimized by UK hip registry."

In the United States this is even more important as total hip replacement and to some degree total hip revision surgery has become a general orthopaedic procedure. Twelve percent of the primary total hip replacements and 49% of the revision total hip replacements are done in centers that do 10 or fewer Medicare cases per year. Fifty-two percent of the primary total hip replacements and 77% of the revision total hip replacements are done by surgeons that do 10 or fewer Medicare cases per year. Based on that experience it is going to be impossible for the majority of surgeons to base implant choices on their own experience alone.

Currently information is disseminated in one of three ways. The most common is case evaluations. Case evaluations represent for the most part retrospective series of a single surgeon or center where a single prostheses or surgical technique is employed. They often represent the expert innovators experience. Valid comparisons between series are difficult because important variables are not controlled and because it is done by experts it is probably not relevant to a community practice and certainly not reported in a timely fashion. The gold standard is of course randomized clinical trials however it is impractical to consider doing randomized clinical trials with all the implants that are currently available for use in our practices. Meta-analysis is sometimes useful. However, this requires prospective studies and preferably randomized clinical trials that can be pooled to examine larger numbers of patients. Since few exist in the total joint replacement world as it relates to outcome of specific implants, this is not going to be practical.

Thus we are left with the fact that we do not have a mechanism currently in the United States for timely dissemination of information as it relates to early failure of orthopaedic implants. Certainly a National Joint Replacement Registry would address this issue.

It is also interesting to note the resources expended for total hip and total knee replacement. In 1999 and 2000, approximately 86,000 hip replacements were done in the Medicare patient population and 155,000 knee replacements each year. There were approximately 20,000 revision hips in each of those years and 16,000 revision knee replacements. The total Part A payments for Medicare were approximately 2.6 billion dollars for those services. An additional $500 million was paid to surgeons, assistant surgeons, and anesthesiologist for a grand total of approximately 3.1 billion dollars. This does not include any readmissions that occurred in this patient population, it does not include treatment for other complications that occurred postoperatively and does not include postoperative services such as rehab, so the total cost is probably closer to 4 billion dollars to Medicare annually. If a registry could over time lead to a decrease in the number of revisions this is an obvious benefit from the standpoint of cost savings.

It is also an obvious benefit to our patients. The goal in optimizing implant surgical technique is not only to provide a satisfactory outcome in the short term, it is to minimize the chances of needing revision surgery in the future. Revision surgeries are not only expensive but they are associated with a high rate of morbidity and mortality. A national joint replacement registry in the United States could aid in accomplishing these goals by defining the epidemiology of total joint arthroplasty, identifying poorly performing implants in a timely fashion, providing a mechanism for feedback to surgeons and identifying patients who may require follow up evaluation.

UPDATES ON TENDON INJURIES OF THE FOOT AND ANKLE (H)

Moderator: Glenn B. Pfeffer MD, San Francisco, CA (n)

Tendon injuries of the foot and ankle are among the most common problems seen in orthopaedic practice. They are often misdiagnosed, however, resulting in prolonged treatment and unnecessary disability. This symposium will present the state of the art evaluation, treatment and rehabilitation of the six major tendon problems of the foot and ankle: Achilles tendinosis and insertional tendinopathy, posterior tibial tendon dysfunction, peroneal tendinopathy, and disorders of the tibialis anterior and flexor hallucis longus tendons.

I. Acute and Chronic Condition of the Achilles
Steven F. Conti, ND, Pittsburgh, PA (n)

II. Insertional Tendinopathy of the Achilles
James A. Nunley, II, MD, Chapel Hill, NC (n)

III. Peroneal tendinopathy
Glenn B. Pfeffer, MD, San Francisco, CA (n)

IV. Posterior Tibial Tendon Dysfunction
Jeffrey E. Johnson, MD, St. Louis (n)

V. Flexor Hallucis and Tibialis Anterior Tendinopathy
Lew C. Schon, MD, Baltimore, MD (c – Aircast, e – DePuy)

UPDATE ON TENDON INJURIES OF THE FOOT AND ANKLE

Stephen F. Conti, MD

Definition of a Tendon
- Stedmans: A fibrous cord or band that connects a muscle to a bone or other structure; it consists of fascicles of very densely arranged, almost parallel collagenous fibers, rows of elongated tendon cells, and a minimal of ground substance.

Anatomy of a tendon
- Tendons that move in a straight line are composed of type 1 collagen surrounded by loose connective tissue called a paratenon, ie Achilles tendon.
- Tendons that have a curved course are composed of type 1 collagen surrounded by a mesotenon contained in a synovial lined sheath, ie PTT

Nutrition of a tendon
- Straight tendons receive their blood supply through the richly vascular paratenon.
- Curved tendons receive their blood supply through vincula that feed the mesotenon. There are often "watershed" areas of lesser circulation between vincula supplied sections of tendon. Synovial fluid diffusion helps feed these tendons.

Diseases of Tendons
- Acute(traumatic)-usually occurs at the musculotendinous junction or insertion of the tendon.
- Acute on Chronic
- Chronic(degenerative)-usually occurs midsubstance.

Tendon Injury
- Occurs as a result of direct trauma, laceration or contusion. Often involves sharp tools and can affect any tendon.
  OR
- Occurs as indirect trauma with tensile overload of the tendon. Effects are multifactorial and have to do with age, anatomic location, vascularity and applied forces.

Question of the Day!
- If you accept what has been presented as factual, then what is TENDINITIS?

AMA Classification of Tendon Disorders
- Peritendinitis-inflammation of the vascular paratenon, often with thickening of the paratenon.
- Peritendinitis with tendinosis-above with alterations in the tendon substance itself with thickening of the tendon.
- Tendinosis-mucinoid degeneration of the collagenous portion of the tendon.
- The treatment of a tendon problem must be based on a proper diagnosis and tailored to the individual patients specific deformity and expectations.

Life of Achilles
- Son of Peleus(human) and Thetis(a sea nymph) whose father was Poseidon
- Thetis wished Achilles to be immortal so she immersed him in the river Styx so the water made him invincible to any weapon. She held him by his Achilles region which did not touch the water
- Very successful warrior-won many battles for the Greeks.
- Hector kills Achilles friend Patroclus
- Achilles kills Hector as retaliation
- Hectors brother Paris finally shoots an arrow which is guided by Apollo into Achilles' heel killing him
- The term Achilles heel was first used by Dutch anatomist, Verheyden, in 1693 when he dissected his own amputated leg

Achilles Tendon Disorders
- Acute tears
- Acute on Chronic tears
- Chronic tears
- Distal Achilles tendonopathy
- Insertional Achilles tendonitis

Anatomic Features
- Large gastrocnemius-soleus muscle sends tendon to insert on posterior inferior calcanceal tuberosity
- Watershed area of vascularity 4-6cm above insertion
- Distal Achilles tendon subject to friction from posterior superior calcaneus(Haglunds deformity) and heel counter of shoes
- Strongest tendon in the body. Can withstand loads of 1,000 pounds or more.

Quantitative assessment of vascularization in the human achilles tendon
- Stein and Petersen-Germany-2000
- Middle of tendon(3-6cm) had lowest intravascular volume compared to rest of tendon
- Proximal tendon most vascular
- Implications for acute tendon rupture and chronic tendonosis?

Acute Tears
- True acute tears of a normal Achilles tendon are rare events
- Occurs in young men performing extraordinary athletic activity
- Usually occurs at insertion of tendon in calcaneus or at musculotendinous junction
- Treatment is always acute operative repair-surgery is very difficult because of location of the tear

Partial Achilles Tendon Tears
- Trauma results in painful and tender nodule 4-6 cm above Achilles insertion
- Give patient 1 1/2 years to maximally improve
- If still painful(may always be tender) and MRI shows cyst within tendon can perform excision of degenerated area and oversew tendon

Acute on Chronic Tears
- Still commonly missed by primary treating physician
- Occurs in middle aged men during routine recreational activity
- Dramatic onset of symptoms
- Physical exam with palpable defect and positive Thompson sign. Most still have good plantarflexion strength to manual muscle testing.

Treatment
- Goal is to establish normal musculotendinous length(to maximize strength) and prevent rerupture.
- Best to start early motion for both ankle joint and tendon healing
- Problem: how to accomplish above since they seem mutually exclusive!

Effect of immobilization on Achilles Tendon Healing
- Murrell, et al-North Carolina-1993
- Rat model
- Immobilization was highly significantly detrimental on the functional and mechanical performance of rat Achilles tendon

- Hand literature

Nonoperative Treatment
- Not usually performed in young or middle-aged serious athletes due to resultant strength deficit
- Best in middle-aged or older recreational athletes or sedentary patients
- Acute risks of treatment minimal(casting)
- Long term problems include weakness and increased risk of rerupture(2x but still small) over operative treatment

Nonoperative Protocol
- If see patient within seven days of injury can plantarflex ankle and cast. If ultrasound or MRI shows tendon ends apposed then continue nonoperative treatment
- After two weeks bring patient back and progressively dorsiflex ankle so by eight weeks ankle is slightly above neutral.
- WB and PT at 8 weeks.

Controversy
- LLC vs SLC
- Casting at each f/u visit or use of an Orthoplast splint or Cam walker boot which allows active plantarflexion but blocks dorsiflexion
- Return to activity(usually when range of motion is equal to other side and strength is 80% of other leg)

Operative Treatment
- Results are consistently good
- Can be performed up to several months after injury but requires greater surgical expertise
- Reported complications include skin slough, infection, sinus formation, etc.
- Complications lessened by proper surgical technique. Do not go directly posteriorly, approach with medial incision

The strength of Achilles tendon repair: A comparison of three suture techniques in cadavers
- Sclamberg-Illinois-2002
- Double Krackow, double Bunnell and double Kessler techniques compared using #2 Mersilene suture
- No differences

Comparative analysis of surgical techniques for repair of acute Achilles tendon rupture:Prospective study
- Mark, et al-Virginia-1994
- Prospective study comparing three techniques:primary end-to-end, turn down flap augmentation and peroneus brevis transfer augmentation, in 18 patients
- No significant difference in results

Open vs closed repair of the Achilles tendon:Animal Study
- Pneumaticos, et al-Texas-1997
- 24 rabbits had tenotomy followed by open suture repair vs casting.
- Serial x-rays demonstrated elongation of the repair site averaging 10mm for surgical group and 21mm for casting group
- Results were confirmed in a human study

Surgical vs non-surgical treatment of Achilles tendon rupture: A prospective, randomized study
- Moller, et al-Sweden-2001
- Compared repair and early functional rehab using a brace vs 8 weeks of plaster cast
- F/U = 2 years
- Rerupture rate: 2% surg vs 21% nonsurg
- Otherwise no differences between groups at longterm f/u
- No surgical complications

Operative vs Nonoperative Management of Acute Achilles Tendon Ruptures:Expected-Value Decision Analysis
- Kocher, et al-Boston/Vail-2001
- 83 studies synthesized 1954-1997
- Operative tx was optimal strategy
- Nonoperative tx only if rerupture rate could be lowered or if complication rate was high

Functional bracing vs surgical repair of Achilles tendon: Clinical results and analysis of GRF
- Adlington, et al-Rochester & Ontario-2003
- 12 patients in each group
- Subjective assessment equivalent
- Passive ankle PF: decr 5o surg vs decr 2o ns
- Passive ankle DF: decr 5o surg vs incr 2o ns
- No differences in kinetic data
- No significant differences

Prevalence of DVT and PE in surgically repaired Achilles tendon ruptures
- Gillespie, et al-Texas-1998
- 39 patients with avg age 36 years
- Only symptomatic patients had studies to prove existence of DVT/PE
- PE=7.7% DVT=15.4%

Paratenonitis
- Occurs in runners
- Physical examination demonstrates crepitus along course of tendon
- Nonoperative treatment=rest, NSAID's, stretching, PT modalities, heel lifts, etc
- Operative treatment=incise thickened medial, lateral and posterior paratenon through medial approach
- Operative results good

Surgical management of Achilles tendon overuse injuries: Long term follow-up
- Leach, et al-Boston-1993
- 75% males with mean age 33
- 87% of patients with paratenonitis were satisfied with surgical treatment

Achilles Tendonopathy
- Easily the most misunderstood and undertreated problem in the lower leg
- Is it a continuum of disease which starts as a Haglunds deformity associated with retrocalcaneal bursitis, progresses through Achilles paratenonitis finishing with severe Achilles tendonopathy and frank tearing or is it a true degenerative process of the substance of the tendon?
- The earlier the treatment the better the results

Terminology
- Clearly two groups in the literature: 1) Middle-aged athletes with some changes on ultrasound/MRI
  2) Older patients without history of excessive activity with severe changes
- Be careful to differentiate the two as the treatments are very different

Ultrasound guided sclerosis of neovessels in painful chronic Achilles tendinosis
- Ohberg and Alfredson-Sweden-2002
- Authors suggest that neovascularization plays a role in pain with Achilles tendinosis
- Sclerosis with polidocanol results in good results in 8/10 patients
- Pilot project

Symptoms and signs
- Patient complains of pain at the Achilles tendon area worse with prolonged standing and certain activities like stair-climbing
- Will complain of intermittent swelling
- Painful to touch such as when resting tendon on a hard surface

Presumed pathophysiology #1
- Prominent posterior superior calcaneus (Haglunds deformity) compresses bursa and tendon between it and the shoe counter
- Over many years get chronic inflammation and spurs which then cut into tendon damaging it with each step
- Progressive damage to tendon occurs which leads to chronic reparative process and scarring and pain.

Presumed pathophysiology #2
- Intrinsic alteration of the tendon occurs secondary to microtrauma leading to intrasubstance mechanical abnormalities
- Tenocytes begin producing altered collagen giving the Achilles tendon abnormal mechanical properties eccentuating the problem
- Decreased vascularity of the central third of the tendon alters the ability of the tendon to heal from the above

Tenocytes from ruptured and tendinopathic Achilles tendons produce greater quantities of type III collagen than tenocytes from normal Achilles tendons
- Maffulli-Scotland-2000
- Tenocytes from normal and ruptures Achilles tendons were compared
- Cells from ruptures tendons produced an abundance of type III collagen rather than normal type I collagen
- Repetitive microtrauma in predisposed tendons may produce type III collagen leading eventually to gross changes seen in tendinopathy

Nonoperative Treatment
- Weight loss and activity modification
- Soft backed shoes and Silipos heel protector
- NSAID's
- Achilles tendon stretching and PT with eccentric load strengthening and modalities
- Immobilization?
- Do Not Inject Steriods

Heavy-load eccentric calf muscle training for treatment of chronic Achilles tendinosis
- Lorentzon et al-Sweden-1998
- Studied 15 patients avg age 44 with chronic Achilles tendinosis
- After 12 week training all were back to preinjury levels of running
- Comparison group treated conventionally had poor outcomes and all went on to surgery.

Operative Treatment
- Younger patients: Debride degenerative portions of Achilles tendon and repair defects. Consider FHL augmentation to aid in vascularization

Surgical treatment for chronic Achilles tendinopathy-prospective 7 months study
- Paavola, et al-Finland-2002
- Assessed surgical results in two groups:
  A) local intratendinous lesion
  B) diffuse tendinopathy
- Group A-67% full activity, 83% asymptomatic or mild pain, 6% complications
- Group B-54% asymptomatic or mild pain, 27% complications

Operative Treatment
- Older patients:If Achilles tendonopathy extends above superior margin of calcaneus then excise distal Achilles and transfer FHL tendon with proximal anastomosis

Achilles tendon and calf muscle strength
- Alfredson, et al-Sweden-1998
- After surgery for Achilles tendinosis pts placed in a cast for two weeks then PT
- Preop: concentric and eccentric strength lower on injured side
- Postop: concentric strength decreased between weeks 0-16 then increased between weeks 26-52 but was always less than uninvolved side. Eccentric strength lower at week 26 but increased to same as uninvolved side by week 52.
- No difference long term if immobilized 2 or 6 weeks-compared to previous study

Outcome of surgery for chronic Achilles tendinopathy
- Maffulli, et al-England-2001
- Assessed 26 studies on surgical repair
- Older studies had poor methodology while newer studies had much improved methodology
- Care should be exercised comparing older vs newer studies results

Short Achilles Tendon Syndrome
- First described by Morton in early 1900's.
- Congenital or acquired?
- Leads to increased midfoot stress during stance phase of gait.
- Leads to prolonged time on ball of foot which accentuates other biomechanical problems such as long second metatarsal

Treatment
- Accommodative-heel elevation
- Functional-Physical therapy stretching
- Surgical-selective gastrocnemius lengthening vs distal TAL

Summary
- Acute rupture treated with either early functional rehab or surgery and early functional rehab. Surgical results better but avoid in patients with risk for complications such as wound healing or DVT/PE
- Chronic tendinopathy occurs in two groups:
  Middle-aged athletes
  Older patients
- Both groups should start with PT
- Younger group gets focal debridement of local lesion and early rehab
- Older group has very little literature to support a uniform treatment plan. Achilles excision and FHL transfer proving to be an excellent procedure in this group

INSERTIONAL ACHILLES TENDON DISORDERS

James A. Nunley, MD

I. Posterior heel pain etiologies
- A. Insertional Achilles tendinopathy
- B. Pump bump (prominent lateral calcaneal ridge)
- C. Retro-calcaneal bursitis (Haglund's disease)
- D. Systemic enthesopathies – enlargement of the superior bursal prominence of the calcaneus

II. Presentation
- A. Posterior heel pain at the bone tendon junction
- B. Often complain of associated fullness with difficulty wearing closed heel shoes
- C. Worse after activity
- D. Onset can be related to a change in activity (e.g. mileage, hills)

III. Demographics
- A. Most often overuse phenomenon
- B. Approximately 20% of all Achilles disorders
- C. In sports common in 20-30 year olds
  1. Runners
  2. Dancers
  3. Basketball players
  4. Tennis
  5. Other sports with repetitive pounding
- D. In non-athletes > 45 years
  1. Often overweight
  2. Female > male
  3. Many other medical conditions – DM, HTN, HD

IV. Physical exam
- A. Examine prone
- B. Point tenderness at Achilles insertion
  1. Centrally & laterally
  2. Rarely medial
- C. Tenderness in retro-calcaneal area ±
- D. Tendon can show fullness/thickening
- E. Loss of ankle dorsiflexion with pain on acute dorsiflexion

V. Diagnostic tests
- A. Plain x-rays
  1. Can see calcific "spur" within Achilles tendon
  2. Presence of Haglund's process
- B. CT scan can show calcium medial, lateral, or central
- C. Local anesthetic into retro-calcaneal bursa to rule out bursitis
- D. Bone scan or MRI in unusual cases

VI. Etiology
- A. Overuse or training errors in younger patients
- B. Attritional degenerative changes (tendonosis) in older patients
- C. Pain is increased by
  1. Bony impingement with Haglund's deformity
  2. Calcification of the diseased tendon
  3. Chronic bursitis with thickening
  4. Shoe pressure with stiff counter
  5. Continued use

VII. Treatment
- A. Non-operative treatment
  1. Rest or change training
  2. Heel lift 1/4 – 3/8 inch
  3. Posterior heel pads with shoe counter
  4. Immobilization
     a. Walking cast or boot for 4-6 wks.
     b. Need to sleep with cast
  5. Works 95% of the time
  6. Will need to place lift in all exercise shoes
- B. Operative treatment
  1. Arthroscopic approach - supine
     a. Can't get to calcified tendon
     b. Can't decompress Haglund's deformity
  2. Prone position for all open procedures
  3. Lateral approach or medial and lateral
     a. Incision from calcaneus proximal 5-7cm on lateral border of Achilles
     b. Lift up lateral insertion of Achilles
     c. If calcific elevate until spur is exposed
     d. Aggressive resection of posterior-superior calcaneal tuberosity
        1) Inferior to the inferior insertional ridge
        2) Superior to completely decompress the tendon
     e. Image to confirm adequacy of decompression
     f. Excise all calcification from tendon
     g. If need, reattach lateral Achilles with suture anchor or drill holes
  4. Central approach
     a. Longitudinal incision approx 8-9 cm to plantar skin
     b. Full thickness flaps without undermining
     c. Excise all degenerative tendon &/or calcific tendon
     d. Through central split excise retro-calcaneal bursa and postero-superior calcaneus
     e. Repair defect side to side and use suture anchor if needed
  5. For failed decompression or excessive degeneration of Achilles tendon, need tendon transfer
     a. If tendon insertion is excessively damaged may need to add an FHL transfer
     b. Can do easily with an accessory medial incision
- C. Post-operative care
  1. 2 weeks touch down in splint
  2. 2 weeks WBAT in SLC
  3. 4 weeks WBAT in boot with ROM exercises
  4. _ inch heel lift in shoe wks 8-12
  5. Begin gastroc strengthening at 10-12 weeks post-op
- D. Complications
  1. Delayed wound healing
  2. Rupture of Achilles tendon
  3. Persistent soreness
  4. Recurrent calcification
- E. Results
  1. Anderson & Davis
     a. 66 patients with surgical approach to insertional Achilles tendonitis (lateral approach)
     b. 38 had insertional calcification
     c. 28 had no calcification
     d. Average time to plateaued improvement
        1) Calcific: 11.4 months
        2) Non-calcific: 6.5 months
     e. Satisfaction rate
        1) Calcific: 79%

2) Non-calcific: 93%
f. Complications
1) Achilles avulsion at 4 months postop with significant traumatic event
2) 5% with minor wound problems

2. Schepsis & Leach
a. 37 surgically treated
b. 24 pts. with Achilles tendonitis
1. 63% excellent
2. 29% good
3. 4% fair
4. 4% poor
c. 14 pts. with retrocalcaneal bursitis
1. 50% excellent
2. 21% good
3. 29% fair
d. Combined group
1) 71% excellent
2) 29% good

3. Nunley & Horst
a. 23 surgical cases
b. follow – up 4 yrs (2-9 yrs)
c. average time to plateau 5.7 mo
d. cybex testing
1) peak torque equal to opposite side
2) strength same on both sides
e. AOFAS score
1) Ave po. 96

REFERENCES

1. Baxter DE: The heel in sport. Clin Sports Med 13:683-693, 1994.
2. Bordelon RL: Surgical and conservative foot care, Thorofare, NJ, 1988, Charles B. Slack.
3. Canoso JJ, Liu N, Trail MR, et al: Physiology of the retrocalcaneal bursa, Ann Rheum Dis 47:910-912, 1988.
4. Clanton TO, Porter DA: Primary care of foot and ankle injuries in the athlete, Clin Sports Med 16:435-461, 1997.
5. Fiamengo SA, Warren RF, Marshall JL, et al: Posterior heel pain associated with a calcaneal step and Achilles tendon calcification, Clin Orthop 167:203-211, 1982.
6. Fowler A, Philip JF: Abnormality of the calcaneus as a cuase of painful heel: its diagnosis and operative treatment, Br J Surg 32:494-498, 1945.
7. Gerken AP, McGarvey WC, Baxter DE: Insertional Achilles Tendinitis: Foot and Ankle Clinics Vol. 1(2):237-246, 1996.
8. Heneghan JA, Pavlov H: The Haglund painful heel syndrome. Experimental investigation of cause and therapeutic implications, Clin Orthop 187:228-234, 1984.
9. Jones DC, James SL: Partial calcaneal osteotomy for retrocalcaneal bursitis, Am J Sports Med 12:72-73, 1984.
10. Keck SW, Kelly PJ: Bursitis of the posterior part of the heel: evaluation of surgical treatment of 18 patients, J Bone Joint Surg 47A:267-273, 1965.
11. Kvist M. Achilles tendon injuries in athletes. Sports Med 18:173-201, 1994.
12. Leach RE, James S, Wasilewski S: Achilles tendinitis, Am J Sports Med 9:93-98, 1981.
13. McGarvey WC, Sparks M, Baxter DE: Causes of heel pain. The rational approach to diagnosis, management, and salvage of complications, Foot Ankle Clin 3:175-187, 1998.
14. Nesse E, Finsen V: Poor results after resection for Haglund's heel: analysis of 35 heels in 23 patients after 3 years, Acta Orthop Scand 65:107-109, 1994.
15. Schepsis AA, Leach RE: Surgical management of Achilles tendinitis, Am J Sports Med 15:308-315, 1987.
16. Pavlov H, Heneghan MA, Hersh A, et al: The Haglund Syndrome: Initial and differential diagnosis. Diagnostic Radiology 144:83-88, 1982.
17. Rufai A, Ralphs JR, Benjamin M: Structure and histopathology of the insertioanl region of the human Achilles tendon. J Orthop Res 13:585-593, 1995.
18. Watson AD, Anderson RB, Davis WH: Comparison of results of retrocalcaneal decompression for retrocalcaneal bursitis and insertional Achilles tendinosis with calcific spur. Foot & Ankle 21:638-642, 2000.

INJURIES OF THE PERONEAL TENDONS

Glenn B. Pfeffer, MD

I. Anatomy
- A. Peroneus Brevis
- B. Peroneus Longus
- C. Extensor retinaculum
- D. Trochlear process
- E. Os Peroneum
- F. Accessory muscles

II. Clinical history
- A. Acute vs. chronic?
- B. Previous ankle sprain?
- C. More than 3-4 months of symptoms?
- D. Dislocation/subluxation of tendons?
- E. Chronic vs. intermittent pain?
- F. Instability or giving way?
- G. Limitation of activity?

III. Examination
- A. Focal tenderness is key
- B. Circumduction of hindfoot
- C. Resisted ankle dorsiflexion and hindfoot eversion
- D. Strength of eversion

IV. Studies
- A. Technichium- 99 bone scan. Highly sensitive but non-specific screening study for occult bone or joint pathology
- B. MRI with extremity coil – false positive and negative studies.
- C. Differential injection of lidocaine into the peroneal sheath.

V. Differential diagnosis must always be considered
- A. Acute injury
  - Rupture of peroneal tendon
  - Dislocation of peroneal tendon
  - Fracture (easily overlooked): Distal fibula (avulsion or stress fracture), lateral process of talus, OCL of lateral talus, anterior process of calcaneus, os trigonum, os peroneum, base of fifth metatarsal
  - Acute peroneal tenosynovitis
  - Syndesmotic sprain of the ankle
- B. Chronic

BONE:
- Occult bone injury/nonunion (see acute fractures above)
- Prominent trochlear process

JOINT:
- Subtalar arthritis
- Subtalar synovitis
- Tarsal coalition
- Calcaneal cuboid arthritis
- Lateral gutter of the ankle (synovitis, loose body, OCL)
- Posterior ankle impingement (os trigonum, etc.)
- Ankle or subtalar laxity (symptoms tend to by intermittent, related to episodes of giving way)
- Calcaneal-cuboid subluxation?

BURSA:
- Retrocalcaneal bursitis (Posterior to peroneals, with bilateral tenderness

NERVE:
- Sural neuralgia (post operative neuroma, rare neuropraxia
- Superficial peroneal entrapment

TENDON:
- Chronic Subluxation/dislocation
- Peroneal tenosynovitis
- Peroneal tendinosis
- Painful Os Peroneum
- Impingement of peroneal (secondary to severe pes planus or malunion of a calcaneal fracture)
- Tendinopathy of anomalous tendon (peroneus quartus)

V. Conservative Care
- A. NSAID
- B. Airstirup
- C. 1/8th inch lateral heel wedge
- D. Cast
- E. One cortisone injection?

VI. Surgical treatment
- A. Acute repair for rupture
- B. Tenosynovectomy
- C. Repair vs debridement of torn tendon – excise up to 65% of tendon
- D. Excision and tenodesis to adjoining tendon for end stage degeneration
- E. Intercalary graft (semitendinosis) if muscle salvageable
- F. Excision of Os Peroneum for degeneration and focal pain/tenderness
- G. Excision of accessory muscle if subluxation present
- H. Reduction of prominent trochlear process if symptomatic
- I. Correction of heel varus
- J. Reconstruct ankle ligaments if lax

SUGGESTED READING:

1. Brandes, CB; Smith, RW: Characterization of patients with primary peroneus longus tendinopathy: a review of twenty-two cases. Foot Ankle Int. 21(6): 462-468, 2000.
2. Krause, JO; Brodsky, JW: Peroneus brevis tendon tears: pathophysiology, surgical reconstruction, and clinical results. Foot Ankle Int. 19(5): 271-279, 1998.
3. Sammarco, GJ: Peroneal tendon injuries. Orthop Clin North Am. 25(1):135-145, 1994.
4. Sobel, M; Bohne, WH; Levy, ME: Longitudinal attrition of the peroneus brevis tendon in the fibular groove: an anatomic study. Foot Ankle. 11(3): 124-128, 1990.

POSTERIOR TIBIAL TENDON DYSFUNCTION

Jeffrey E. Johnson, MD

I. Introduction: Posterior Tibial Tendon Dysfunction (PTTD)
- A. Most common cause of an acquired flatfoot deformity
- B. Anatomy of Tibialis Posterior Muscle
  1. origin: posterior tibia, medial fibula and interosseus membrane
  2. tendon passes posterior to axis of rotation of the ankle and medial to axis of subtalar joint to insert on tarsal bones
  3. action: plantar flexor of ankle and invertor of hindfoot
- C. Dysfunction of the PTT due to tendinitis or rupture results in a spectrum of pathology:
  1. pain
  2. loss of tendon function
  3. progressive pes planovalgus deformity

II. Etiology -- Proposed Theories
- A. Pes pronation and ligamentous laxity
  1. chronic stress on PTT
  2. EMG shows increased intensity and duration of PTT activity in pronated foot (Keenan, et.al)
- B. Intratendinous shear stress
  1. multiple insertions
  2. independent motion of insertion sites generates shear stresses between groups of tendon fibers
- C. Seronegative Inflammatory Disease (Psoriatic, Reiter's, Ankylosing Spondylitis)
  1. Enthesopathy
  2. Family History
  3. HLA studies
  4. Probably NOT related to rheumatoid arthritis
- D. Attritional Tendon Degeneration -- zone of hypovascularity
- E. Trauma - beware of the medial ankle sprain --25-75% recall injury
- F. Iatrogenic
  1. steroid injection into tendon
  2. cortisone weakens collagen fibers of tendon

III. Pathophysiology of Pes Planovalgus Deformity following tendon failure
- A. stretch of unsupported medial ligaments
- B. unopposed pull of peroneus brevis muscle
- C. pull of tendo-Achilles lateral to midline -----> results in pes planovalgus
- D. Pes Planovalgus Deformity
  1. hindfoot valgus
  2. midfoot pronation
  3. forefoot abduction
- E. Late changes
  1. lateral impingement (subtalar joint, calcaneofibular abutment)
  2. subtalar joint DJD and fixed deformity
  3. valgus tibiotalar tilt

IV. Stages of Clinical Presentation
- A. Stage I
  1. activity pain
  2. swelling, tenderness along PTT
  3. single limb heel rise (+/-)
  4. no deformity
- B. Stage II
  1. pain along PTT
  2. flexible pes planovalgus foot
  3. single limb heel rise test (+)
  4. +/- lateral impingement
- C. Stage III
  1. stiff, fixed deformity of subtalar or transverse tarsal joints
  2. lateral abutment pain
  3. DJD hindfoot
- D. Stage IV
  1. Severe stage II or III with deltoid ligament laxity and valgus tibiotalar tilt.

V. Radiographic Evaluation
- A. Standing Anteroposterior (AP) x-ray
  1. abducted forefoot
  2. lateral subluxation talonavicular joint (increased T-N coverage angle)
- B. Standing lateral x-ray
  1. midfoot sag (T-N, N-C,C-MT joints)
- C. Standing Anteroposterior ankle x-ray
  1. demonstrate calcaneofibular abutment
  2. rule out valgus tilt at tibiotalar joint
- D. Tenography
  1. invasive
  2. difficult to interpret
  3. correlates poorly with surgical findings
- E. MRI
  1. sensitive
  2. clearly defines anatomy
  3. useful when diagnosis in question
- F. Ultrasound
  1. tendon size, presence of fluid
  2. intratendinous echoic changes
  3. "live" exam
  4. cheaper, faster than MRI
  5. under investigation (?sensitivity, ?specificity)

VI. Treatment Overview
- A. Stage I (tendinitis, no deformity)
  1. Non-operative
     a. rest, short leg cast
     b. anti-inflammatory medications
     c. physical therapy
        Achilles stretching
        PTT resistive strengthening
     d. In-depth shoe, firm counter
     e. total contact insert with medial posting and firm arch support
     f. short custom AFO
  2. Operative
     If no response to nonoperative treatment in 3-4 months:
     a. exploration and debridement of tendon and synovial sheath
     b. tendon repair, tendon transfer augmentation
     c. consider adding a boney correction such as a medial displ. calc. osteotomy for patient with pre-existing flexible flatfeet with hindfoot valgus to reduce stress on repaired tendon
- B. Stage II (tendon degeneration with elongation, flexible deformity)

1. Non-operative
   a. NSAID
   b. corrective TCI, UCBL
   c. In-depth shoe, firm counter
   d. medial flare, wedge, stabilizer
   e. short custom molded AFO
      - short articulated AFO (R. Marzano-see ref.)
      - Arizona brace (E. Castro-see ref.)
2. Operative
   a. tendon repair with tendon transfer/augmentation using FDL (or FHL) - often fails when used alone
   b. arthrodesis (many different fusions described)
      1. subtalar
      2. talonavicular
      3. "double arthrodesis"= T-N and C-C
      4. triple arthrodesis (subtalar, T-N, C-C)
      5. lateral column lengthening C-C joint arthrodesis
      6. Combination of limited arthrodesis with tendon reconstruction
   c. medial displacement calcaneal osteotomy with tendon reconstruction
   d. Evans type calc.lengthening osteotomy with tendon reconstruction
   e. combined Evans type calc.lengthening osteotomy with medial displacement calcaneal osteotomy and tendon reconstruction

C. Stage III (fixed deformity, DJD)
1. Nonoperative
   a. accommodative TCI
   b. in-depth shoe with reconstructed last
   c. custom shoe
   d. AFO (styles: polypropylene,double upright, lace-up ankle gauntlet, short articulated)
2. Operative
   a. arthrodesis
      1. subtalar
      2. double (CC and TN)
      3. triple - usually required

VII. Adjunctive procedures for restoring foot alignment

A. Concept of the foot "tripod"
B. Medial column procedures for correction of residual forefoot varus. Procedure depends on location of deformity and status of involved joints:
1. First TMT joint fusion –(for severe TMT instability or DJD)
2. Plantarflexion opening wedge cuneiform-1 osteotomy with bone graft interposition (for normal or mild instability of TMT-1)
3. Reduction and arthrodesis naviculo-cuneiform joints.

C. Arthroresis of subtalar joint in conjunction with other boney and soft tissue procedures for severe (flexible) stage II.
— better correction of talocalcaneal relationship than forefoot abduction at the transverse tarsal joint?
— less morbidity?
— long-term results in adults lacking, but may have a role?

Operative Technique

VIII. Medial Displacement Calcaneal Osteotomy with Posterior Tibial Tendon Reconstruction with FDL Tendon Transfer

A. Indications
1. Stage II (flexible pes planovalgus)
2. Without DJD of subtalar jt.
3. Failure of nonoperative treatment (ie. persistent tenosynovitis/pain)
4. Combined with tendon debridement/reconstruction for Stage I IF pt. has pre-existing pes planovalgus feet

B. Contraindications
1. significant fixed forefoot varus (needs triple)
2. marked forefoot abduction (may need lateral column lengthening)
3. stiffness or DJD of hindfoot joints

C. Rationale
1. Medial shift of calcaneus reduces valgus moment arm of gastroc-soleus muscle
2. Heel valgus is corrected
3. Subtalar motion is preserved
4. Moment at ankle restored by FDL replacement of Post tib.

D. Technique
1. Address Achilles contracture if present (Percutaneous triple cut tendoachilles lengthening or gastroc slide)
2. Oblique lateral hindfoot incision posterior to peroneal tendons to expose lateral calcaneus (avoid sural n.)
3. Transverse osteotomy across body of calcaneus posterior to posterior facet
4. Displace tuberosity fragment medially approx. 7-12 mm. (Depending on amount of valgus)
5. Fix osteotomy with (2) 4.5 mm. screws from separate stab incision in posterior heel.
6. Medial soft tissue procedure performed through medial incision over course of PTT from medial malleolus to plantar edge of base of first MT.
7. Expose and debride PTT tear. Typically whole tendon is excised.
8. Expose medial talonavicular (TN) capsule and spring ligament (SL):
   —If torn-->debride edges of tear and place sutures to imbricate "pants over vest"....tag sutures
9. Harvest FDL tendon distal enough to reach thru drill hole in navicular.
10. Make 4.5mm. dorsal to plantar drill hole in navicular tuberosity and pull FDL into hole and tag sutures.
11. Tie sutures in TN capsule with foot held in inversion and plantar flexion.
12. Pull FDL taut thru hole in navicular and suture in place.
13. Cast x 4wks. in plantar flexion and inversion then bring to neutral in cast
14. At 6 wks. begin weight bearing in removable boot brace and begin physical therapy. At 10 wks. remove brace and wean into shoe with foot orthotic.

IX. Conclusions

1. Careful exam of patient important to determine staging and to identify all the components of the deformity. Questions the exam should answer:
   —P.T. tendon intact?
   —gastroc-soleus tight?
   —pes planovalgus deformity passively correctable?
   —how much heel valgus and forefoot abduction?
   —instability of the first ray?
   —significant forefoot varus?
   —ankle joint mortise intact (i.e., no talar tilt)?
2. Non Op treatment has a role, but proper bracing and PT program important
3. Choose a procedure that will adequately correct all the components of the deformity.
4. Treatment of the AFFD secondary to P.T.T.D. is a controversial area with the optimal treatments still being evaluated (and perhaps yet to be discovered).

REFERENCES

1. Alvarez RG, Marini AL: Posterior tibialis tendon dysfunction non-operative management. Presented at AOFAS Annual Meeting, Boston, MA, July 26, 1998.
2. Anderson RB, Davis WH: Calcaneocuboid distraction arthrodesis for the treatment of adult-acquired flatfoot: The Modified Evans procedure. Foot and Ankle Clinics 1:279- 294, 1996.
3. Astion DJ, Deland JT, Otis JC, Kenneally S. Motion of the hindfoot after simulated arthrodesis. J Bone Joint Surg 79A(2):241-6,1997.
4. Brage M, Adult Acquired Flat Foot Deformity. In: Foot And Ankle Clinics. Myerson, MS, ed., Philadelphia, PA: W.B. Saunders Company; 2003;8(3)
5. Chao W, Wapner KL, Lee TH, Adams J, Hecht PJ: Nonoperative management of posterior tibial tendon dysfunction. Foot Ankle 17(12): 736-741, 1996.
6. Clain MR and Baxter DE: Simultaneous calcaneocuboid and talonavicular fusion: long-term follow-up study. J. Bone and Joint Surg. [Br] 76:133-136, 1994.
7. Coetzee JC, Hansen Jr ST. Surgical management of severe deformity resulting from posterior tibial tendon dysfunction. Foot Ankle Int 22(12):944-9, 2001.
8. Cooper PS, Nowak MD, Shaer J. Calcaneo-cuboid joint pressures with lateral column lengthening (Evans) procedure. Foot Ankle Int 18(4):199-205, 1997.
9. Deland J, Otis JC, Lee KT, et al.: Lateral column lengthening with calcaneocuboid fusion: range of motion in the triple joint complex. Foot Ankle, 16(11):729-733, 1995.
10. Easley ME, Trnka HJ, Schon LC, et al. Isolated subtalar arthrodesis. J Bone Joint Surg 82A:613-24, 2000.
11. Evans DE: Calcaneo-valgus deformity. J Bone Joint Surg, 57B:270- 278, 1975.
12. Gazdag AR, Cracchiolo III A. Rupture of the posterior tibial tendon. Evaluation of injury of the spring ligament and clinical assessment of tendon transfer and ligament repair. J Bone Joint Surg, 79A:675-81, 1997
13. Graves S, Mann R, Graves K: Triple arthrodesis in older adults. J Bone Joint Surg, 75A, 355-362, 1993.
14. Hinterman B, Valderrabano V, Kundert HP. Lengthening of the lateral column and reconstruction of the medial soft tissue for treatment of acquired flat foot deformity associated with insufficiency of the posterior tibial tendon. Foot Ankle Int 20(10): 622-9, 1999.
15. Holmes GB, Mann RA: Possible epidemiological factors associated with rupture of the posterior tibial tendon. Foot and Ankle 13(2): 70-79, 1992
16. Johnson JE, Cohen BE, DiGiovanni BF, Lamdan R: Subtalar arthrodesis with flexor digitorum longus transfer and spring ligament repair for treatment of posterior tibial tendon insufficiency. Foot Ankle Int 21(9): 722-9, 2000.
17. Johnson KA, Strom DE: Tibialis posterior tendon dysfunction. Clin Orthop 239: 196-206, 1989.
18. Mann, RA: Rupture of the tibialis posterior tendon. AAOS Instructional Course Lecture, p. 302-309, 1984
19. Mann RA, Thompson FM: Rupture of the posterior tibial tendon causing flat foot -surgical treatment. JBJS 67-A: 556-561, 1985.
20. Marks, RM: Posterior Tibial Tendon Reconstruction with medial displacement calcaneal osteotomy. Foot and Ankle Clinics 1:295-313, 1996.
21. Mosier-LaClair S, Pomeroy G, Manoli A. Operative treatment of the difficult stage 2 adult acquired flat foot deformity. Foot Ankle Clin 6(1):95-119, 2001.
22. Myerson MS: Adult Acquired Flatfoot Deformity. JBJS 78-A(5): 780-792, 1996.
23. Myerson MS, Corrigan J, Thompson FM, Schon LC. Tendon transfer combined with calcaneal osteotomy for treatment of posterior tibial tendon insufficiency: a radiological investigation. Foot Ankle Int 16:712-8, 1995.
24. Myerson M, Solomon G, Shereff MJ: Posterior tibial tendon dysfunction: Its association with seronegative inflammatory disease. Foot Ankle 9(5): 1989.
25. O'Malley MJ, Deland JT, Lee KT. Selective hindfoot arthrodeses for the treatment of adult acquired flat foot deformity: an in vitro study. Foot Ankle Int 16(7):411-7, 1995.
26. Pedowitz WJ and Kovatis P: Flatfoot in the adult. J. of AAOS 3(5):293-302, 1995.
27. Phillips GE: A review of elongation of os calcis for flat feet. J Bone Joint Surg, 65B:15-18, 1983.
28. Sangeorzan BJ, Mosca V, Hansen ST,Jr: Effect of calcaneal lengthening on relationships among the hindfoot, midfoot, and forefoot. Foot and Ankle 14:136-141, 1993.
29. Teasdall RD, Johnson KA: Surgical treatment of Stage I posterior tibial tendon dysfunction. Foot and Ankle Intl. 15(12):646- 648, 1994.
30. Toolan BC, Sangeorzan BJ, Hansen Jr ST. Complex reconstruction for the treatment of dorsolateral peritalar subluxation of the foot. J Bone Joint Surg 81A:1545-60, 1999.

Short Articulated AFO:
Roger Marzano, C.P., C.Ped
Yanke Bionics
3975 Embassy Parkway, Ste. 001
Akron, Ohio 44313
216-668-4070

Arizona AFO:
Ernesto Castro, C.Ped.
Custom Footwear, Inc.
835 E. Southern, Ste. 1
Mesa, Arizona 85204
602-926-4130

Disorders of the Anterior Tibial & Flexor Hallucis Longus Tendons

AAOS 04 San Francisco Symp H

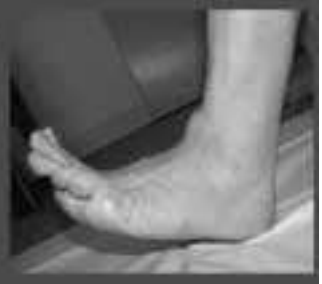
Lew Schon MD
Union Memorial Hospital
Baltimore, MD
USA

Tibialis Anterior Tendon

- Major dorsiflexor of ankle
- Origin: anterior proximal half upper 2/3 of the lateral tibial border and the anterior interosseous membrane
- Inserts: medial aspect of 1st cuneiform and 1st metatarsal
- Innervation from deep peroneal nerve (L4 and L5)

Tibialis Anterior Tendon

- Active in **heel strike phase** in an eccentric mode as it allows the ankle to slowly plantarflex until foot flat
- Active again in the **swing phase** in a concentric mode as it keeps the ankle dorsiflexed and the forefoot from dragging



•Petersen W, Stein V, Bobka T.: **Structure of the human tibialis anterior tendon. Journal of Anatomy, 197 Pt 4:617-25, 2000.**

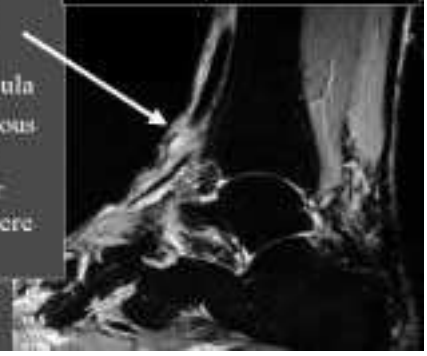
- The **structure** and **vascular** pattern of the tibialis anterior tendon was investigated using **injection** techniques, light and **transmission electron microscopy** and **immunohistochemistry**
- The **well-vascularized peritenon**, blood vessels penetrate the tendon and anastomose with a longitudinally oriented **intratendinous network**

•Petersen W, Stein V, Bobka T.: **Structure of the human tibialis anterior tendon. Journal of Anatomy, 197 Pt 4:617-25, 2000.**

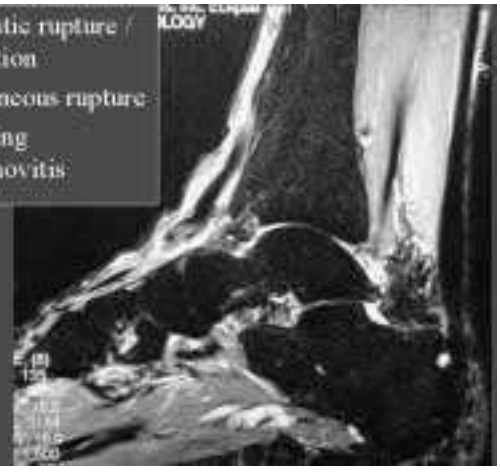
- The distribution of **blood vessels** was **not homogenous**
- The **posterior** tendon had a **complete vascular network** from the musculotendinous junction to the insertion at the first metatarsal and medial cuneiform
- In the **anterior** half, **avascular** zone length 45-67 mm

- The avascular zone is where the tibialis anterior tendon goes under the superior and inferior retinacula
- Most spontaneous ruptures of the tibialis anterior tendon occur here

•Petersen W, Stein V, Bobka T.: **Structure of the human tibialis anterior tendon. Journal of Anatomy, 197 Pt 4:617-25, 2000.**



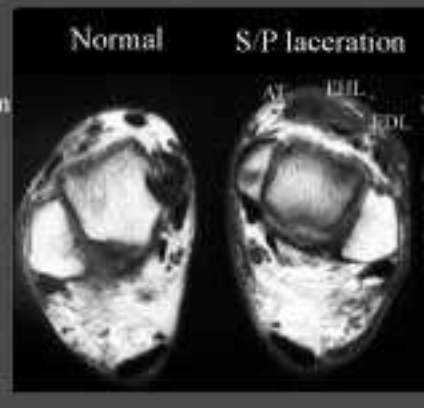
- Traumatic rupture / Laceration
- Spontaneous rupture
- Stenosing tenosynovitis



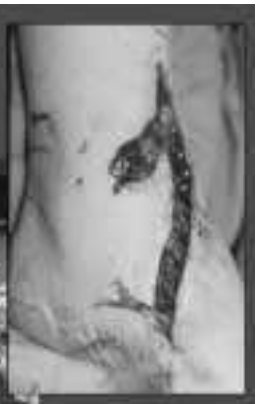
Acute Laceration

- From outside in
- Or inside out

Nirza MA, KoberKE Orthopaedics, 7/8 1329-1332, 1984

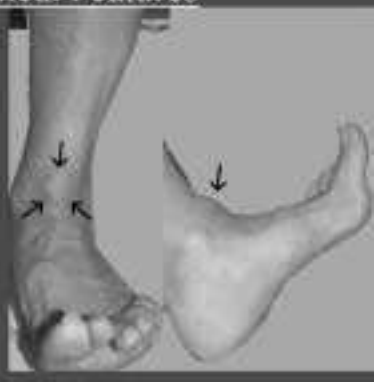


- Lacerations have been reported in hockey players



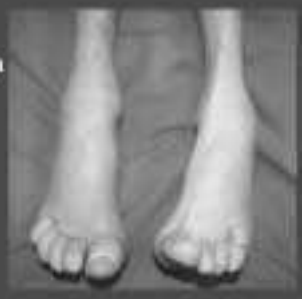
Tibialis Anterior Tendon: Clinical Features

- Weakness with foot dorsiflexion and with foot inversion (with ankle dorsiflexed)
- Fullness or a growing nodule typically located anterior to the ankle



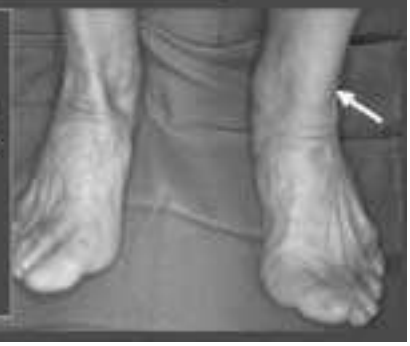
Tibialis Anterior Tendon

- Spontaneous ruptures are most commonly encountered 1.5 to 3 cm proximal to the insertion site
- Also reported at the musculotendinous junction



Tibialis Anterior Tendon: Clinical Features

- Pain along tendon
- Palpable defect along the course of the tendon
- Lack of definition of tendon



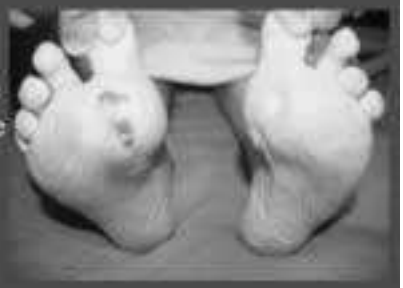
Tibialis Anterior Tendon

- Acute on chronic tears "spontaneous rupture":
  - Inflammatory arthritis
  - Impingement from osteophyte
  - Steroid injection
  - Diabetes
  - Gout

- Ouzounian T, Anderson R. 1995
- Richter R, Schlitt R. Subcutaneous rupture of the tibialis anterior tendon. Z Orthop. 133:271-273, 1975

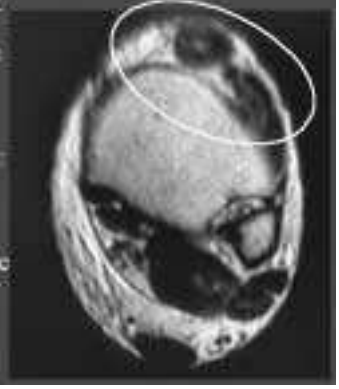
Tibialis Anterior Tendon: Clinical Features

- Fatigue
- Foot or toes catching on the ground: can see plantar ulcers
- Foot slap gait (Steppage)



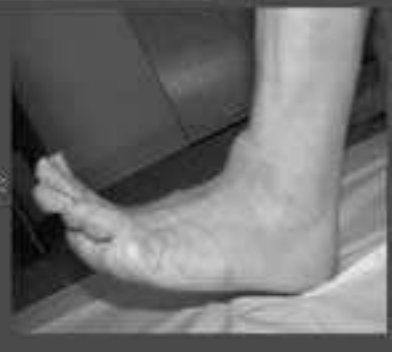
Tibialis Anterior Tendon: Clinical Features

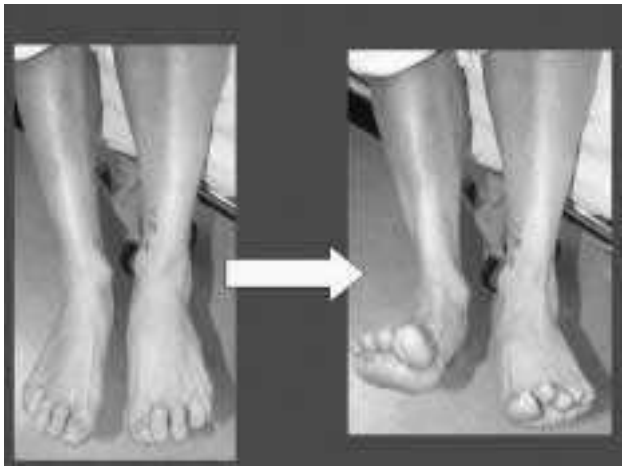
- Patients may be unable to recall a specific mechanism of injury
- In the older population slowly progressive with foot drop and swelling and pain in the anterior ankle



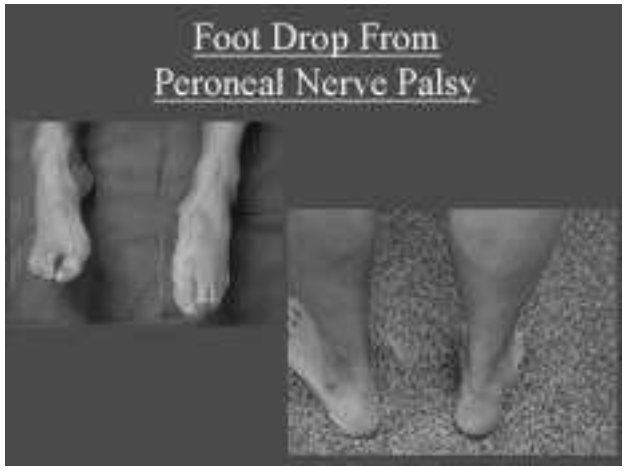
Tibialis Anterior Tendon: Clinical Features

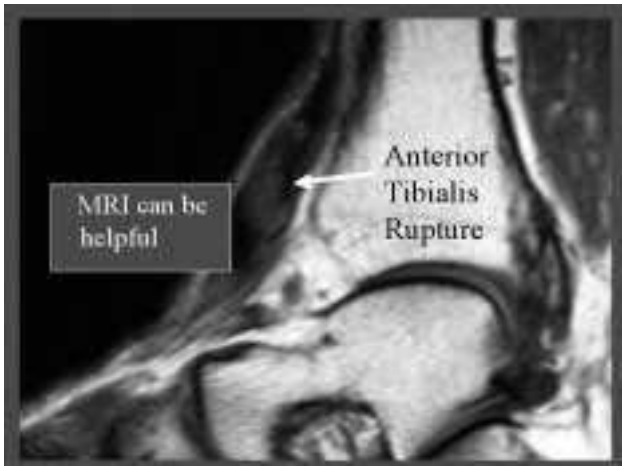
- Dorsiflexion can often be preserved
- Recruitment of other dorsiflexors: EHL and EDL





Foot Drop From Peroneal Nerve Palsy





Tibialis Anterior Tendon

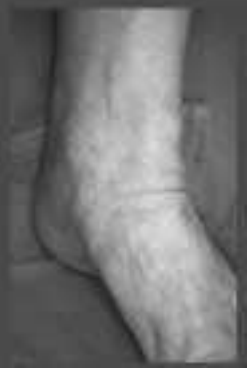
Treatment

- Achilles Stretching
- Strengthening of EHL, EDL
- AFO brace

Tibialis Anterior Tendon

Stenosing tenosynovitis

- Complain of pain and swelling
- Peritendinitis crepitance: rubbing or crackling sensation overlying the anterior ankle



Tibialis Anterior Tendon

Surgical Treatment

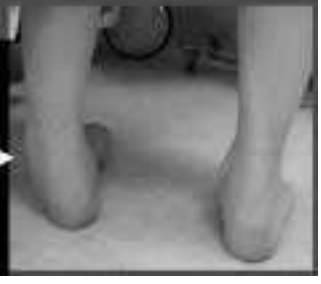
- Direct repair, if acute

Tibialis Anterior Tendon

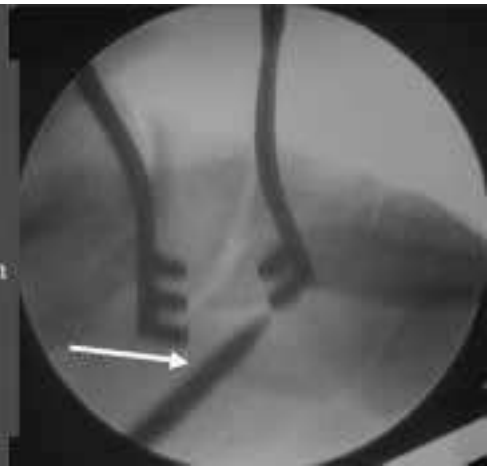
Differential diagnosis of spontaneous rupture:

- Peroneal nerve palsy
- Neoplasm
- Disc herniation

Note: The heel varus in conjunction with the weak dorsiflexion is indicative of involvement of the common peroneal nerve or higher nerve lesions



Suture anchor is inserted into medial cuneiform to reattach Tibialis Anterior



- Direct repair into medial cuneiform
- Or end-to-end anastamosis
- Brace for 3months: day and night
- Allow full weight bearing
- Stretch Achilles

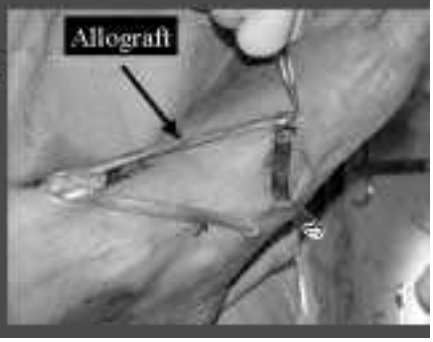
Anterior Tibial Tendon Ruptures: Results Of Surgical Treatment

- Morris,O'Malley, Deland, Gage, Backus
- Eight patients
- An average age 58 years
- Surgically repaired anterior tibial tendon ruptures
- Do not regain full dorsiflexion strength compared to the opposite unaffected ankle
- 75% of average peak torque, 62% of work capacity compared to contralateral side
- Not functionally impaired

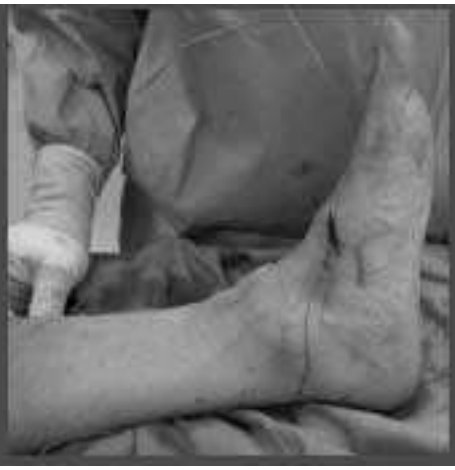
Tibialis Anterior Tendon

Treatment

- Chronic: re-approximation is difficult
  - –Turn down
  - –EHL graft
  - –Free graft



- Markarian GG, Kelikian AS, Brage M, Trainor T, Dias L.: **Anterior tibialis tendon ruptures**: an outcome analysis of operative versus non-operative treatment. Foot & Ankle Int. 19(12):792-802, 1998.
- This study analyzes the treatment of 16 **anterior tibialis tendon ruptures**
- Eight patients in this group had operative treatment of their **ruptures**, and eight patients had non-surgical treatment of their **ruptures**



- Markarian GG, Kelikian AS, Brage M, et al
- No statistically significant difference between operative and non-operative treatment
- May be a reflection of the age bimodality
- Elderly low demand pts treated non-surgically
- Young active pts treated operatively
- Increased incidence of toe deformities in the non-operative group (recruitment of the long toe extensors)
- Authors support the need to repair/reconstruct anterior tibialis tendon ruptures in young active patients with high functional demands

- Brace for 3months: day and night
- Allow full weight bearing
- Stretch Achilles

Ouzounian TJ, Anderson R.

Anterior tibial **tendon rupture.** Foot & Ankle Int. 16(7):406-10, 1995.

- 12 patients
- Nine patients were aware of an acute event
- Complete **rupture** of the **tendon** was noted in 10 patients
- Incomplete **rupture** was seen in two patients
- Treatment was individualized based on age, etiology, pre-injury function, patient health, and personal considerations

Ouzounian TJ, Anderson R.

- Five patients were treated without surgery
- Three preferred no orthotic devices, and two believed their function was improved with an ankle-foot orthosis
- Seven variety of individualized reconstructive techniques
- All operatively treated patients demonstrated increased function and strength
- Based on our findings, operative reconstruction is recommended in appropriate patients

Tibialis Anterior Tendon: Conclusion

- Diagnosis can be delayed
- MRI or Ultrasound may be helpful
- AFO with Achilles stretch for non operative
- Reinsertion of the **tendon** directly into bone or direct **tendon** repair is preferred
- After delayed diagnosis, secondary reconstruction with **tendon** transfer or graft is often necessary
- Some weakness may persist after surgery

Otte S, Klinger HM, Lorenz F, Haerer T.:
Operative treatment in case of a closed **rupture** of the **anterior** tibial **tendon.** Archives of Orthopaedic & trauma surgery. 122(3):188-90, 2002 Apr.

- Closed **rupture** of the tibial **anterior tendon** is a rare clinical entity

Trout BM, Hosey G, Wertheimer SJ.:
Rupture of the **tibialis anterior tendon**. Journal of foot & ankle surgery. 39(1):54-8, 2000 Jan-Feb

Flexor Hallucis Longus

- Origin: lower two thirds of the interosseous membrane and the periosteum of the fibula
- Posterior to talus
- Under sustentaculum
- Knot of Henry

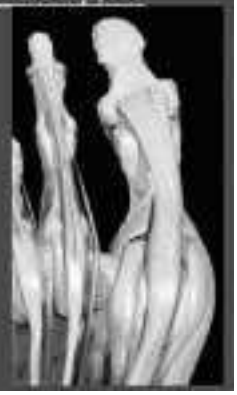
Patten A, Pun WK:
Rupture of the tibialis anterior tendon: a case report and literature review. Foot & Ankle Int. 21(8):697-700, 2000.

- Spontaneous rupture secondary to a gouty tophaceous deposit within the tendon

Velan GJ, Hendel D.: Degenerative tear of the tibialis anterior tendon after corticosteroid injection--augmentation with the extensor hallucis longus tendon, case report. Acta Orthopaedica Scand. 68(3):308-9, 1997.

Flexor Hallucis Longus

- Plantar to the FHB tendon and in between the sesamoids
- Insertion: the distal phalanx of the hallux



Kausch T, Rutt J.:
Subcutaneous **rupture** of the **tibialis anterior tendon**: review of the literature and a case report. Archives of Orthopaedic & Trauma Surgery. 117(4-5):290-3, 1998.

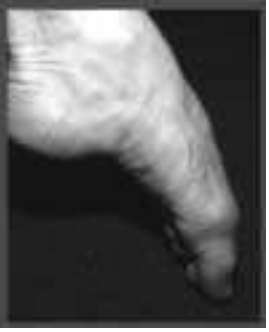
- Closed **rupture ant** tibial **tendon** is uncommon
- 33 cases being reported previously
- Late diagnosis is frequent
- The injury occurs in middle-aged and elderly patients after twisting of the foot in plantar flexion and eversion

Flexor Hallucis Longus: *Tenosynovitis*

- The etiology likely an overuse phenomenon (ballet dancers)
- Found following calcaneal fractures due to scarring of the FHL in the tunnel
- Other associated conditions are synovial hypertrophy, tendon nodularity, hypertrophy of the fibrotic stenotic tunnel, and a low-lying FHL muscle belly causing the same

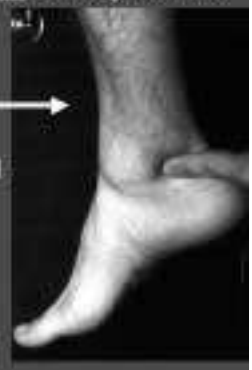
Flexor Hallucis Longus: *Tenosynovitis*

- Typically presents with pain in the posterior ankle, arch, or plantar aspect of the MTP joint
- Distinguishing between posterior ankle impingement (os trigonum, trigonal process) and FHL tendinitis is challenging because the two structures are close to one another and these conditions may coexist



Flexor Hallucis Longus: *Tenosynovitis*

- The point of maximum tenderness
  - Posteromedial in FHL tendinitis
  - Posterolateral with trigonal impingement



FHL: *Tenosynovitis*

- The trigonal or posterior ankle impingement usually occurs with passive full plantarflexion of the ankle, whereas FHL tendinitis does not

Flexor Hallucis Longus: *Tenosynovitis*

Tomassen's Sign

Prof. Elvind Tomassen, Arhus Denmark

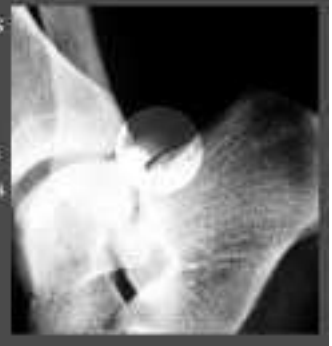
- **With dorsiflexion of the ankle**
- **Dorsiflexion of the 1st MPJ is lost**
- **Muscle fibers of the FHL are drawn into the FHL tunnel**
- **Temporary hallux rigidus**

Flexor Hallucis Longus: *Tenosynovitis*

- Dorsiflexion of the great toe while ankle is in the fully plantarflexed position does not usually induce symptoms in posterior ankle impingement but may in FHL tendinitis
- Palpate arch and ankle for crepitance

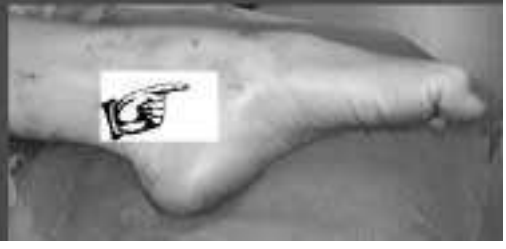
Flexor Hallucis Longus: *Tenosynovitis*

- Lateral ankle x-rays full plantarflexion
  - Abutment of trigonum between tibia and calcaneus
  - Subluxation of talus and tibiocalcaneal abutment
- Bone scan + in impingement



Flexor Hallucis Longus: *Tenosynovitis*

- Active plantarflexion of the great toe while ankle is in the fully plantarflexed position will usually increase symptoms in in FHL tendinitis
- Palpate arch and ankle for crepitance



Flexor Hallucis Longus: *Tenosynovitis*

Nonoperative treatment

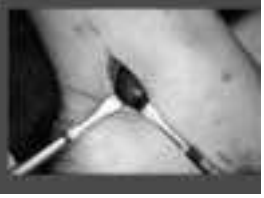
- Most often successful
- Rest (boot brace or cast) followed by a graduated physical therapy program
- NSAIDS
- Careful lidocaine or steroid injection occasionally

Flexor Hallucis Longus: *Tenosynovitis*

Operative treatment

- Release of the FHL fibroosseous tunnel with patient in the supine position

- A posteromedial incision is made along the course of the FHL tendon from behind the medial malleolus to just below the level of the sustentaculum



Flexor Hallucis Longus: *Tenosynovitis*

Operative treatment

- A symptomatic os trigonum, or posterior impingement needs resection
- The FHL and bundle are retracted posteriorly.
- Remove the os & shave edges
- Assess the resection by a lateral fluro image

Flexor Hallucis Longus: *Tenosynovitis*

Operative Treatment

- The neurovascular bundle is then identified. Usually it is easiest to retract the bundle posteriorly by dissecting anterior to it. The variable branching of the posterior tibial nerve is avoided this way.
- The FHL sheath is readily identified once the bundle is retracted. The fibroosseous sheath is entered sharply and released to its distal extent.

Results: Flexor Hallucis Longus: *Tenosynovitis*

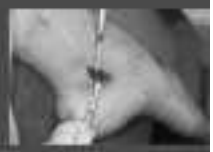
Sammarco GJ, Cooper PS. **FHL** Tendon Injury in Dancers & Nondancers. Foot & Ankle International, 19(6):356-62, 1998.

- 31 of FHL injuries in 26 patients (1977-1993)
- Dance-related injuries (group I) and other causes (group II)
- The two groups were compared
- Surgical treatment gave consistently good results

Flexor Hallucis Longus: *Tenosynovitis*

Operative treatment

- Ideally under local ankle block with IV sedation
- Dynamic evaluation of the release intra-operatively
- Determine that there is no further stenosis
- Occasionally triggering is still noted and all of the sheath has to be divided



- Hamilton WG, Geppert MJ, Thompson FM.: Pain in the posterior aspect of the ankle in dancers: differential diagnosis and operative treatment. *JBJS AM*. 78(10):1491-500, 1996.
- A retrospective review
- 37 dancers (41 operations)
- Follow-up 7 years
- 26 operations for tendinitis and posterior impingement
- 9 for isolated tendinitis
- 6 for isolated posterior impingement syndrome

- Occasionally there are FHL tendon tears
- Excise or repair tendon

- Medial incision 33 procedures
- Lateral incision 6 procedures
- Anterior and medial incision, in one
- Lateral and medial incisions, in one
- 30 ankles had a good or excellent result
- 6 fair result
- 4 poor result
- The result was good or excellent for 28/34 ankles in professional dancers, compared with 2/6 ankles in amateurs

Hamilton WG, Geppert MJ, Thompson FM. Pain in the posterior aspect of the ankle in dancers: differential diagnosis and operative treatment. JBJS Am. 78(10):1491-500, 1996.

- Kolettis GJ, Micheli LJ, Klein JD.: Release of the **flexor hallucis longus** tendon in ballet dancers. JBJS- Am, 78(9):1386-90, 1996.

- Thirteen female ballet dancers had an operative release of the **flexor hallucis longus** tendon because of isolated **stenosing** tenosynovitis
- All of the patients danced at the advanced or professional level, and all had failed to respond to non-operative management.

- Five cases had accompanying pathology
- Three cases responded to inflation of the tendon sheath with 1% lidocaine anesthesia
- The remainder required tenolysis of the sheath plus surgery to the accompanying pathology for relief
- Early recognition of this problem and prompt inflation with lidocaine may be the only required treatment if this is the only entity.
- Chronic cases will respond to tenolysis
- A plantar full visualization surgical approach is recommended

- All patients returned to dancing, within 5 months (range, 2-9 months), and 11 reached a level of full participation in dancing
- All patients noted improvement compared with the pre-operative condition
- 8 patients were professional ballet dancers
- 4 were students at advanced ballet schools
- One had stopped performing ballet for reasons unrelated to the tenosynovitis of the **flexor hallucis longus**

Kolettis GJ, Micheli LJ, Klein JD.: Release of the **flexor hallucis longus** tendon in ballet dancers. JBJBS- Am, 78(9):1386-90, 1996.

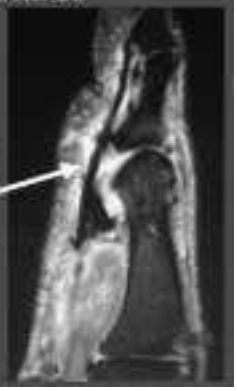
- Cowell HR, Elener V: Bilateral tendonitis of the FHL in a ballet dancer. J Ped Orthop, 2:582-586,1982.
- Fond D: FHL tendinitis- a case of mistaken identity and posterior impingement of syndrome in dancers: evaluation and management. J Orthop sports phys Ther, 5:204-206, 1984.
- Hamilton WG: Tendinitis about the ankle joint in classical ballet dancers. Am J sports med, 5:84-88,1977.
- Hamilton WG: **Stenosing** tenosynovitis of the FHL tendon and posterior impingement upon the os trigonum in ballet dancers. Foot & ankle, 3(2):74-80, 1982.
- Newman NM Fowles JV: A case of "trigger toe". Can J Surg, 27:378-379,1984.
- Rasmussen RB Thyssen EP: Rupture of the FHL tendon: a case report foot and ankle. 10:288-289, 1990.

Sanhudo JA, Lompa PA

- Checkrein deformity entrapment of the FHL following ankle and calcaneus fracture
  - Carranza-Benzaco, et al. Foot Ankle Surgery 2000 6:133-135.
  - Rosenberg, Sferra FAI 20:591-594,1999.
  - Carr J Orthop trauma 4:166-168,1990.
- The deformity increases with dorsiflexion and decreases with plantarflexion
- Release posterior medial ankle or in the arch of the foot

Flexor Hallucis Longus: *Lacerations Ruptures*

- Occurs infrequently
- Spontaneous rupture has also been reported
- Rule out: Plantar plate injury if suspecting distal FHL injury

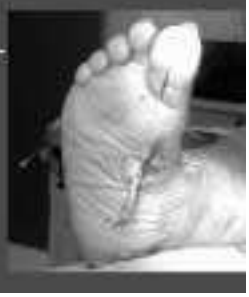


Gould N.: **Stenosing** tenosynovitis of the **flexor hallucis longus** tendon at the great toe. Foot & ankle, 2(1):46-8, 1981.

- Test the FHL with the ankle in neutral and the 1st MTP joint stabilized by the thumb….patient should be able to plantar flex the hallux
- Previously overlooked entity: **stenosing** in the sesamoid area
- Nine patients successfully treated
- An average 2 1/2-year follow-up
- Trauma seems to be the causative factor

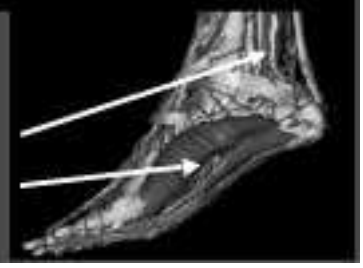
Flexor Hallucis Longus: *Lacerations Ruptures*

- Direct laceration can occur anywhere along the length of the tendon
- Deciding on operative vs non-operative management
  - The zone of injury
  - Etiology (spontaneous or traumatic)
  - Length of time since rupture



Petersen W, Pufe T, Zantop T, Paulsen F

Blood supply of the **flexor hallucis longus** tendon with regard to dancer's **tendinitis**: injection and immunohistochemical studies of cadaver tendons.
Foot & ankle international. 24(8):591-6, 2003



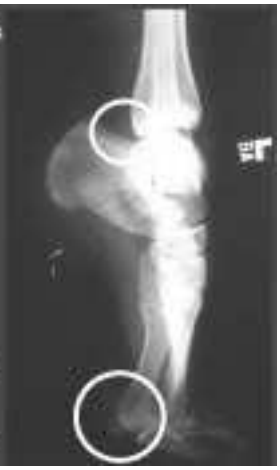
- Blood supply
  - Posterior tibial artery
  - Medial plantar artery

Flexor Hallucis Longus

Lacerations

- Our results no pull through is noted in a large percentage of cases we still feel that power is transferred with repair to the MP and the ankle joint as well
- Post-operative care includes immobilization for 4 weeks in a splint with early institution of passive flexion/active extension exercises

- Peritendinous blood vessels penetrated the tendon and anastomosed with a longitudinally oriented intratendinous network
- Two avascular zones by injection and immunohistochemistry :
  - Posterior talus
  - First metatarsal head
- These are the most typical areas for tendon degeneration and **rupture**



Scaduto AA, Cracchiolo A:
Lacerations and **ruptures** of the **flexor** or extensor **hallucis longus** tendons. Foot & Ankle Clinics. 5(3):725-36, 2000

- Not all tendon injuries of the hallux require repair
- The effectiveness of a repair will depends on the goals
  - Pain relief
  - Active joint motion
  - Correction of deformity

Flexor Hallucis Longus

Lacerations

- Results of repair are variable
- Repair of traumatic lacerations usually has a better outcome with respect to IP flexion than to spontaneous ruptures
- This is likely because of the pre-existing tendon degeneration that exists in the rupture cases and the increased difficulty of repair of frayed tendon ends vs those of sharp laceration

Flexor Hallucis Longus: Conclusions

- Stenosing tenosynovitis: post med pain in dancers
  - Rule out trigonal impingement
  - Release sheath
  - Beware nerve
- FHL rupture/ laceration:
  - Posterior ankle, arch, 1st MTP joint
  - Consider repair

Flexor Hallucis Longus

Lacerations

- Romash found in open tendon lacerations that were sutured 11 of 18 had active IP flexion
- In none of those treated operatively was there a significant deformity of flexion contraction or contracture of the MTP joint or IP joint
- Of the five open lacerations not sutured, only one needed a secondary procedure to correct IP deformity

Romash M. Closed rupture of the flexor hallucis longus tendon in a long distance runner: report of a case and review of the literature. Foot Ankle Int 15:433-436, 1994

CURRENT CONCEPTS IN THE MANAGEMENT OF DISTAL RADIUS FRACTURES (Q)

Moderator: David S. Ruch, MD, Winston-Salem, NC (e – Orthofix)

To present emerging principles and new ideas for the management of distal radius fractures. Specific concepts to be addressed include: an update on operative indications, techniques of reducing and maintaining articular surfaces, the management of bone loss, salvage of complex injuries and distal radio-ulnar joint. The goal of this symposium is to present evolving principles in the management of this common fracture. The panel will present a "case-oriented" approach to specific concepts including both operative and non-operative management. The panel will address changing operative indications with our aging population. The trend to open reduction and internal fixation will be examined, including identification and management of the major articular fragments with newer plate designs. The status of arthroscopy in these injuries will be addressed, as well as new techniques for the management of bone loss. Finally, the panel will address the spectrum of the distal radio-ulnar joint injuries seen with these fractures. The session will conclude with an open-microphone presentation of cases of distal radius fractures.

I. Evolution of Operative Indications
Jesse B. Jupiter, MD, Boston, MA (a – AO Foundation)

II. The Evolution of Plate Design
Andrew J. Weiland, MD, New York, NY (c, e – Wright Medical)

III. A Fragment-Specific Approach to Operative Intervention
Scott W. Wolfe, MD, New York, NY (b – TriMed)

IV. The Role of Arthroscopy
William B. Geissler, MD, Jackson, MS (e – Acumed)

V. New Techniques for Management of Bone Loss
Mark S. Cohen, MD, Chicago, IL (a – Kyphon, Inc)

VI. The Management of Distal Radio-Ulnar Joint Injuries Associated with Distal Radius Fractures
David S. Ruch, MD, Winston-Salem, NC (e – Orthofix)

OPERATIVE TREATMENT OF THE DISTAL RADIUS FRACTURE

Jesse Jupiter, MD

I. Evolution of Operative Management

a. Pattern Recognition
- Radiographic advances
  1. angled views to show articular surfaces
  2. CT
  3. 3D CT

Accuracy of CT proven in numerous published studies
- Fracture classification
  1. Eponymic
  2. Frykman—important for identifying DRUJ
  3. Melone—identified "medial complex" patterns
  4. AO/ASIF—the most comprehensive regarding patterns
  5. Fernandez—identified mechanisms of different patterns
  6. Universal—a treatment oriented classification

b. Structural Anatomy
- Column concepts
  1. Medoff—cortical columns, especially the radial column
  2. Rikli and Regazzoni
     a. included the unlnar as a column
     b. the column concepts have led to the approach of "fragment specific" fixation
- Carpal kinematics
  1. associated ligament injuries now well defined by arthrography and arthroscopy
- Distal radioulnar joint
- Type I—stable
- Type II—unstable
- Type III—potentially unstable

c. Implant Development
- Implants specific to the anatomy of the distal radius
- fragment fixation implants
- fixed angle implants
- locking bolts and screws
- Biologic advances
- cements
- bone substitutes

d. Outcome Assessments
- Physician rated/Patient rated
- DASH
- Patient rated evaluation
- Physical scale of the elderly

II. Which Fractures Need Operative Management

a. Complex Fractures
- Unstable
- Impacted articular
- Open
- Associated complex injuries
- Failed closed reduction

b. Volar Metaphyseal (Smith's) Fracture
- Pitfall—avoid dorsal translation of distal fragment

c. Volar Shearing
- Pitfall—most have 2 or more fragments
- Beware of a small medial fragment

d. Rotated Volar Lunate Facet
- Pitfall—often part of 4-part compression pattern
- Fragment may be rotated 180 degrees

e. High Energy Fracture-Dislocations
- Pitfall—may require combined approach

f. Combined Injuries
- Carpal fractures
- Compartment syndromes
- Unstable ulnar neck fractures

g. Fractures Seen Late
- "Nascent malunions"—may approach dorsal deformity from volar side

BIBLIOGRAPHY

1. Cooney WP, Berger RA. Treatment of complex fractures of the distal radius. Hand Clinics 1993; 9: 603–12.
2. Fernandez DL, Jupiter JB. Fractures of the distal radius. Second edition. New York, Springer 2001.
3. Fontes D, Lenoble E, de Somer B, et al. Lesions ligamentaires associees aux fractures distales du radius. Ann Chir Main; 11: 119–25.
4. Geissler WB, Freeland DL, Savoie FH et al. Intercarpal soft tissue lesions associated with an intraarticular fracture of the distal end of the radius. J Bone Joint Surg 1996; 78A: 357–65.
5. Hanker GJ. Arthroscopic evaluation of intraarticular distal radius fractures. In: Book of abstracts of the ASSH meeting, Orlando 1991.
6. Hixson ML, Fitzrandolph R, Andrew MM, et al. Acute ligament tears of the wrist associated with Colles' fractures. In: Book of abstracts of the ASSH meeting, Seattle, 1989.
7. Jupiter J, Lipton H. The operative treatment of intraarticular fractures of the distal radius. Clin Orth Rel Res 1992; 292: 48–61.
8. Jupiter J, Fernandez D, Toh C-L, Fellman T, Ring D. Operative treatment of volar intraarticular fractures of the distal end of the radius. J Bone Joint Surg 1996; 78A: 1817–23.
9. Knirk J, Jupiter J. Intraarticular fractures of the distal end of the radius in young adults. J Bone Joint Surg 1986; 68A: 647–59.
10. Medoff RJ, Koplyov P. Open reduction and immediate motion of intraarticular distal radius fractures with a fragment-specific fixation system. Arc Am Acad Orthop Surg 1999; 2: 53–61.
11. Melone CP. Open treatment for displaced articular fractures of the distal radius. Clin Orthop 1986; 202: 103–11.
12. Rikli DA, Regazzoni P. Fractures of the distal end of the radius treated by internal fixation and early function. J Bone Joint Surg 1996; 78B: 588–92.
13. Trumble T, Schmitt SR, Vedder NB. Factors affecting functional outcome of displaced intraarticular distal radius fractures. J Hand Surg 1994; 19A: 325–40.

EVOLUTION OF PLATE DESIGN

Andrew J. Weiland, MD

Treatment Goals
- Anatomic Reduction
- Achieved by a method that does not Compromise hand function
- Minimize morbidity

Internal Fixation
Advances --- Dorsal Plate
- Stress low profile
- Theoretically avoid problem with tendon irritation and rupture

Advances: Volar plates
- Contoured to the volar aspect of the distasl radius
- Locking screws with fixed angles

Internal Fixation
- A0 Plate systems (dorsal/volar)
  Pie Plate (dorsal)
  Fragment specific (dorsal/volar)
- Forte™ plate (dorsal)
- Avanta plate (volar/dorsal)
- DVR-locking screws (distal volar radius)
- LoCon T™ (dorsal/volar)
- Trimed Wrist Fixation (distal/volar/radial)

Trimed System
- Demanding-fragment specific
- Not for surgeon who does not frequently treat wrist fractures
- Innovative-reconstruct radial column

Avanta Plate
- Fixed prongs
- Dorsal and volar application

DVR-Hand Innovations
- unique, locked screws
- volar application stressed
- rigid fixation

Forte™ Plate
- first low profile dorsal plate-contoured to the distal radius

LoCon T ™ System
- Low profile-dorsal application
- Contoured to dorsal aspect of distal radius
- No tendon ruptures in over 150 applications-
  Two plates removed
- Volar locking plate introduced in 2004

SUMMARY
- Trend towards ORIF of distal radius fractures
- Low profile plates-dorsal application
- Volar plate-trend towards locking screws
  o Application for dorsally displaced fracture
  o Rigid fixation
- Fragment specific reduction
  o Tri Med System
  o New AO System
- Need for prospective randomized studies to determine which systems yield the best results

FRAGMENT SPECIFIC FIXATION AND EARLY RANGE OF MOTION

Scott W. Wolfe, MD

I. Treatment of distal radius fractures has evolved
- A. Better understanding of propensity of unstable fractures to displace in plaster
- B. Recognition of importance of augmentation using K-wires [1]
- C. Use of bone graft to support crushed metaphyseal component [2-6]
- D. Attention to individual unstable components of complex fractures
  1. "Fragment-specific" fixation[7]
  2. Bi-columnar fixation

II. External fixation relies on "Ligamentotaxis"[8]
- A. Distraction force through articular capsulo-ligamentous tissues (from Gr. "arrangement")
  1. Innovative use of technique previously reserved for long bone fractures [9]
  2. Described in hip, ankle, spine, knee, wrist
  3. Recommended for severe articular fractures not amenable to internal fixation
  4. "...a technique for reducing complex comminuted fractures, reconstructing articular surfaces and preserving joint space..."
- B. Widespread use for wrist fractures over last three decades
  1. Least effective for volar lip fragments [10]
  2. Ineffective for impacted articular fragments [2,11]

H Traction alone is insufficient to restore articular congruency

  3. Viscoelasticity of collagenous tissues precludes maintenance of effective traction
     1. stress relaxation
     2. Are there detrimental effects of excessive tension on ligaments? [12]
  4. Original Roger Anderson tenets frequently overlooked (1944) [13]
     a. Fracture reduction easy to attain, difficult to maintain
     b. Inevitable subsidence is due to metaphyseal crushing
     c. Distraction is necessary for 8-12 weeks
     d. Limited open reduction is required for articular fragments
     e. Bone graft all unstable fractures
  5. Complications of ligamentotaxis directly related to degree and duration of distraction [14]

H Without direct fixation, unstable fragments will tend to settle into injury position

III. Internal fixation
- A. Makes intuitive sense
  1. Improved outcomes of ORIF for articular fractures in upper and lower extremities
  2. Open reduction allows accurate assessment and reconstruction of joint surface
  3. Enables support of articular surface with bone graft [4]
  4. Rigid internal fixation facilitates early joint motion, benefits articular cartilage
  5. Removal of cast simplifies management of ipsilateral bony or ligament injuries
  6. Open reduction allows repair of associated intercarpal pathology
- B. Traditional fixation implants lack modular design
  1. Fail to capture smaller articular fragments
  2. Unable to secure radial styloid
  3. Use of dual plates (volar/dorsal) unable to compensate[15]
- C. Complications of ORIF attributable in large part to soft-tissue disruption
  1. Complication rate reported between 15-35%
     a. Early (infection, wound dehiscence, loss of reduction)[15,16]
     b. Late; including plate removal and tendon ruptures[16,17]
     c. Nonunion [18,19]
  2. Do "low profile" internal fixation systems reduce soft tissue complications?
     a. B plate: 13/22 satisfactory results, 23% tendonopathy, plate removal[20]
     b. Forte plate: 59/73 excellent results[21]
        i. 28% - unable to achieve rigid internal fixation intra-operatively
        ii. 12% loss of reduction during healing
        iii. 19% incidence of plate removal, tendonopathy
- D. Steady improvements in ORIF outcomes over past decade

Author	# Pts	Type	% Bone Grafted	% ROM Flex/ext	% Grip	Gartland & Werley
Axelrod, 1990	17	88% Frykman 7-8	55%	61%	83%	
Fernandez, 1991	40	33% AO C3	58%	94%	85%	
Missakian, 1992	32	88% Mayo III-IV	50%	80%	73%	87% G-E
Jupiter, 1993	13	85% AO C3	69%	74%	76%	
Fitoussi, 1997	34	50% AO C3	50%	80%	76%	82% G-E
Carter, 1998	60	78% AO C2-3	78%	82%	87%	94% G-E
Jakob, 1999	74	55% AO C2-3	52%	84%	85%	97% G-E

- E. Critical developments in past decade
  1. Appreciation of complex fracture patterns
  2. Biomechanical understanding of forces across fracture site
  3. Enhancement in hardware design
  4. Liberal use of bone graft

Bone graft all unstable distal radius fractures with impacted articular fragments

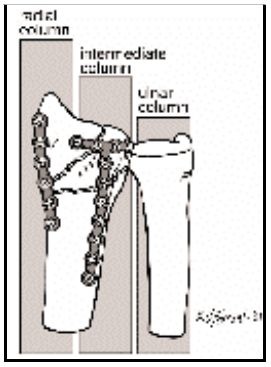
IV. Mechanical forces at fracture site can be substantial
- A. Unanticipated externally applied loads (shopping bags, driving, raking leaves etc.)
- B. Internal muscle forces
  1. Primary deforming forces on radial styloid fragment
     a. Pronator quadratus (rotates styloid into pronation)
     b. Abductor pollicis longus, EPB (shear force across fracture)
     c. Brachioradialis (inserts directly on styloid, causes subsidence)
  2. Estimated muscle loads vary considerably
     a. Physiologic muscle tone 40N [22,23]
     b. Active unresisted wrist motion 88-135N [24,25]
     c. "Upper limit" of wrist forces estimated at 50N [26]
  3. Grip forces generate extreme loads across wrist
     a. 26-52N generated across wrist for each 10N of hand grip [27]
     b. Average male generates upwards of 450N grip
     c. Upper limit of grip force = 2410N

Requirements: low profile implants, limited incision techniques, improved mechanics

V. Bicolumnar concept of internal fixation

A. Ultra-low profile implants placed strategically along wrist "columns" [28,29]
   1. Radial, intermediate and ulnar columns
   2. 2.0mm implants placed in two planes 50 - 70 degrees apart
      a. Dorsoradial (2nd comp.) supports styloid
      b. Dorsoulnar (4th comp.) resists dorsal angulation
   3. 74 fractures reported; majority complex AO C-type fractures
   4. Excellent or good results reported in 97% [28]
   5. 23% implant removal, 7% tendon rupture

B. Bicolumnar fixation compared to standard internal fixation [29]



   1. Orthogonal 2.0mm plates compared to Pi plate, dorsal T-plate
   2. 4-point bending over 100-400N applied force in three planes
   3. Bicolumnar fixation = incr. stiffness over Pi and dorsal T-plate ($p < 0.0001$)
   4. Decreased angle of deformation and gap formation

C. Trimed (Valencia, CA) implants; incorporates bicolumnar concept of fixation
   1. Minimizes disruption of soft tissue envelope
   2. Modular system permits "Fragment-specific fixation"
   3. Pin-plates augment stability of percutaneous Kirscher wires
   4. Support articular fragments with wire forms (small fragment clamp, buttress pins)
   5. Biplane fixation: plates placed in orthogonal relationship for maximal stability

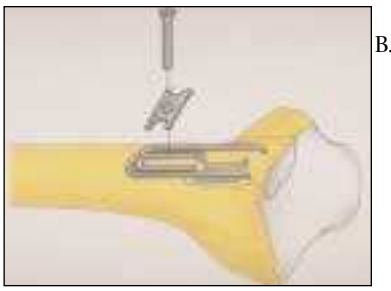
D. Biomechanical analysis: FSF compared to stability of augmented external fixation[30]
   1. Intra-articular fracture model
   2. Styloid pin plate, ulnar pin plate compared to fully augmented ext fixation
   3. 100 N load; 3N moment
   4. FSF wrists allowed to fully flex, extend under applied load
   5. Significant increases in stability during wrist motion when compared with ext fix

VI. Principles of Fragment-specific fixation (TriMed system)[31]

A. Reduce fracture through closed or limited open incisions
B. Bone graft metaphyseal defect
C. Preliminary fixation of radial styloid with 0.045 Kirschner wire
D. Support articular fragments with wire forms (small fragment clamp,buttress pins)
E. Apply pin-plates to augment stability of Kirschner wires
F. Tailor modular system to meet requirements of individual fracture pattern

VII. Specific columnar applications

A. Radial column
   1. Key supporting structure of fixation construct
   2. Restores length, facilitates articular surface realignment



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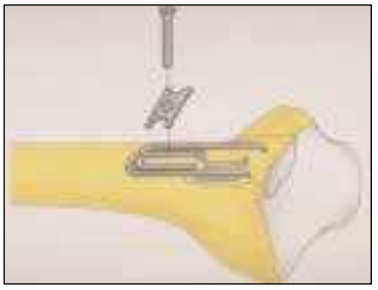
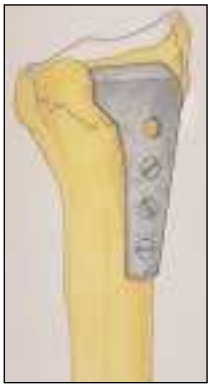
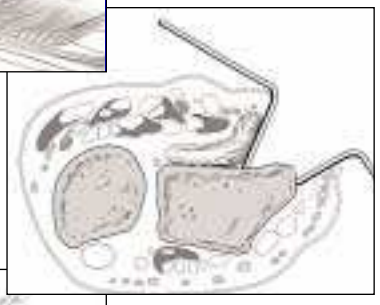




B. Intermediate column
   1 Modular implants to accomodate individual fracture configuration
   2. Precise restoration of sigmoid notch to restore DRUJ alignment
   3. Volar plate buttress of unstable shear components

Incision: radial and palmar implants



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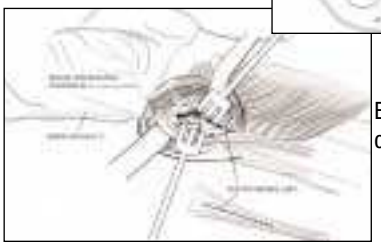


Exposure of palmar and radial cortex

C. Ulnar column
   1. Unstable ulna shaft or neck fractures require internal fixation
   2. Assess DRUJ stability at conclusion of fixation
   3. Grossly unstable joint usually implies bony and soft tissue components
      a. Anatomically reconstructed and aligned sigmoid notch is crucial
      b. Dorsal and palmar DRUJ ligaments & IOM insufficiency
   4. Surgical options
      a. Casting in position of maximum stability
      b. Fixation of ulnar styloid to restore DRUJ ligaments
         i. Single 0.045in K-wire placed through mini-open incision into ulnar styloid
         ii. Engage metaphysis of ulna

iii. Three hole Ulnar pin plate applied; fixed with two screws

c. Open TFCC repair to fovea

d. Cross pinning of radius to ulna in neutral position

i. Two 0.062" K-wires

ii. Penetrate all four cortices, leave prominent on radial cortex

iii. 4 weeks generally sufficient to restore soft tissue stability

REFERENCES

1. Seitz, W. H., Jr., Froimson AI, Leb R, Shapiro JD. Augmented external fixation of unstable distal radius fractures. J. Hand Surg. [Am]. 1991; 16:1010-1016.
2. Geissler, W. B., Fernandez DL. Percutaneous and limited open reduction of the articular surface of the distal radius. J. Orthop. Trauma. 1991; 5:255-264.
3. Leung, K. S., Shen WY, Leung PC, Kinninmonth AW, Chang JC, Chan GP. Ligamentotaxis and bone grafting for comminuted fractures of the distal radius. J. Bone Joint Surg. [Br]. 1989; 71:838-842.
4. Leung, K. S., Shen WY, Tsang HK, Chiu KH, Leung PC, Hung LK. An effective treatment of comminuted fractures of the distal radius. J. Hand Surg. [Am]. 1990; 15:11-17.
5. Leung, K. S., So WS, Chiu VD, Leung PC. Ligamentotaxis for comminuted distal radial fractures modified by primary cancellous grafting and functional bracing: long-term results. J. Orthop. Trauma. 1991; 5:265-271.
6. Wolfe, S. W., Pike L, Slade JF, III, Katz LD. Augmentation of distal radius fracture fixation with coralline hydroxyapatite bone graft substitute. J. Hand Surg [Am]. 1999; 24A:816-827.
7. Swigart, C. R., Wolfe SW. Limited incision open techniques for distal radius fracture management. Orthop. Clin. North Am. 2001; 32:317-328.
8. Vidal, J., J. Adrey, H. Connes, and C. Buscayret. 1979. A biomechanical study and clinical application of the use of Hoffman's external fixator. In External fixation: current state of the art. A. F. Brooker and C. C. Edwards, editors. Williams & Wilkins, Baltimore. 327-343.
9. Hoffmann, R. Rotules a os pour la reduction dirigee, non sanglante, des fractures (osteotaxis). Helv. Med. Acta. 1938; 5:844-856.
10. Bartosh, R. A., Saldana MJ. Intraarticular fractures of the distal radius: a cadaveric study to determine if ligamentotaxis restores radiopalmar tilt. J. Hand Surg. [Am]. 1990; 15:18-21.
11. Fernandez, D. L., Flurry MC. History, evolution and biomechanics of external fixation of the wrist. Injury 1994; 25:S-D1-S-D13.
12. Davenport, W. C., Miller G, Wright TW. Wrist ligament strain during external fixation: A cadaveric study. J. Hand Surg [Am]. 1999; 24A:102-107.
13. Anderson, R., O'Neil G. Comminuted fractures of the distal end of the radius. Surg. Gyn. Obstet. 1944; 78:434-442.
14. Kaempffe, F. A., Wheeler DR, Peimer CA, Hvisdak KS, Ceravolo J, Senall J. Severe fractures of the distal radius: effect of amount and duration of external fixator distraction on outcome. J. Hand Surg. [Am]. 1993; 18:33-41.
15. Fitoussi, F., Ip WY, Chow SP. Treatment of displaced intra-articular fractures of the distal end of the radius with plates. J. Bone Joint Surg Am. 1997; 79:1303-1312.
16. Axelrod, T. S., McMurtry RY. Open reduction and internal fixation of comminuted, intraarticular fractures of the distal radius. J. Hand Surg. [Am]. 1990; 15:1-11.
17. Kambouroglou, G. K., Axelrod TS. Complications of the AO/ASIF titanium distal radius plate system (pi plate) in internal fixation of the distal radius: a brief report. J. Hand Surg [Am]. 1998; 23:737-741.
18. Segalman, K. A., CLark GL. Un-united fractures of the distal radius: A report of 12 cases. J. Hand Surg. [Am]. 1998; 23A:914-919.
19. Smith, V. A., Wright TW. Nonunion of the distal radius. J. Hand Surg [Br]. 1999; 24:601-603.
20. Ring, D., Jupiter JB, Brennwald J, Buchler U, Hastings H, 2nd. Prospective multicenter trial of a plate for dorsal fixation of distal radius fractures. J. Hand Surg [Am]. 1997; 22:777-784.
21. Carter, P. R., Frederick HA, Laseter GF. Open reduction and internal fixation of unstable distal radius fractures with a low-profile plate: a multicenter study of 73 fractures. J. Hand Surg [Am]. 1998; 23:300-307.
22. Smith, D. K., An KN, Cooney WP, III, Linscheid RL, Chao EY. Effects of a scaphoid waist osteotomy on carpal kinematics. J. Orthop. Res. 1989; 7:590-598.
23. Ruby, L. K., Cooney WP, III, An KN, Linscheid RL, Chao EY. Relative motion of selected carpal bones: a kinematic analysis of the normal wrist. J. Hand Surg. [Am]. 1988; 13:1-10.
24. Hara, T., Horii E, An KN, Cooney WP, III, Linscheid RL, Chao EY. Force distribution across wrist joint: Application of pressure-sensitive conductive rubber. J. Hand Surg. [Am]. 1992; 17:339-347.
25. Short, W. H., Palmer AK, Werner FW, Murphy DJ. A biomechanical study of distal radial fractures. J. Hand Surg. [Am]. 1987; 12:529-534.
26. Simpson, N. S., Wilkinson R, Barbenel JC, Kinninmonth AW. External fixation of the distal radius. A biomechanical study. J. Hand Surg. [Br]. 1994; 19:188-192.
27. Putnam, M. D., Meyer NJ, Nelson EW, Gesensway D, Lewis JL. Distal radial metaphyseal forces in an extrinsic grip model: Implications for postfracture rehabilitation. J. Hand Surg [Am]. 2000; 25:469-475.
28. Jakob, M., Rikli DA, Regazzoni P. Fractures of the distal radius treated by internal fixation and early function. J. Bone Joint Surg. [Br]. 2000; 82B:340-344.
29. Peine, R., Rikli DA, Hoffmann R, Duda G, Regazzoni P. Comparison of three different plating techniques for the dorsum of the distal radius: A biomechanical study. J. Hand Surg [Am]. 2000; 25A:29-33.
30. Dodds, S. D., Cornelissen S, Jossan S, Wolfe SW. A Biomechanical Comparison of Fragment-Specific Fixation and Augmented External Fixation for Intra-articular Distal Radius Fractures. J. Hand Surg. 2002; 26A:
31. Barrie, K. A., Wolfe SW. Internal fixation for intraarticular distal radius fractures. Tech. Hand Upper Ext. Surg 2002; 6:10-20.

ADVANCES IN DISTAL RADIUS FRACTURE MANAGEMENT: COMBINING BONE CEMENT WITH BALLOON TAMP TECHNOLOGY

Mark S. Cohen, MD

I. BONE CEMENT
1. Bone Mineral Substitute
2. Carbonated Apatite
3. Physiological pH and Temperature
3. Biocompatible
4. Remodeling Potential
5. Working Time
   A. 3-5 Minutes
   B. Injection or Manual Packing
   C. Temperature Dependent
6. Setting Period
   A. 10 Minutes
   B. Monolithic Construct
   C. Crystallization
   D. Temperature Dependent
7. Curing Period
   A. 12 Hours
   B. Carbonated Apatite
8. Final Cement
   A. 5 Times Strength Cancellous Bone (Compression)
   B. Cell Mediated Remodeling

II. DISTAL RADIUS FRACTURE STUDY
1. Prospective Multicenter Design
2. Randomized
   A. Fracture Type (Intraarticular)
   B. Standard Treatment (Cast versus External Fixator)
   C. Dominance
   D. Bone Quality
3. Early Motion (Bone Cement)
4. Results – Cement Allows More Rapid Functional Recovery
5. Complications – Inadequate Metaphyseal Fill

III. BONE TAMP
1. Spinal Osteoporotic Compression Fractures
2. Methylmethacrylate
3. Compress Compromised Cancellous Bone
4. Reduce Fracture Deformity
5. Create Metaphyseal Cavity

IV. COMBINED TECHNOLOGY
1. Technique Developed
2. Biomechanical Cadaveric Study
3. Results - Balloon Tamp Equal or Superior to Open Cementing
4. Preliminary Clinical Results
5. Future Applications

REFERENCES

1. Belkoff SM, Mathis JM, Deramond H, Jasper LE: An ex-vivo Biomechanical Evaluation of a Hydroxyapatite Cement for use with Kyphoplasty, Am J Neuroradiol 22(6): 1212-6, 2001.
2. Cassidy C, Jupiter JB, Cohen MS, Delli-Santi M, Fennell C, Leinberry C, Husband J, Ladd A, Seitz W, Constanz B: Norian SRS Cement with Conventional Fixation in Distal Radius Fractures, J Bone Jont Surg 85A: 2172-35, 2003.
3. Cohen MS and Whitman K: Calcium Phosphate Bone Cement: The Norian Skeletal Repair System in Orthopaedic Surgery, AORN Journal, 65(5): 958-62, 1997.
4. Constance BR, Ison IC, Fulmer MT, et al.: Skeletal Repair by in situ Formation of the Mineral Phase of Bone, Science, 267: 1796-99, 1995.
5. Francis MD and Webb NC: Hydroxyapatite Formation from a Hydrated Calcium Phosphate Precursor, Calc Tissue Research, 6: 335-42, 1971.
6. Frankenburg EP, Goldstein SA, Bauer TW, et al.: Biomechanical and Histological Evaluation of a Calcium Phosphate Cement, J Bone Joint Surg 80A: 1112-24, 1998.
7. Fulmer MT, Martin RI and Brown PW: Formation of Calcium Deficient Hydroxyapatite at Near Physiologic Temperature, J Material Science, 3: 299-305, 1992.
8. Garfin SR, Yuan HA, Reiley MA: New Technologies in Spine: Kyphoplasty and Vertebroplasty for the Treatment of Painful Osteoporotic Compression Fractures, Spine 26(14): 1511-5, 2001.
9. Hayes DEE, Matthews JG, Poser RD, et al., Augmentation of Cementless Femoral Stems to Improve Initial Stability Using a Remodelable Calcium Phosphate Bone Mineral Substitute, AAOS, February 1994.
10. Hidaka N, Yamano Y, Kadoya Y, Nishimura N: Calcium Phosphate Bone Cement for Treatment of Distal Radius Fractures: A Preliminary Report, J Orthop Sci 7(2): 182-7, 2002.
11. Higgins TF, Dodds SD, Wolfe SW: A Biomechanical Analysis of Fixation of Intra-Articular Distal Radius Fractures with Calcium-Phosphate Bone Cement, J Bone Joint Surg 84A: 1579-86, 2002.
12. Husband J, Cassidy C, Leinberry C, Cohen MS et al.: Multicenter Clinical Trial of Norian SRS versus Conventional Therapy in the Treatment of Distal Radius Fractures, AAOS, February, 1997.
13. Jupiter JB, Winters S, Sigman S, Et al. Repair of Five Distal Radius Fractures with an Investigational Cancellous Bone Cement: A Preliminary Report, J Orthop Trauma, 11(2): 110-16, 1997.
14. Kopylov P, Jonsson K, Thorngren KG, Aspenberg P: Injectable Calcium Phosphate in the Treatment of Distal Radius Fractures, J Hand Surg 21B: 768-81, 1996.
15. Kopylov P, Runnqvist K, Jonsson K, Asperberg P: Norian SRS versus External Fixation in Redisplaced Distal Radius Fractures, Acta Orthop Scand 70(1): 1-5, 1999.
16. Ladd A, Pliam NB: The Role of Bone Graft and Alternatives in Unstable Distal Radius Fracture Treatment, Orthop Clin N America 30(2): 337-51, 2001.
17. Larsson S, Bauer TW: Use of Injectable Calcium Phosphate Cement for Fracture Fixation: A Review, Clin Orthop 395: 23-32, 2002.
18. Lieberman IH, Dudeney S, Reinhardt MK, Bell G: Initial Outcome and Efficacy of "Kyphoplasty" in the Treatment of Painful Osteoporotic Vertebral Compression Fractures, Spine 26(14): 1631-8, 2001.
19. Moore DC, Frankenburg EP, Goulet JA: Hip Screw Augmentation with an In-Situ Setting Calcium Phosphate Ceramic: An In-Vitro Biomechanical Analysis, Orthopaedic Research Society, February 1993.
20. Poser RD, Hayes DEE, Ladd AL, et al., Augmentation of Colles Fracture Fixation Using an Injectable In Situ Hardening Bioresorbable Calcium-Phosphate Bone Mineral Substitute, AAOS, February, 1994.
21. Putnam MD, Meyer NJ, Nelson EW, Gesensway D, Lewis JL: Distal Radial Metaphyseal Forces in an Extrinsic Grip Model: Implications for Postfracture Rehabilitation, J Hand Surg 25(3): 469-75, 2000.
22. Sanchez-Sotelo J, Munuera L, Madero R: Treatment of Fractures of the Distal Radius with a Remodellable Bone Cement, J Bone Joint Surg 82-B: 856-63, 2000.
23. Stankewich CJ, Swintowski MF, Tencer AF, et al. Augmentation of Femoral Neck Fracture Fixation with an Injectable Calcium-Phosphate Bone Mineral Cement, J Orthop Res 14: 786-93, 1996.
24. Verlaan JJ, van Helden WH, Oner FC, Verbout AJ, Dhert WJ: Balloon Vertebroplasty with Calcium Phosphate Cement Augmentation for Direct Restoration of Traumatic Thoracolumbar Vertebral Fractures, Spine 27(5): 543-8, 2002.
25. Yetkinler DN, Ladd Amy L, Poser Robert D, Constanz Brent R, Carter D: Biomechanical Evaluation of Fixation of Intra-articular Fractures of the Distal Part of the Radius in Cadavera: Kirschner Wires Compared with Calcium Phosphate Cement, J Bone Joint Surg 81(3): 391-9, 1999.

INTERNAL FIXATION OF DISTAL RADIUS FRACTURES "THE MANAGEMENT OF DRUJ INJURIES"

David S. Ruch, MD

I. Introduction

Outcomes following distal radius fractures must be assessed from an immediate functional perspective and a concern for future arthritis. The primary cause of immediate functional impairment for the wrist (not the hand) is failure to restore full painless forearm rotation.

Clinical Studies Reflect Increased Concern Over DRUJ Function

"DRUJ instability following distal radius fracture in young patients was associated with a poor wrist score and doubled the VAS 1."

II. Functional Anatomy

"Stability of the DRUJ primarily ligamentous, not boney."

A. Sigmoid Notch

Radius of curvature of radius (sigmoid notch) ª 47∞-80∞

Radius of curvature of ulna ª 90∞ - 135∞

At most, 20% of stability may be afforded by the articular congruity of the sigmoid notch 2.

B. Ligamentous Anatomy

1. The components of the TFCC:
   a. Palmar distal radioulnar ligaments
   b. Dorsal distal radioulnar ligament
   c. Articular disc
   d. ECU sub-sheath
   e. Ulno-carpal ligaments

C. Role of the DRUJ Ligaments in Stability Remains Controversial

1. Dorsal displacement of the ulna relative to the radius
   a. Major constraint: Palmar radio-ulnar ligament 2
   b. Major constraint: Dorsal radio-ulnar ligament 3
2. Palmar displacement of the ulna relative to the radius
   a. Major constraint: Dorsal radio-ulnar ligament 2
   b. Major constraint: Palmar radio-ulnar ligament 3.

"Most significant increases in translation occurred after sectioning of dorsal radioulnar ligament in pronator and after sectioning the palmar radioulnar ligament in supination4."

III. Role of the TFCC – Clinical Studies

A. Injuries to the TFCC occur in 26%-86% of distal radius fractures 5;6 Variation is dependent on fracture pattern and classification of injury.

B. "Peripheral tears of the TFCC cause DRUJ instability after distal radius fractures."

- 51 patients, median age 41 y
- 43/51 had partial or complete injuries to the TFCC
  – At one-year follow up, 10/11 had DRUJ instability at follow-up exam, compared with 7/32 with partial or no tears.

IV. Role of the Ulnar Styloid (specifically the base)

Ulnar styloid fracture with associated non-union is a strong predictor of a poor prognosis in young adult patients 7.

V. Role of Sigmoid Notch

Clinically little data

– Cadaveric Study

Osteotomy of the dorsal lunate facet does not result in statistically significant increase in palmar dorsal translation of the DRUJ with an intact palmar radioulnar ligament (Kuzma et.al., submitted).

References

1 Lindau, T., Hagberg, L., Adlercreutz, C, Jonsson, K., and Aspenberg, P. Distal Radioulnar Instability is an Independent Worsening Factor in Distal Radial Fractures. Clinial Orthopaedics and Related Research 376, 229-235. 2000.

2. Stuart, P. R., Berger, R. A., Linscheid, R. L., and An, K. N. The Dorsopalmar Stabillity of the Distal Radioulnar Joint. J Hand Surg (Am) 25A, 689-699. 2000.

3. Kihara, H., Short, W. H., Werner, F. W., Fortino, M. D., and Palmer, A. K.: The Stabilizing Mechanism of the Distal Radioulnar Joint During Pronation and Supination. The Journal of Hand Surgery. 20A:930-936, 1995.

4. Ward, L. D., Ambrose, C. G., Masson, M. V., and Levaro, F. The Role of the Distal Radioulnar Ligaments, Interosseous Membrane, and Joint Capsule in Distal Radioulnar Joint Stability. J Hand Surg 25[2], 341-351. 2000.

5. Geissler, W. B., Freeland, A. E., Savoie, F. H., McIntyre, L. W., and Whipple, T. L.: Intra-carpal soft tissue lesions associated with an intra-articular fracture of the distal end of the radius. J Bone Joint Surg (AM). 78:357-365, 1996.

6. Lindau, T., Aldercreutz, C., and Aspenberg, P.: Peripheral tears of the triangular fibrocartilage complex cause distal radioulnar joint instability after distal radius fractures. J Hand Surg (Am). 25:464-468, 2001.

7. Knirk, J. and Jupiter, J.: Intra-articular fractures of the distal and of the radius in young adults. J Bone and Joint Surg. 68:647-659, 1986.

◆ MANAGEMENT OF PEDIATRIC FRACTURES IN THE LOWER EXTREMITY: AN INTERNATIONAL PERSPECTIVE (F)

Moderator: Kamal N. Ibrahim, MD, Oakbrook Terrace, IL (n)

Pediatric trauma is a widespread global orthopaedic problem. This program was designed to review new treatments and perspectives with regard to some of the most commonly encountered pediatric trauma injuries. The program was also designed to be broadly appealing to US and international orthopaedic surgeons.

I. What's New in Growth Plate Injuries?
Julio de Pablos, MD, Pamplona, Spain (n)

II. Femoral Neck Fractures
Peter Engelhardt, MD, Berlin, Germany (n)

III. Polytrauma
Michael Bell, MD, Sheffield, United Kingdom (n)

IV. Pediatric Fractures: Foot and Ankle
Bertil Romanus, MD, Goeteborg, Sweden (n)

V. Knee and Tibia Fractures
Carol-Claus Hasler, MD, Basel, Switzerland (n)

VI. Femoral Shaft Fractures in Children
Klaus Parsch, MD, Stuttgart, Germany (n)

WHAT'S NEW IN PHYSEAL FRACTURES

J. de Pablos, MD

1. **Introduction.** Much of what we know now about Physeal Fractures was already written in John Poland's book "Traumatic Separation of the Epiphyses" (1898) (13). The physis is the "locus minoris resistentiae" of the immature bone. In children, it fails easier than the ligaments but, injuries to both structures may co-exist.

2. **Pathology.**
   - Histologically there are two main types of growth plate failure after trauma:
     - Metaphyseal-epiphyseal separation which most often takes place between the degenerative and provisional calcification physeal layers.
     - Longitudinal Physeal (transphyseal) fracture which can be macroscopic or microscopic and can co-exist with the former.
   - Premature Physeal Closure (PPC). Its mechanism remains controversial (9,15) but, it seems that, Physeal Bridges are more likely to appear after:
     - Transphyseal fractures or gaps that allow communication between the metaphyseal and epiphyseal blood circulations.
     - Interruption of the epiphyseal and/or metaphyseal blood supply, tipically in joints with completely intra-articular epiphyses (i.e. hip).
   - The widening of the physeal line often seen 2-3 weeks post-fracture is most probably due to a storage of physeal degenerative cells (3). Once the endochondral ossification is re-stablished at the provisional calcification layer the width of the physis returns to normal.

3. **Imaging**
   - Conventional X-Rays should always come first. Use oblique views when in doubt.
   - Stress X-rays should be abandoned.
   - MRI. High value imaging tool in physeal fractures, useful for:
     - Fracture detection and, perhaps, prognosis even in minimal injuries (6).
     - Determine fracture morphology and management.
     - Mapping of bony bridges and planning of surgery.
     - Important drawback: high sensibility (risk of false positives).
   - CT-scan, Ultrasounds, Isotopic scan, all are of limited value.

4. **Classifications.** Most based on Poland's from 1898 (13).
   - Salter & Harris (S&H) classification (1963) still the most popular (14). Controversies:
     - Prognostic value: A significant percentage of S&H I and II, particularly about the knee, produce growth disturbances due to PPC.
     - A few physeal fractures cannot be included in S&H classification. Peterson devised his own classification adding two more types (12).
     - Type V (compression) fractures. Whether it is "fact or fiction" still remains a question open for discussion but some are sceptical about its existence (11).
   - Especial types of Physeal Traumatic injuries
     - Stress Fractures due to repeated application of sub-maximal forces.
     - "Slow" Epiphysiolysis, most probably as a result of a mechanical joint imbalance.
     - Physeal fractures in adults, i.e. epiphysiolysis of the proximal clavicle which can mimic an esterno-clavicular dislocation.
     - Traumatic Vascular Injuries with intact physis, i.e. femoral neck fractures.

5. **Epidemiology.** 15-30% of all fractures in children (12). Now that contact sports have become very popular among girls, the differences between both genders are less dramatic. Nevertheless physeal fractures, especially at ages close to puberty, are still clearly more frequent among boys than in girls (ratio 2:1) which could probably be related to hormonal factors (3). S&H Type II is the most frequent (50% approx.).

6. **Management Principles**
   - Avoid Joint incongruency, Non-union and Growth disturbances by achieving good reduction/stable fixation.
   - Anatomic reduction should be the goal even in fractures with, "a priori", good prognosis (i.e. S&H I or II of the distal tibia) (1).
   - Minimize further (iatrogenic) physeal damage
   - Try not to use transphyseal fixation, if possible. Consider alternative methods which do not cross the physis (i.e. cannulated screws, external fixation…) since even well placed, thin and non-threaded K-wires can harm the growth plate.
   - Avoid multiple transphyseal perforations.
   - "Stress" fractures do usually well if identified early and overuse stops.
   - Prophylactic treatments, as Langenskiöld's operation (4), in the acute/subacute phase are very controversial, since prognosis is very difficult to establish at that time.

7. **Sequels of Physeal Fractures: PPC**
   - No close relationship with S&H classification.
   - Physeal fractures of the distal femur present growth disturbances in about 50% of cases; their S&H type has little prognostic value.
   - Important prognostic factors: age, location, energy of trauma, soft tissues integrity and adequacy of management.
   - MRI: able to detect very small transphyseal disruptions at the time of fracture (16) but difficult to establish a prognosis because of risk of false positives.

8. **Management of PPC**
   - Exceptionally, growth disturbances due to PPC improve spontaneously.
   - Langenskiöld's physeal bar excision (7)
     - Indication: young individuals (< 10 y.o.), <50% of physis closed (central) or 25% (peripheral).
     - Interposition material (IM): Use fat (7) or Cranioplast® (10) (Silastic® no longer used). IM should be fixed to the epiphysis (5). Insulin-like Growth Factor (8) and other IM are being used with promising experimental results.
     - Regeneration of the growth plate after this operation is controversial (5).
     - Drawback: Unpredictability.
   - Epiphysiodesis (Indications)
     - To complete physeal closure particularly in recurrent

angular deformities.
- On the contralateral side, to help compensate discrepancies.

– Leg Lengthening
- Useful to address length discrepancy and angular deformity simultaneously.
- Callotasis can be considered for mature individuals or immature with large PPC (>50%). Also, in recurrent angular deformities, it can be associated to a surgical completion of epiphysiodesis.
- Physeal distraction has clear advantages in adolescents and pre-adolescents with PPC of less than 50% in size, particularly in the tibia (2). Physeal bridges less than 50% can be disrupted just by distraction (no need for additional osteotomy of the bridge).

REFERENCES

1. Barmada A, Gaynor T, Mubarak SJ. Premature Physeal Closure Following Distal Tibia Physeal Fractures. J Pediatr Orthop 2003; 23: 733-9
2. De Pablos J. Bone Lengthening by Physeal Distraction. In: Surgery of the Growth Plate. Madrid, Ergon 1998 pp. 250-7
3. De Pablos J, Alfaro-Adrián C. Fractures of the Growth Plate. In: Surgery of the Growth Plate. In: Surgery of the Growth Plate. Madrid, Ergon 1998 pp. 143-70.
4. Foster BK, John B, Hasler C. Free fat Interpositional Graft in Acute Physeal Injuries: the Anticipatory Langeskiöld Procedure. J Pediatr Orthop 2000; 20:282-5.
5. Jouve JL, et al. Growth Plate Behavior After Desepiphysiodesis. J Pediatr. Orthop. 2003, 23:774-9.
6. Kasser JR (2003). Unpublished data.
7. Langeskiöld A. An Operation for Partial Closure of an Epiphyseal Plate in Children, and its Experimental Basis. J Bone Joint Surg (Br) 1975; 57: 325-30
8. Lee WX et al. Muscle-based Gene Therapy and Tissue Engineering for Treatment of Growth Plate Injuries. J Pediatr. Orthop 2002; 22:565-72.
9. Lee MA, Nissen TP, Otsuka NY. Utilization of a Musine Model to Investigate the Molecular Process of Transphyseal Bone Formation. J. Pediatr Orthop 2000; 20:802-6.
10. Peterson HA. Treatment of Physeal Bony Bridges by Means of Bridge Resection and Interposition of Cranioplast. In: de Pablos J, ed. Surgery of the Growth Plate. Madrid: Ediciones Ergon, 1998; pp 299-307.
11. Peterson HA, Burkhart SS. Compression Injury of the Epiphyseal Growth Plate. Fact or fiction? J Pediatr Orthop 1981; 1: 377-84.
12. Peterson HA, Mahok R, Benson JT, Ilstrup DM, Melton LJ. Physeal Fractures: Parts I, II and III. J Pediatr Orthop 1994; 14: 423-30
13. Poland J. Traumatic Separation of the Epiphyses. London: Smith, Elder & Co., 1898.
14. Salter RB, Harris WR. Injuries Involving the Epiphyseal Plate. J Bone Surg 1963; 45-A: 587-622.
15. Wattenbarger JM, Gruber HE, Phieffer LS. Physeal Fractures, Par I: Histologic features of Bone Cartilage and Bar Formation in a Small Animal Model. J Pediatr Orthop 2002; 22:703-9.

FEMORAL NECK FRACTURES

Prof. Dr. Peter W. Engelhardt

Frequency and Mechanism of Injury
Uncommon, violent force necessary. Highest incidence after 10 years of age. Stress fracture of the femoral neck possible. Slipped Capital Femoral Epiphysis (SCFE) could be misdiagnosed as fracture.

Classification
1. Transepiphyseal. Traumatic separation of a previously normal epiphysis
2. Transcervical. Mid-femoral neck
3. Cervicotrochanteric
4. Intertrochanteric (extracapsular)

Assessment
By plan x-rays, by CT for intracapsular haematoma. Bone Scan and NMR detect AVN.

Principles of Treatment
Emergency treatment. Anterolateral approach. Capsulotomy for evacuation of hematoma. Preliminary fixation with K-wires under fluoroscopic control. ORIF with anatomical precise reduction of the fragments. Stabilisation with pins or screws allowing early protected weight bearing. Avoidance of injury to the epiphyseal plate. Careful technique to minimize additional vascular complications.

Complications
Different patterns of AVN as a result from rupture or tamponade of the retinacular vessels.

Prognosis
Growth arrest, Coxa vara, Non-union, Osteoarthrosis may be seen on follow up. Individual evaluation and treatment mandatory.

REFERENCE

Engelhardt PW: Femoral neck fractures. In (Ed.) Benson MK, Fixsen JA, Macnicol MF, Parsch K.: Children's Orthopaedics and Fractures.Churchill Livingstone London, New York, Toronto 2002

POLYTRAUMA

Michael Bell, MD

I. Introduction
- Why bother
- Biggest killer in children
- MVA
- Passenger
- Pedestrian

II. Polytrauma in Children
- Children are individuals in their own right
- Children are not small adults

III. Differences
- Physiological
- Anatomical
- Psychological

IV. Physiological
- Heart rate
- Blood pressure
- Circulating volume
- Respiratory rate

V. Anatomy
- Small airway
- Nasal breathers
- Pliable rib cage
- Head size

VI. Management
- In tertiary centres
- ATLS
- APLS

VII. Management
- A Airway
- B Breathing
- C Circulation
- D Neurology
- S Support

VIII. Management
- Patient + family
- Limb
- Fracture

IX. Specific Problems
- Spine
- Pelvic injury
- Neurological injury
- Fracture sequelae
- Timing of Second look

X. Timing of second look
- Wait
- How long
- Why?

XI. Spine
- Sciwora
- ? clear spine
- Imaging
- Conscious patient

XII. Spine
- False positive
- High lesions
- Multiple levels

XIII. Polytrauma
- Long bone fractures
- Bone et al
- Indication for fracture stabilization

XIV. Pelvic Injuries
- Associated abdominal injuries
- Splenic injuries
- Save our spleen

XV. Save our Spleen
- 5 grades splenic injuries
- Costs of spleen removal
- Overwhelming infection

XVI. Pelvic Fracture
- ? delay fixation
- Pelvis
- Long bones

XVII. Neurological Injury
- Prevention of harm
- Aid recovery

XVIII. Neurological Injury
- Associated fractures
- Early stabilization
- Aid recovery

XIX. The Future
- Prevention better than cure
- Lap seat belts
- Traffic calming measures
- Daylight saving
- School planning

XX. Specific Fracture Problems
- Femoral neck fractures
- Bone loss
- Growth plate injuries

XXI. Specific Fracture Treatment
- Acute bone shortening
- Osteogenesis imperfecta
- Osteoporosis

KNEE AND TIBIA FRACTURES

Carol-Claudius Hasler, MD

1. **Intraarticular fractures of the distal femur**
   - Rare! Salter type III, IV and transitional fractures.
   - Treatment: open reduction and internal fixation (ORIF)if >2mm displacement
   - Complication: partial growth arrest

2. **Fractures of the patella**
   - Rare because of high proportion of shockabsorbing cartilage in children
   - Fracture types:avulsion fracture (extraarticular) of the medial patella retinaculum.
     Longitudinal, usually undisplaced
     Transverse, usually displaced. Exeptionally as stress fracture
     Sleeve fracture of the inferior pole, usually displaced.
   - Differential diagnosis: M.Sinding-Larsen-Johansson, Patella bipartita
   - Treatment: Tense hemarthrosis: aspiration
     Undisplaced fractures: cylinder cast for 4-5 weeks
     Displaced fractures: Tension band wiring and CPM
     Avulsion fragments: depends upon extent of separation of fragments.

3. **Fractures of the tibial spine**
   - The most common intra-articular fracture of the proximal tibia in children.
   - Prior to avulsion of the tibial spine the ACL stretches (plastic deformity) due to sequential failure of its fibres
   - Classification (Meyers and McKeevers):
     I undisplaced: Cylinder cast 4 weeks
     II partial displacement (posterior hinge): Closed reduction by extension. Arthroscopy if irreducible (e.g. impingement of intermenisceal ligament). Cylinder cast 4 weeks
     III Arthroscopic anatomical or even countersunk reduction and fixation.to compensate for ACL elongation.
   - Complication: Chronic anterior instability and loss of extension. Few subjective complaints if secondary restraints remain intact.

4. **Intraarticular physeal fractures of the proximal tibia**
   - Even more rare than at the distal femur. Patterns and treatment are the same.

   Special attention to concomitant ligamentous injuries!

5. **Epiphysiolysis of the proximal tibia** (Salter-Harris types I and II)
   - Rare. Indirect valgus force or forceful hyperextension (Cave: popliteal vessels!)
   - Treatment: Undisplaced: long-leg plaster for 5 weeks
     Displaced: correct malrotation and malalignment since remodelling is poor. High remodelling capacity for sagital malaligment in children <10 years.
   - Growth disturbances:rare. Usually caused by the trauma and therefore not Preventable.

6. **Avulsion of the tibial tuberosity**
   - Mostly adolescents. Violent quadriceps contraction e.g. landing after a jump
   - Size and displacement of the fragment often larger than visible on the X-ray.
   - Fracture types: Extraarticular: displaced if >5mm elevation
     Intraarticular (Salter-Harris-type III): displaced if >2mm step-off
   - Treatment :Undisplaced : Cylinder cast 5-6 weeks
     Displaced : ORIF after relief of periosteal flap under the avulsed fragment.
   - Complications :Partial growth arrest rare; genu recurvatum in young children

7. **Metaphyseal torus fractures of the proximal tibia**
   - Stable. No risk for secondary displacement or growth disturbance.
   - Treatment: Long-leg plaster for 4-5 weeks.

8. **Metaphyseal bending fractures of the proximal tibia**
   - Fracture types:Complete fracture
     Greenstick: bending of the lateral, complete fracture of the medial cortex. Often only slight valgus deformity
   - Treatment: Reduce valgus deformity with complete closure of medial gap
   - Complications: Greenstick fractures: Progressive valgus deformity due to delayed medial consolidation and partial stimulation of growth on the medial side.

9. **Diaphyseal fractures of the tibia**
   - Most frequent fracture of the lower extremity, initial angulation mostly <10°.
   - Secondary varus angulation in about 50% of the patients.
   - Remodelling capacity: Up to 15° varus, up to 20° recurvatum when age <10y.
   - Rotational deformities will persist.
   - Treatment: Long leg plaster 6-8 weeks for most fractures.
     Radiographic follow-up after 8-10 days. Wedging of plaster in case of Varus deformity.
     External fixation for completely displaced, unstable transverse, open fractures and in case of impending compartment syndrome.

10. **Diaphyseal fractures of the tibia and fibula**
    - Risk of secondary valgus deformity. No spontaneous remodelling.
    - Treatment: Intramedullary nailing or external fixation for unstable Fractures.

11. **Metaphyseal greenstick fractures of the distal tibia**
    - Impaction of the anterior border and complete fracture of the posterior cortex. Plaster application in slight plantarflexion necessary.

12. **Metaphyseal bending fractures of the distal tibia**
    - Same issues as proximal tibia but subtalar joint may compensate for mild Deformities.
    - Remodelling: up to 20° valgus, varus and recurvatum in patients <10 years of age.

REFERENCES

1. Burkhart SS, Peterson HA 1979 Fractures of the proximal tibial epiphysis. Journal of Bone and Joint Surgery 61-A:996-1002
2. Baxter MP, Wiley JJ 1988 Fractures of the tibial spine in children. An evaluation of knee stability. Journal of Bone and Joint Surgery 70-B:228-230
3. Grogan DP, Carey TP, Leffers D, Ogden JA 1990 Avulsion fractures of the patella. Journal of Pediatric Orthopaedics 10:721-730
4. Harries TJ, Lichtmann DM, Lonon WD 1983 Irreducible Salter Harris II fracture of the proximal tibia. Journal of Pediatric Orthopaedics 3:92-95
5. Janarv PM, Westblad P, Johansson C, Hirsch G 1995 Long-Term Follow-up of anterior tibial spine fractures in children. Journal of Pediatric Orthopaedics 15: 63-68
6. Maguire JK, Canale ST 1993 Fractures of the patella in children and adolescents. Journal of Pediatric Orthopaedics 13:567-571
7. Noyes FR, Delucas JL, Torvik PJ 1974 Biomechanics of anterior cruciate ligament failure: an analysis of strain-rate sensity and mechanisms of failure in primates. Journal of Bone and Joint Surgery 56-A:236-253
8. Ogden JA , Tross RB, Murphy MJ 1980 Fractures of the tibial tuberosity in adolescents. Journal of Bone and Joint Surgery 62-A:205-215
9. Shannak AO 1988 Tibial fractures in children: a follow-up study. Journal of Pediatric Orthopaedics 8:306-310
10. Smith JB 1984 Knee instability after fractures of the intercondylar eminence of the tibia. Journal of Pediatric Orthopedics 4:462-464
11. Teitz CC, Carter DR, Frankel VH 1980 Problems associated with tibial fractures with intact fibulae. Journal of Bone and Joint Surgery 62-A:770-776
12. Von Laer L, Kaelin L, Girard T 1989 Late results following shaft fractures of the lower extremities in the growth period. Zeitschrift für Unfallchirurgie und Versicherungsmedizin 82:209-215
13. Willis RB, Blokker C, Stoll TM, Paterson DC, Galpin RD 1993 Long-term follow-up of anterior tibial eminence fractures 13:361-364
14. Zionts LE, Harcke HAT, Brooks KM, MacEwen GD 1977 Post-traumatic tibia valga: a case demonstrating asymmetric activity at the proximal growth plate on technetium bone scan. Journal of Pediatric Orthopaedics 7: 458-462

FEMORAL SHAFT FRACTURES

Klaus Parsch, MD

I Introduction
- Considerable move from conservative to surgical treatment during the last ten years
- 10 % of orthopedic malpractice judgements in the USA (1996) have been in pediatric femoral fractures

II Management depends
- Age of patient
- Severity of trauma

III Spica cast treatment
- Children from 0 - 5 years for transverse, oblique or spiral fractures
- Reduction under general anesthesia, shortening of 1-2 cm can be accepted
- In the first year of life 70°/70° spica cast for transverse fractures
- In the kindergarten and pre-school age group 40° / 40° spica cast
- 0° abduction for the involved side, comfortable abduction for healthy side
- Spica cast for 3-6 weeks depending on age of patient

IV Alternative to spica cast in pre-school children
- 3 - 5 weeks traction: OUT (too uncomfortable, too expensive!)
- Intramedullary nails or wires: Not necessary in this age group
- External fixator: Too uncomfortable, complications
- Plating OUT (infection risk, scar, overgrowth)

V Standard treatment for school children with open physis
- Closed reduction
- Intramedullary stabilization with elastic nails with olive end
- No additional cast, immediate mobilization

VI Advantages with intramedullary stabilization using elastic titanium nails
- Minimal invasive procedure
- Closed reduction
- Early mobilization
- Short hospital stay
- Early weight bearing

VII Intraoperative problems while using elastic nails, and how to avoid:
- Correct measurement of nail length and nail diameter (2,0 to 4,0 mm)
- Use of traction table to avoid problems during reduction in OR
- Correct rotation to be controlled before child wakes up
- Skin incision distal to metaphyseal entry point to avoid skin break-down
- Retrograde pinning fort proximal and midshaft fractures for 3 point fixation
- Antegrade pinning for distal fractures for 3 point fixation

VIII Problems with intramedullary elastic titanium nails
- Insufficient stability in comminuted fractures
- Bursitis at entry point with sharp cut off ends (nails without olive)
- Overgrowth of femur after anatomic closed reduction (average 0,5 cm)

IX Alternative to elastic titanium nails
- Traction : Uncomfortable in hospital or at home, risk of compartment syndrome Spica cast: Rather uncomfortable in school age, risk of shortening
- External fixator: relatively high complication rate even in experienced hands.

Use only in open fractures
- Interlocking nail: more invasive, more blood loss, risk of AVN of femoral head

X When to use elastic intramedullary titanium nails?
- proximal, mid-shaft or distal fracture in age group 5-14 (Closure of growth plate)
- Proximal and mid-shaft fracture treated by retrograde nails
- Distal fractures treated by antegrade nails
- Comminuted fractures need delayed weight bearing
- Do not use the device in 2nd and 3 rd degree open fractures

REFERENCES

1. Dietz HG, Schmittenbecher PP, Illing P. Intramedulläre Osteosynthese im Wachstumsalter Urban & Schwarzenberg München-Wien Baltimore 1997 pp 135-168
2. Bar-on E, Sagiv S, Porat S. External fixation or flexible intramedullary nailing for femoral shaft fractures in children. J Bone Joint Surg 1997; 79 B: 975-978
3. Carey TP, Galpin RD. Flexible intramedullary nail fixation of pediatric femoral fractures. Clin Orthop Rel Res 1996; 332: 110-118
4. Flynn JM, Hresko T, Reynolds RA, Blasier RD, Davidson R, Kasser J. Titanium elastic nails for pediatric femur fractures: a multi-center study of early results with analysis of complications. J Pediatr Orthop 2001; 21: 4-8
5. Heinrich SD, Drvaric D, Darr K, MacEwen GD: The operative stabilization of pediatric femoral fractures with flexible intramedullary nails: a prospective analysis. J Pediatr Orthop 1994; 14: 501-507
6. Ligier JN, Metaizeau JP, Prévot J, Lascombe P : Elastic stable intramedullary nailing of femoral shaft fractures in children. J. Bone Joint Surg 1988; 70A: 74-77
7. Metaizeau JP: Ostéosynthèse chez l'enfant. Embrochage centromédullaire élastique stable. Montpellier, Sauramps 1988 pp 77-84
8. Parsch K : Modern trends in internal fixation of femoral shaft fractures in children : A critical review. J Pediatr Orthop part B 1997; 6: 117-125
9. Parsch K: Fractures of the femoral shaft. In: Benson MKD, Fixson JA, Macnicol MF, Parsch K (ed): Children's Orthopaedics and Fractures. London, New York, Churchill Livingstone 2002 pp 640-646

UPPER EXTREMITY PEDIATRIC FRACTURES: OPERATIVE TECHNIQUES – AVOIDING PROBLEMS WITH PROBLEM FRACTURES (J)

Moderator: James H. Beaty, MD, Memphis, TN (n)

Choice of the appropriate procedure and meticulous surgical technique are essential to avoid complications after "problem" upper extremity fractures in children. Review of the surgical indications and options, combined with operative procedures highlighting technique tips, will help participants decrease the risk of complications after fractures of the upper extremity in children.

I. Fractures of the Lateral and Medial Humeral Epicondyles, T-Condylar Fractures
James R. Kasser, MD, Boston, MA (n)

II. Supracondylar Humeral Fractures
Vernon T. Tolo, MD, Los Angeles, CA (n)

III. Fractures of the Forearm
Charles T. Price, MD, Orlando, FL (n)

IV. Fractures About the Shoulder
R. Jay Cummings, MD, Jacksonville, FL (n)

V. Fractures of the Radial Head and Neck, Monteggia and Intraarticular Fractures of the Humerus
John M. Flynn, MD, Philadelphia, PA (n)

FRACTURES OF THE LATERAL AND MEDIAL HUMERAL EPICONDYLES, T-CONDYLAR FRACTURES

James R. Kasser, MD

LATERAL CONDYLE FRACTURE

Fractures of the lateral condyle of the distal humerus occur at average age 6. These represent 16.9% of distal humeral fractures in children with supracondylar being by far the most common. The fracture generally:

1) Includes a small metaphyseal fragment laterally
2) Exits through the distal humeral epiphysis either through the capitellum (Milch I) or into the cartilaginous portion of the epiphysis (Milch II)
3) The fracture may exit through the trochlea with lateral displacement of the ulna

Stage of Displacement:

1) Articular surface intact = hinged fragment and rather stable
2) Articular surface disrupted - unstable fracture with lateral translation

Problems:

1) Identification of the fracture:
   a) high suspicion with lateral tenderness in appropriate age child
   b) plain x-ray with oblique views
   c) ultrasound, MRI and arthrogram
   d) follow up x-ray out of splint in one week
2) Non-union:
   a) < 2mm displacement - all fractures heal
   b) 2-5mm displacement - 85% heal with immobilization
   c) > 5mm displacement - non union and malunion are frequent and expected requiring operative intervention always

Treatment:

1) Cast immobilization - best for fractures displaced 0-2 mm which are hinged. Perhaps in the 2-5 mm group the stage I or hinged fractures could be managed simply in a cast. Look for "triangular" shaped displacement zone with no lateral translation to identify these stable fractures. Frequent x-rays are required to document healing.
2) Percutaneous pinning - best in the 2-5 mm displaced group where problems with non-union increase in frequency. The pins are placed under x-ray control and the anatomic appearance of the articular surface is documented with arthrography. I do the arthrogram after pinning and I use either 062 or 5/64 pins to stabilize the fracture.
3) Open reduction - this is the standard for all lateral condyle fractures displaced > 5 mm or those that demonstrate instability based on lateral translation < 5mm. Lateral approach is used through the fracture site taking down the periosteum and capsule anteriorly and minimum amount of extensor musculature off the fragment. Anatomic reduction is documented visually and radiologically and the fracture is stabilized with two pins.

Complications:

1) Growth inhibition with non-union, valgus deformity and tardy ulnar nerve palsy
2) Growth acceleration with varus deformity
3) Trochlear avascular necrosis with varus deformity
4) Stiffness with flexion deformity

MEDIAL CONDYLE FRACTURES.

1) Age of occurrence 8 to 14 years old greater than lateral epicondyle fractures.
2) It may appear like a medial epicondyle fracture. Characteristically the medial epicondyle goes with the medial condyle when displaced.
3) Valgus stress or fall on the ulna with the olecranon splitting the medial condyle is the mechanism of injury.
4) The major problem with this fracture is awareness of it given its rarity. Making the diagnosis is critical to proper management.
5) Treatment:
   a) Non-displaced fractures may be treated in a cast expecting normal healing.
   b) Displaced fractures require open reduction internal fixation through an anteromedial or medial approach to the elbow.

MEDIAL EPICONDYLE FRACTURES

Facts:

1) Incidence is 14% of distal humeral fractures. 79% of those sustaining this fracture are males. It is associated with elbow dislocation in a high proportion of cases. The age of occurrence is 9 to 14 yeas of age.
2) This is an apophyseal fracture connected to the distal humeral metaphysis not to the distal humeral epiphysis.
3) The flexor pronator group inserts into the medial epicondyle.
4) The ulnar collateral ligament inserts into the metaphysis and the apophysis.
5) Treatment:
   a) Minimally displaced or non-displaced fractures are generally treated with immobilization for a brief period of time generally three weeks followed by an active exercise program.
   b) Fractures associated with gross instability and elbow dislocation particularly if the medial epicondyle remains entrapped should be treated with open reduction internal fixation of the epicondylar fragment and reduction of the elbow.
   c) Avulsed fragments greater than 5mm remain an area of controversy. At the present time such fractures occurring in a dominant arm of an athlete are generally repaired. The question remains open as to whether repair should be done. Most recent study indicated repair was not necessary and results were not influenced by open reduction internal fixation or by union of the fragment. Clearly excision of the fragment is wrong.

REFERENCES

Lateral Condyle Fracture

1. Badelon O, Bensahel H, Mazda K, et al. Lateral humeral condylar fractures in children: a report of 27 cases. J Pediatr Orthop 1988; 8:31-34.
2. Bast SC, Hoffer MM, Aval S. Nonoperative treatment for minimally and non-displaced lateral humeral condyle fractures in children. J Pediatr Orthop 19989; 18:448-450.
3. Flynn, JC, Richards JF, Saltzman RI. Prevention and treatment of non-union of slightly displaced fractures of the lateral humeral condyle in children. J Bone Joint Surg [Am] 1975; 57:1087-1092.
4. Foster DE, Sullivan JA, Gross RH. Lateral humeral condylar fractures in children. J Pediatr Orthop 1985; 5:16-22.
5. Herring JA. Lateral condylar fracture of the elbow. J Pediatr Orthop 1986; 6:724-727.
6. Mintzer CM, Waters PM, Brown DJ, et al. Percutaneous pinning in the treatment of displaced lateral condyle fractures. J Pediatr Orthop1994; 14:462-465.
7. Morrissy RT, Wilkins KE. Deformity following distal humeral fracture in childhood. J Bone Joint Surg [Am] 1984; 66:557-562.

Medial Condyle Fractures

1. Fahey JJ, O'Brien E. Fracture-Separation of the medial humeral condyle in a child confused with fracture of the medial epicondyle. J Bone Joint Surg 1971; 53:1102.
2. Fowles, JV, Kassab MT. Displaced fractures of the medial humeral condyle in children, J Bone Joint Surg 1980; 62:1159-1163.
3. Hasner E, Husby J. Fracture of epicondyle and condyle of humerus. Acta Chir Scand 1951; 101:195-203.
4. Papavasiliou V, Nenopoulos S, Venturis T. Fractures of the medial condyle of the humerus in childhood. J. Pediatr Orthop 1987; 7:421-423.

Medial Epicondyle Fractures

1. Albright JA, Clinical studies of baseball players: correlation of injury to throwing arm with method of delivery. Am J Sports Med 1978; 6:15.
2. Dias JJ, Johnson GV, Hoskinson J, et al. Management of severely displaced medial epicondyle fractures. J Orthop Trauma 1987; 1:59-62.
3. Fowles, JV, Slimane N, Kassab MT. Elbow dislocation with avulsion of the medial humeral epicondyle. J Bone Joint Surg [Br] 1990; 72B: 102-104.
4. Pappas, AM. Elbow problems associated with baseball during childhood and adolescence. Clin Orthop 1982; 164:30-41.
5. Woods GM, Tullos HG. Elbow instability and medial epicondyle fracture. Am J Sports Med 1977; 5:23-30.

SUPRACONDYLAR FRACTURE OF THE HUMERUS

Vernon T. Tolo, MD

Supracondylar fractures of the humerus
- 70% of elbow fractures in children
- Over 95% extension type, flexion type harder to treat
- Mean age about 6 years
- Careful neurologic and vascular exam at initial presentation
  - Status before reduction is key
  - Associated injuries:
    - Vascular from brachial artery injury
      - If no pulse and hand cool, partially reduce and extend
        - Urgent trip to OR even if pulse returns
        - Arteriogram in OR vs. artery exploration if no pulse
          - --intimal tear
          - --caught in fracture site
  - Neurologic:
    - Any nerve or combination of nerves may be injured
    - Assess specific nerve function
      - PosteromedialÆ ulnar
      - PosterolateralÆ radial
      - Anterior interosseous and median nerve
- Classification: Type I—nondisplaced
  - Type II- angulated, posterior cortex contact
    - -anterior humeral line anterior to capitellum
  - Type III—displaced without cortical contact
- Most common treatment
  - Type I----long arm cast for 2-3 weeks in elbow flexion > 90 degrees
  - Type II—closed reduction, requires heavy sedation or anesthesia
    - ---long arm cast with at least 110 degrees flexion to hold
    - ---percutaneous pinning preferred by me
  - Type III—closed reduction and percutaneous pinning preferred
    - ---other options: traction
      - ORIF if vascular injury or irreducible

No detrimental effect of waiting until next morning for surgery if vascular/neuro okay

Technique for closed reduction, percutaneous pinning
- General anesthesia with fluoroscopy
- Traction to align on AP view
- Reduce with manual pressure over olecranon as elbow flexed
- Hold in hyperflexion
- Check images in lateral and internal/external obliques
- Pin with 2-3 K-wires 0.062
  - Prefer 2 lateral pins divergent
    - --can add 3rd lateral pin if needed
  - Medial and lateral crossed pins
    - --primarily if medial comminution
    - --iatrogenic ulnar nerve injury rate higher with crosspins (5%)
    - --if medial pin used, insert with elbow less flexed
    - --view anterior starting point on fluoro
- Assess point of flexion where pulse disappears
  - --cast at 20∞-30∞ more extension than this amount of flexion
- Evaluate for N/V status in hospital if marked swelling
- Consider cast loop to limit external rotation in sling
- Repeat xray within first week to assess change
  - --repeat reduction and pinning within 1st week if not acceptable
- Remove pins at 3 weeks and leave out of cast
- Physical therapy if motion not nearly normal by 3 weeks post-cast

Complications
- Neurologic
  - From injury—7%
  - Iatrogenic from pinning—5%
    - --ulnar nerve mobile with elbow flexion in younger children < 6 y.o.
    - --avoid with divergent lateral pins instead of cross-pins
    - --if medial pin used, need to see anterior start point on fluoro
- Vascular
  - Injury rate about 1%
    - If radial pulse present→lost after reduction→ explore artery
      - --very possibly caught in fx site
    - If radial pulse absent from injury and hand warm→ observe
      - --in hospital, monitor for compartment syndrome and vascular
    - If radial pulse absent from injury/ hand cool→partial ER reduction
      - --if hand stays cool and pulseless→ explore urgently
- Early post-op change in fracture reduction
  - Need to check xray within 1 week of fx reduction
  - Usually rotation change
    - --associated with non-divergent pins that cross at fx site
  - If rotational change, remove cast and obtain AP xray in extension
    - --can have rotation change without varus but need to prove
    - --hard to assess varus with elbow flexed
    - --compare Baumann's angle with other side
  - Repeat closed reduction and pinning in first week if → varus
    - --difficult to move fx closed after about 8-10 days
- Hyperextension deformity
  - Usually type II treated with splint with not enough elbow flexion
  - Physical finding of ↑ elbow flexion and hyperextension
    - --bony block to flexion on lateral xray
  - Very little remodeling due to little growth at distal physis
  - Osteotomy needed if correction sought
- Cubitus varus
  - 1%-20%, lowest with pinning and highest with traction
  - Due to malunion in 99%
    - --rare to have growth arrest from SCH fx
    - --after insufficiently treated type II
    - --type III with medial comminution
  - Function often normal or nearly so
    - --may have predisposition to other elbow fx
    - --deformity cosmetically troublesome
  - Valgus osteotomy can be done at any age
    - --no need to wait for skeletal maturity
    - --be careful of radial nerve stretch

REFERENCES

1. Alburger, PD, Weidner, PL, Betz, RR: Supracondylar fractures of the humerus in children. J. Pediatr. Orthop. 12:6, 1992
2. Beaty, JH: Fractures and dislocations about the elbow in children. AAOS Instr. Course Lect. 41:373, 1992
3. Boyd, DW, Aronson, DD: Supracondylar fractures of the humerus: a prospective study of percutaneous pinning. J. Pediatr. Orthop. 12:789, 1992
4. Clement, DA, Phil, D: Assessment of a treatment plan for managing acute vascular complications associated with supracondylar fractures of the humerus in children. J. Pediatr. Orthop. 10:97, 1990
5. Culp,RW, Osterman, A, Davidson,RS, et al.: Neural injuries associated with supracondylar fractures of the humerus in children. J. Bone Joint Surg. 72A:1211, 1990
6. France, J, Strong, M: Deformity and function in supracondylar fractures of the humerus in children variously treated by closed reduction and splinting, traction, and percutaneous pinning. J. Pediatr. Orthop. 12:494, 1992
7. Kasser, JR: Percutaneous pinning of supracondylar fractures of the humerus in children. AAOS Instr. Course Lect. 41:385, 1992
8. Kim, WY, Chandru, R, Bonshahi, A, Paton, RW: Displaced supracondylar humeral fractures in children: results a national survey of paediatric orthopaedic consultants. Injury 34(4):274-7, 2003
9. Kocher, MS, Waters, PM, Micheli, LJ: Upper extremity injuries in the paediatric athlete. Sports Med. 30(2):117-35, 2000
10. Lee, SS, Mahar, AT, Miesen, D, Newton, PO: Displaced pediatric supracondylar humerus fractures: biomechanical analysis of percutaneous pinning techniques. J Pediatr. Orthop. 22(4):440-3, 2002
11. Leet, AI, Frisancho, J. Ebramzadeh, E: Delayed treatment of type 3 supracondylar humerus fractures in children. J Pediatr. Orthop. 22(2):203-7, 2002
12. Mehlman, CT, Strub, WM, Roy, DR, Wall, EJ, Crawford, AH: The effect of surgical timing on the perioperative complications in treatment of supracondylar humeral fractures in children. J Bone Joint Surg. Am 83-A(3):323-7, 2001
13. Merchan, ECR: Supracondylar fractures of the humerus in children: treatment by overhead skeletal traction Orthop Rev 21:475, 1992
14. Omololu, AB, Alonge, TO, Adebisi, A: A review of 100 cases of supracondylar fractures in children seen in Ibadan. Afr J Med Sci 29(2):167-9, 2000
15. Reynolds, RAK, Mirzayan, R: A technique to determine proper pin placement of crossed pins in supracondylar fractures of the elbow. J. Pediatr. Orthop., 20:485-489, 2000
16. Royce, RO, Dutkowsky, JP, Kasser, JR, Rand, FR: Neurologic complications of K-wire fixation of supracondylar humerus fractures in children. J. Pediatr. Orthop. 11:191, 1991
17. Shaw, BA, Kasser, JR, Emans, JB, Rand, FR: Management of vascular injuries in displaced supracondylar humerus fractures without arteriography. J. Orthop. Trauma 4:25, 1990
18. Skaggs, DL, Hale, JM, Bassett, J, Kaminsky C, Kay, RM, Tolo, VT: Operative treatment of supracondylar fractures of the humerus in children. The consequences of pin placement. J Bone Joint Surg. Am. 83-A(5):735-40, 2001
19. Wind, WM, Schwend, RM, Armstrong, DG: Predicting ulnar nerve location in pinning of supracondylar humerus fractures. J Pediatr. Orthop. 22(4):444-7, 2002

FOREARM FRACTURES: OPERATIVE TECHNIQUES FOR AVOIDING PROBLEMS WITH PROBLEM FRACTURES

Charles T. Price, MD

Distal Radius Metaphyseal Fractures
- ORIF rarely necessary
- No reduction needed
  - Complete displacement
  - 1 cm shortening
  - 15 degrees angulation: radial, or dorsal-volar
- When reduction performed
  - Incomplete reduction is more likely to require remanipulation
  - Percuatneous pinning for incomplete reductions
    - Reduces risk of remanipulation
    - Introduces other potential complications
    - Similar results compared to closed management
- Acceptable malunion: >2 years of growth remaining
    - 30° Dorsal-volar tilt
    - 15° Radial-ulnar tilt

Forearm Shaft Fractures

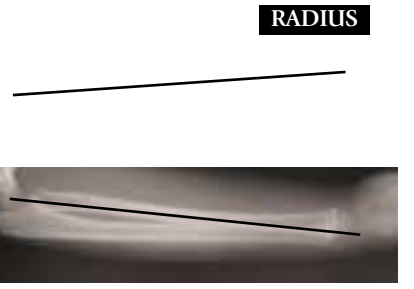
Closed Management
- Principles
  - Acceptable reduction is more strict than acceptable malunion
  - Reductions may drift into more angulation
- Acceptable Alignment less than age 8 years
  - Complete displacement
  - 15∞ angulation
  - 45∞ malrotation
- Acceptable Alignment age 8 - 13 years
  - Complete displacement
  - 10∞ angulation
  - 30∞ malrotation
- Dealing with closed management
  - Closed management is difficult
  - Need to explain more to parents
  - Need to follow closely
  - Consumes time in busy clinic
  - Patients only accept excellent results

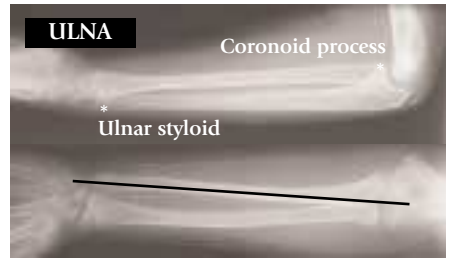
Intramedullary Fixation
- Advantages
  - Minimally invasive
  - Simple surgery
  - Anatomic alignment
  - Simpler post-op management
- Indications
  - Open fractures
  - Unacceptable reduction – especially proximal fractures
  - Multiple fractures
  - Re-fractures with displacement
- Technique



  - Nail the easiest bone first
  - Ulna - enter lateral to olecranon tip or in distal metaphysis
  - Radius - oblique drill hole in distal metaphysis
  - Small Steinmann pin or flexible titanium nail
    - 1.5-2.0 mm usually sufficient (0.062 in., or 3/32 in.)
    - Dull the tip
    - Bend tip 30∞
  - Limit tourniquet time to one hour
  - Expose fracture rather than making false passes
- Post-op Management
  - Pins under skin – remove in three months
  - Pins through skin – remove in 4 weeks with continued casting
  - Bivalve cast of use long arm splint post-op
  - Watch for compartment syndrome
  - Immobilization 6-8 weeks

Malunion
- Acceptable malunions
  - Less than 20∞ with 2 years of growth remaining
- Osteotomy recommended
  - Observe 20∞-30∞ deformity if distal
  - Correct deformity within one year of injury
  - Early osteotomy if malunion ≥ 30∞
- Normal forearm alignment





BIBLIOGRAPHY

Distal Radius Fractures:

1. Choi, K.Y., et.al., Percutaneous Kirschner-Wire Pinning for Severely Displaced Distal Radial Fractures in Children, JBJS 77B, 797-801, 1995
2. Reduction vs. Remodeling in Pediatric Distal Forearm Fractures: A Preliminary Cost Analysis, Do, T.T., et.al. JPO 12B:109-115, 2003
3. McLauchlan, G.J., et.al., Management of Completely Displaced Metaphyseal Fractures of the Distal Radius in Children, JBJS 84B:413-417, 2002
4. Price, C.T. Evidence-Based Medicine Invited Commentary: Management of Completely Displaced Metaphyseal Fractures of the Distal Radius in Children, JBJS 84A:2109, 2002
5. Proctor, M.T., et.al., Redisplacement after Manipulation of Distal Radial Fractures in Children, JBJS 75B:453-454, 1993

Forearm Shaft Fractures:

1. Alpar, EK, et al: Midshaft Fractures of Forearm Bones in Children Injury, 13:153-158, 1981.
2. Carey, PJ, et al: Both Bone Forearm Fractures in Children. Orthopedics 15:1015-1019, 1992.
3. Daruwalla, JS: A Study of Radioulnar Movements Following Fractures of the Forearm in Children. CORR 139:114-120, 1979.
4. Evans, E.M: Fractures of the Radius and Ulna. JBJS Vol. 33B:548-561, 1951.
5. Fuller DJ, McCullough CJ: Malunited Fractures of the Forearm in Children. JBJS 64A, 1982.
6. Hogstrom H., Nilsson BE, Willner S: Correction with Growth Following Diaphyseal Forearm Fracture. Acta Orthop Scand 47:299-303, 1976.
7. Holdwsorth BJ, Sloan JP: Proximal Forearm Fractures in Children: Residual Disability. Injury 14:174-179, 1982.
8. Lascombes P, et al.: Plastic Stable Intramedullary Nailing in Forearm Shaft Fractures in Children – 85 Cases. JPO 10:167-171,1990.
9. Matthews L, et al.: The Effect on Supination-Pronation of Angular Malalignment of Fractures of Both Bones of the Forearm: JBJS Vol. 64A,1982.
10. Nilsson BE, Obrant K: The Range of Motion Following Fracture of the Shaft of the Forearm in Children: Acta Orthop Scan. 48:600-602, 1977.
11. Price CT, et al.: Malunited Forearm Fractures in Children: JPO 10:705-712.
12. Tarr RR, et al.: The Effects of Angular and Rotational Deformities of Both Bones of the Forearm: JBJS 66A:65-70, 1984.
13. Verstreken L, Delronge, Lamoureau J: Shaft Forearm Fractures in Children: Intramedullary Nailing with Immediate Motion. JPO 8:450-453, 1988.

AVOIDING PROBLEMS WITH PROBLEM FRACTURES

R. Jay Cummings, MD

Introduction

Aside from fractures of the middle third of the clavicle, fractures about the shoulder are relatively uncommon in children and adolescents. Perhaps due to this fact, there has been the perception that bad results from fractures in this anatomic region are uncommon and therefore these fractures have, for the most part, been treated nonoperatively. The recent literature has brought into question this perception and identified certain situations in which operative treatment may actually been the preferred choice.

Proximal Humeral Epiphyseal Fractures

These fractures account for 4 to 7% of all epiphyseal fractures but only .45% of all pediatric fractures. The vast majority of these fractures are Salter-Harris I and II injuries. The Salter-Harris I injuries are more common in children younger than five years and the Salter-Harris II injuries are usually seen in adolescents older than age 11. Since 80% of the longitudinal growth of the humerus occurs at the proximal humeral physis and the shoulder joint is the most mobile joint in the body, common wisdom has been that remodeling and shoulder motion would accommodate considerable malunion and lead to good functional outcome. The literature on this injury includes not only series showing excellent outcomes without surgery, even in patients with markedly displaced fractures, but also patients who have had surgery whose outcome is essentially the same as patients with comparable injuries who have been treated nonoperatively.1,2,3,4

Burgos-Flores et al. reported on a series of twenty-two patients with markedly displaced proximal humeral epiphyseal separations, fourteen of which were 13 years old or older. They found 14 of 22 patients had either decreased motion, residual angulation, or dysmetria. Decreased motion was present in 6 of the 22 patients. They noted that decreased range of motion has been reported in fractures treated surgically, but that none of the three patients they treated with open reduction and internal fixation had decreased range of motion.4

More recently, Dobbs et al.5 have published an algorithm for the treatment of these fractures. All patients with tenting of the skin, vascular injury, multiple fractures, and head injury with significantly displaced fractures are candidates for closed reduction. Children between ages eight and eleven with greater than 60 degrees and those over age 12 with greater than 45 degrees angulation are also candidates. If reduction is successful (less than 70 degrees in 7 year old and younger patients, less than 60 degrees in patients 8 to 11 years old, and less than 45 degrees in those over 12 years of age), spica cast or percutaneous pins are recommended. If closed reduction is unsuccessful, open reduction and internal fixation is performed. These authors reported on 28 patients with Neer grade III or IV displacement. Three had closed reduction and cast, 20 had closed reduction and percutaneous pins, 3 open reduction and internal fixation with screws and 2 open reduction and internal fixation with pins. In 4 of the patients with open reduction and internal fixation the biceps tendon was trapped in the fracture site. At a mean follow-up of 4 years, all patients reported no pain, subjective loss of motion or strength, or functional limitation. There were no operative complications.

Surgeons attempting closed reduction and percutaneous pinning should understand that obtaining the reduction and then maintaining it while inserting the pins and getting x-rays can be challenging. A two C-arm technique may facilitate the procedure. When closed reduction fails, a delto-pectoral incision is made for open reduction and internal fixation. While the scar from this approach may be objectionable, I could find no reports on the use of more cosmetic incisions for the treatment of this problem.

Fractures of the Clavicle

Clavicle fractures account for 10-15% of all children's fractures and are the most common fractures in the shoulder region. Mid-shaft fractures account for 90% of these fractures. Since virtually all of these fractures heal without sequelae, it is almost impossible to find surgeons who mention treating these operatively, much less a report on a series of these fractures treated surgically.

In 2002 Kubial and Slango reported on a series of fifteen children who had clavicular fractures treated with surgery.6 Eight of these fractures were mid-shaft. The patients' ages ranged from 9.5 to 15.6 years. Surgical indications included concern that the displaced fragments might penetrate the skin, cosmesis, pain, and shortening. The authors recommended fixation with elastic nails or external fixators. Complications included tender scars, unsightly scars, and hardware problems when K-wires were used for fixation.

A still rare, but probably more valid, indication for operative treatment of mid-shaft clavicular fractures in children and adolescents is nonunion. Treatment usually consists of plating along with autologous bone grafting. Resection of the lateral fragment and attachment of the coracoclavicular ligament to the lateral end of the medial fragment (Weaver-Dunn Procedure) has also been recommended.7

Fractures at the lateral end of the clavicle have been classified by Dameron and Rockwood. Types I, II, and III injuries are non- to minimally-displaced fractures. These respond well to nonoperative treatment. In the Type V injury, the medial clavicular fragment ruptures through most of the periosteal sleeve and is markedly superior displaced. In Type IV fractures the medial clavicular fracture is displaced posteriorly and in Type VI injuries, the medial clavicular fracture is trapped under the coracoid. Some authors have recommended surgical treatment of Type IV, V, and VI fractures. The goals of surgery include prevention of the development of a "double" clavicle, prevention of claviculoscapular synostosis, and improved cosmesis.

The clavicle has epiphyses at both its lateral and medial ends. These close at age 19 and 25 years respectively. Because of this dislocation of the acromioclavicular and sternoclavicular joints are extremely rare in the pediatric patients, physeal injury being the more usual injury. After age 13 adult-type acromioclavicular joint dislocations are more common than physeal separation and surgery may be indicated.

Fractures at the medial end of the clavicle are the least common clavicular fracture. When nondisplaced or anteriorly displaced, treatment is nonoperative. Fractures with posterior displacement that do not compromise mediastinal structures can be treated nonoperatively. When these fractures compromise mediastinal structures, closed or if necessary open reduction on an emergent basis is necessary.

Scapular Fractures

Pediatric scapular fractures are in some ways similar to pediatric pelvic fractures. Both account for approximately 1% of pediatric fractures. Fifty-eight percent of pediatric pelvic fractures have associated injuries. Seventy-five percent of scapular fractures have associated injuries. The mortality of those injuries associated with pelvic fractures averages approximately 12%. The mortality rate of those injuries associated with scapular fractures average about 14%.

Radiographic tools in evaluating scapular fractures include, in addition to routine AP and lateral views, axillary plane films and frequently CT scans. Pediatric scapular fractures are classified into those fractures involving the acromion, the spine, the coracoid, the neck, the glenoid and the body. Thirty-five percent of fractures involve the body, 27% the neck. The least common class is the coracoid fracture, which makes up only 7% of the total.

The indications for surgery for pediatric scapular fractures are not well defined and tend to be theoretical based upon experience with similar injuries in adults. The concept of the "superior shoulder suspensory complex" for shoulder injuries (SSSC) is much like the concept of the pelvic ring for pelvic fractures, i.e., a single break does not affect the stability of the ring, but a double break does.8 As the scapular body and spine are not part of the SSSC, surgery for fracture of these structures is rarely indicated. With displaced fractures of the scapular neck and clavicle, on the other hand, surgery is recommended usually fixing the clavicle alone or the clavicle and the scapular neck. That having been said, I can find no report of any such surgery having been performed for this injury in the pediatric age group. Similarly fractures of the glenoid neck with greater than 1-cm displacement or 40 degrees of angulation are reported to do poorly when treated nonoperatively in adults. Therefore surgery on children with similar injuries is recommended but not reported on in the literature. And so it goes for coracoid fractures associated with ipsilateral distal clavicular fractures and glenoid rim fractures. There is one case report of a glenoid fossa fracture treated by open reduction and internal fixation in an eight-year-old (9).

Summary

Most fractures about the shoulder in the pediatric age group can be managed successfully without surgery. There are, however, certain types of injuries involving this anatomical region that may benefit from surgery. In order to avoid problems, these problem fractures must be recognized and treated if necessary with surgery.

REFERENCES

1. Neer CS, Horwitz BS. Fractures of the proximal humeral epiphyseal plate. Clin. Orthop. 1965; 41: 24-31.
2. Kohler R, Trillaud JM. Fracture and fracture separation of the proximal humerus in children: report of 136 cases. J. Pediatr. Orthop. 1983; 3(3): 326-332.
3. Beringer DC, Weiner DS, Noble JS, Bell RH. Severely displaced proximal humeral epiphyseal fractures: a follow-up study. J. Pediatr. Orthop. 1998; 18(1): 31-37.
4. Burgos-Flores J, Gonzalez-Herranz P, Lopez-Mondejar JA, et al. Fractures of the proximal humeral epiphysis. Int. Orthop. 1993; 17: 16-19.
5. Dobbs MB, Luhmann SL, Gordon JE, Strecker WB, Schoenecker PL. Severely displaced proximal humeral epiphyseal fractures. J. Pediatr. Orthop. 2003; 23(2): 208-215.
6. Kubiak R, Slongo T. Operative treatment of clavicle fractures in children: a review of 21 years. J. Pediatr. Orthop. 2002; 22(6): 736-739.
7. Nogi J, Heckman JD, Hakala M, Sweet DE. Non-union of the clavicle of a child. Clin. Ortho. 1975; 110: 19-21.
8. Goss TP. Scapular fracture and dislocations: diagnosis and treatment. J. Am. Acad. Orthop. Surg. 1995; 3: 22-33.
9. Lee SJ, Meinhard BP, Schultz E, Taledano B. Open reduction and internal fixation of a glenoid fossa fracture in a child. J. Orthop. Trauma 1997; Aug: 11 (8): 452-454.

PROXIMAL FOREARM FRACTURES: MONTEGGIA, RADIAL HEAD AND NECK AND OLECRANON

John M. Flynn, MD

MONTEGGIA FRACTURE-DISLOCATIONS

Background/Key Facts

Any ulna fracture associated with radiocapitellar dislocation
Fracture types (direction of ulnar angulation and radial head disloc.)
- I. anterior (70%)
- II. posterior (very rare)
- III. lateral (common in kids)
- IV. anterior, assoc with radial shaft fracture

- Line drawn along axis of radius through radial head should bisect capitellum on every view
- Always image the elbow in any forearm injury
- Don't mistake a chronic congenitally dislocated radial head for Monteggia

Treatment considerations

More important than Bado type:
- Age of patient
- Pattern of injury
- Time from initial injury
- Fracture stability

Acute Monteggia

Incomplete fractures, stable/plastic deformation (usually <10-12 y/o)
- Closed reduction
- Immobilization in above-elbow cast (thin fiberglass at elbow)
- 90-110° flexion, forearm supination for type I, III, IV
- 30∞ flexion for type II (rare)

- Get a clear forearm and elbow image 1x/week for 3 weeks—if you can't see, take the cast off and re-xray

★ Rare: radial head won't reduce—could be interposed tissue (open joint)

Complete, unstable ulna fractures (usually >10-12 y/o)
- Operative stabilization of ulna recommended
- Transverse/short oblique: intramedullary fixation
- Long oblique/segmental/comminuted: ulnar plate fixation

Late Monteggia

Subtle diagnosis
Often: minimal deformity and near-normal range of elbow motion
Long-term prognosis uncertain
- Pain, stiffness, progressive deformity, instability, and/or arthrosis are all possibilities

<3 weeks from injury:
- Closed reduction and cast immobilization or attempt internal fixation

>3weeks from injury:
- Usually need open reduction with annular ligament repair or reconstruction and/or corrective osteotomy of ulna

>6 months from injury:
- treatment controversial
- depends upon symptoms, range of motion, and alignment

RADIAL HEAD AND NECK FRACTURES

Background/Key facts

About 5% of elbow fractures in children
Usually metaphyseal or physeal

★ Pattern of ossification can be confused with a fracture

- The proximal radius has natural angulation

AP—12 degrees lateral
Lateral—3 degrees anterior
Classification
- Valgus injuries
- Dislocation injuries (rare)
- Other: Monteggia (III), torsional, & stress

Displacement
- Angulated
- Translated
- Completely displaced

Treatment considerations

★ Results are worse if there is another fracture (e.g. elbow dislocation, olecranon fx, med epicondyle)

Remarkably high rate of poor results in literature
- 15-30% poor results overall
- 50% poor results in high energy injuries
- Warn parents of motion loss from day #1
- ROM at 6mo will be the "final result"

Acceptable angulation

0-20∞ ang., no translation: accept as is, LAC for 2 weeks
>20∞ang.: attempt ER closed reduction
- Sedation, +/- aspiration/lidocaine
- Methods
  - Patterson—extension, varus
    - Israeli technique—flexion/pronation
  - If reduced to < 30∞, accept and cast
  - If unable to reduce < 30∞, go to OR

Operative indications

If ER reduction with sedation fails to improve angulation to < 30∞, or translation < 3mm
Severely displaced (initial angulation > 60∞)
"Flipped head"
Unstable Monteggia III equivalent

Operative techniques, pearls and pitfalls

Closed reduction under GA
- Try flexion/pronation first
- Try Esmarck wrap next
- Good fluoro views, confirm adequate pro/sup
- Reduction usually successful and stable

Percutaneous pin manipulation
- Prep and drape over c-arm

- Use blunt end of a larger k-wire

★ Consider location of post. inteross. n.

- Good fluoro views, confirm adequate pro/sup

Metaizeau technique
- Indication: CR and percutaneous pin have failed and you are about to do an open reduction
- Technique
  - Prep and drape over c-arm or hand table

Select biggest TEN you can get up the medullary canal of radius (Mconsider
the width of the curved nail tip in this decision)
Enter lateral radial metaphysis
Watch out for radial sensory nerve at distal radius
Advance curved tip to proximal radial physis-aimed lateral
Push nail slightly to disimpact the fracture
Rotate fragment into satisfactory reduction
Remove nail after healing
Open reduction
Considerations
Rarely needed in children
- A CR to <45∞ will do better than an anatomic open reduction
- If you are going to open, do it soon after injury

Indications
All other techniques have failed
"Flipped head", or completely displaced, free fragment
Irreducible, intra-articular fracture
Approach
Pronate arm, anconeus/ECU interval
Gently and directly reduce the fragment
Fixation may not be necessary
If unstable, smooth k-wires obliquely across the fracture

OLECRANON FRACTURES

Background/Key facts

Prox ulna fracture types
Apophyseal
Metaphyseal
Flexion
Extension
Shear
Apophyseal disruption rare due to distal extent of triceps insertion
★ Pattern of ossification can be confused with a fracture
- Apophyseal fractures reported in OI tarda—may be first sign

Intra-articular flap fracture
Associated injuries in >50% of cases
Non-displaced/min displaced: cast for 3-4 weeks, 30∞ elbow flexion

Operative indications

Unstable fractures
Articular step-off

Operative techniques, pearls and pitfalls

Displaced transverse fracture
Tension band technique
- Use strong absorbable suture, not wire

Young kids—leave k-wires out, pull at 3 weeks, move
Older kids—bury k-wires or use screw, move within 1-2 weeks
Shear fracture
Interfragmentary screw
Move within 1-2 weeks

REFERENCES

1. Bado, J.: The Monteggia lesion. Clin Orthop, 24: 1263-1266, 1967.
2. Bell-Tawse, A.: The Treatment of Malunited Anterior Monteggia Fractures in Children. J Bone Joint Surg Br, 47: 718-23, 1965.
3. Bernstein, S. M.; McKeever, P.and Bernstein, L.: Percutaneous reduction of displaced radial neck fractures in children. J Pediatr Orthop, 13(1): 85-8, 1993.
4. Caterini, R.; Farsetti, P.; D'Arrigo, C. et al.: Fractures of the olecranon in children. Long-term follow-up of 39 cases. J Pediatr Orthop, 11(4): 320-8, 2002.
5. D'Souza, S.; Vaishya, R.and Klenerman, L.: Management of radial neck fractures in children: a retrospective analysis of one hundred patients. J Pediatr Orthop, 13(2): 232-8, 1993.
6. Fraser, K. E.: Displaced fracture of the proximal end of the radius in a child. A case report of the deceptive appearance of a fragment that had rotated one hundred and eighty degrees. J Bone Joint Surg Am, 77(5): 782-3, 1995.
7. Futami, T.; Tsukamoto, Y.and Itoman, M.: Percutaneous reduction of displaced radial neck fractures. J Shoulder Elbow Surg, 4(3): 162-7, 1995.
8. Gaddy, B. C.; Strecker, W. B.and Schoenecker, P. L.: Surgical treatment of displaced olecranon fractures in children. J Pediatr Orthop, 17(3): 321-4, 1997.
9. Gonzalez-Herranz, P.; Alvarez-Romera, A.; Burgos, J. et al.: Displaced radial neck fractures in children treated by closed intramedullary pinning (Metaizeau technique). J Pediatr Orthop, 17(3): 325-31, 1997.
10. Graves, S. C.and Canale, S. T.: Fractures of the olecranon in children: long-term follow-up. J Pediatr Orthop, 13(2): 239-41, 1993.
11. Kay, R.and Skaggs, D.: The pediatric Monteggia fracture. Am J Orthop, 1998(27): 606-9, 1998.
12. Letts, M.; Locht, R.and Wiens, J.: Monteggia fracture dislocations in children. J Bone Joint Surg Br, 67B: 724-7, 1985.
13. Lincoln, T. L.and Mubarak, S. J.: 'Isolated' traumatic radial head dislocation. J Pediatr Orthop, 14: 454-7, 1994.
14. Metaizeau, J. P.; Lascombes, P.; Lemelle, J. L. et al.: Reduction and fixation of displaced radial neck fractures by closed intramedullary pinning. J Pediatr Orthop, 13(3): 355-60, 1993.
15. Olney, B. W.and Menelaus, M. B.: Monteggia and equivalent lesions in childhood. J Pediatr Orthop, 9(2): 219-23, 1989.
16. Papandrea, R.and Waters, P.: Posttraumatic reconstruction of the elbow in the pediatric patient. Clin Orthop, 370: 115-26, 2000.
17. Peters, C. L.and Scott, S. M.: Compartment syndrome in the forearm following fractures of the radial head or neck in children. J Bone Joint Surg Am, 77(7): 1070-4, 1995.
18. Ring, D.; Jupiter, J. B.and Waters, P. M.: Monteggia fractures in children and adults. J Am Acad Ortho Surg, 6: 215-24, 1998.
19. Steele, J. A.and Graham, H. K.: Angulated radial neck fractures in children. A prospective study of percutaneous reduction. J Bone Joint Surg Br, 74(5): 760-4, 1992.
20. Steinberg, E. L.; Golomb, D.; Salama, R. et al.: Radial head and neck fractures in children. J Pediatr Orthop, 8(1): 35-40, 1988.
21. Vocke, A. K.and Von Laer, L.: Displaced fractures of the radial neck in children: long-term results and prognosis of conservative treatment. J Pediatr Orthop, Part B, 7(3): 217-22, 1998.
22. Ward, W. T.and Williams, J. J.: Radial neck fracture complicating closed reduction of a posterior elbow dislocation in a child: case report. J Trauma, 31(12): 1686-8, 1991.
23. Waters, P.and Stewart, S. L.: Radial neck fracture nonunion in children. J Pediatr Orthop, 21(5): 570-6, 2001.
24. Wilkins, K.: Changes in the management of monteggia fractures. Journal of Pediatric Orthopedics, 22(4): 548-54, 2002.
25. Wray, C. C.and Harper, W. M.: The upside-down radial head: brief report. Injury, 20(4): 241-2, 1989.

CURRENT CONCEPTS IN THE TREATMENT OF PEDIATRIC FOOT DISORDERS (X)

Moderator: Norman Y. Otsuka, MD, Los Angeles, CA (n)

An International Faculty of clinicians will discuss current concepts in the treatment of pediatric foot disorders. The nonoperative and operative treatment of common foot disorders will be discussed and evaluated for outcomes. Current controversies in treatment will be discussed. The treatment of clubfoot will be highlighted.

I. Introduction: Classification and Outcome Evaluation
Norman Y. Otsuka, MD, Los Angeles, CA (n)

II. Nonoperative Treatment of Pediatric Foot Disorders
Richard E. Bowen, MD, Los Angeles, CA (n)

III. Operative Treatment of Pediatric Foot Disorders
James G. Wright, MD, Toronto, ON, Canada (a – Canadian Institute of Health Dept.)

IV Treatment of Pediatric Foot Trauma
Robert M. Kay, MD, Los Angeles, CA (n)

V. Treatment of Clubfoot – North American Experience
Wallace B. Lehman, MD, New York, NY (n)

VI Treatment of Clubfoot – European Experience
Henri Bensahel, MD, Paris, France (n)

INTRODUCTION: CLASSIFICATION AND OUTCOME EVALUATION

Norman Y. Otsuka, MD

Introduction
- the foot is not a joint" – Mosca; POSNA, 2001 "
- diagnosis and treatment of pediatric foot disorders is challenging
- foot has articulations of 26 bones with the tibia and fibula of the ankle joint
- foot disorders usually have two or more segmental deformities

Classification

Consider multiple deformities present:
- calcaneovalgus
- cavovarus
- cavus
- eqinovarus

} rigid or flexible?

Consider etiology:
- idiopathic
- postural
- congenital
- neuromuscular

calcaneovalgus: congenital vertical talus (rigid); tarsal coalition (rigid); accessory navicular; newborn postural (flexible); flatfeet (flexible)
cavovarus/cavus: neuromuscular (cerebral palsy, Charcot-Marie Tooth disease, Friedreich's ataxia, polio)
equinovarus: clubfoot (Dimeglio-Bensahel, 1995; Pirani, 1995); neuromuscular (rigid or flexible)
other forefoot: metatarsus adductus; congenital toe deformities

Management and Outcome
- in pediatric foot disorders, the two or more deformities, that are usually present, must be identified for management in order to optimize outcome
- important to recognize age-dependent variations of the pediatric foot
- evaluation of radiographs should be weight-bearing or simulated weight-bearing
- in the pediatric foot, preserve joints and growth with soft tissue surgery and osteotomies, rather than arthrodeses

Patient Outcome Measures
- functional outcome goal is a painless, flexible, plantigrade foot that allows the patient to lead a normal life
- no good outcome measures for the foot in children
  - Foot Function Index measures pain disability and activity restriction in adults (Budiman-Mak, Conrad and Roach; J Clin Epidemiol, 1991)
  - Leveeg and Ponseti (JBJS, 1980) for clubfoot
  - International ClubFoot Study Group Rating System (2003)
  - AOFAS Clinical Rating System (Kitaoka et al., 1994) for foot and ankle in adults
- outcome measures in children
  - ASK (Activities Scale for Kids; Young and Wright, Hospital for Sick Children, Toronto) is a good overall measure of physical activity
  - CHQ (Child Health Questionnaire; Landgraf and Ware) is a good measure of overall health
  - PODCI (POSNA Pediatric Musculoskeletal Functional Health Questionnaire)

REFERENCES

1. Bensahel H, Kuo K, Duhaime M; International Clubfoot Study Group. Outcome evaluation of the treatment of clubfoot: the international language of clubfoot. J Pediatr Orthop B 2003; 12(4): 269-271.
2. Budiman-Mak E, Conrad KJ, Roach KE. The Foot Function Index: a measure of foot pain and disability. J Clin Epidemiol 1991; 44(6): 561-570.
3. Daltroy LH, Liang MH, Fossel AH, Goldberg MJ. The POSNA pediatric musculoskeletal functional health questionnaire: report of reliability, validity, and sensitivity to change. Pediatric Outcomes Instrument Development Group. Pediatric Orthopaedic Society of North America. J Pediatr Orthop 1998; 18(5): 561-571.
4. Dimeglio A, Bensahel H, Souchet P, Mazeau P, Bonnet F. Classification of clubfoot. J Pediatr Orthop B 1995; 4(2): 129-136.
5. Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. Foot Ankle Int 1994; 15(7): 349-353.
6. Laaveg SJ, Ponseti IV. Long-term results of treatment of congenital clubfoot. J Bone Joint Surg Am 1980; 62(1): 23-31.
7. Landgraf JM, Maunsell E, Speechley KN, Bullinger M, Campbell S, Abetz L, Ware JE. Canadian-French, German and UK versions of the Child Health Questionnaire: methodology and preliminary item scaling results. Qual Life Res 1998; 7(5): 433-445.
8. Mosca VS. Complex foot deformities in children: surgical decision making and management. Pediatric Orthopaedic Society of North America, Cancun; 2001.
9. Pirani S, Outerbridge H, Moran M, Sawatsky B. A method of evaluating virgin clubfoot with substantial inter-observer reliability. Pediatric Orthopaedic Society of North America, Miami, Florida; 1995.
10. Young NL, Yoshida KK, Williams JI, Bombardier C, Wright JG. The role of children in reporting their physical disability. Arch Phys Med Rehabil 1995; 76(10): 913-918.

NONOPERATIVE TREATMENT OF SELECTED PEDIATRIC FOOT DISORDERS

Richard E. Bowen, MD

I. Introduction: "does my child need orthopaedic shoes?"

II. Flexible Flat Foot (FFF)

A. Definition: no clear definition (hindfoot eversion, midfoot sag, forefoot compensatory supination)
   1. footprint analysis
   2. radiographs (lateral talo-first metatarsal angle = Meary's angle)

B. Natural medial arch development (possible relation to shoewear)
   1. 0-2 years age: "fat" foot
   2. 2-6 years age: rapid medial arch development

C. Types of FFF
   1. FFF
   2. painful FFF
   3. FFF with short Achilles tendon
   4. FFF with connective tissue disorder

D. Differential diagnosis
   1. rigid
      a. tarsal coalition
      b. congenital vertical talus
   2. flexible

E. Treatment
   1. FFF: none (benign natural history: arch supports don't affect ultimate arch height)
   2. painful FFF:
      a. UCBL
      b. Medial heel wedge
   3. FFF with short Achilles: stretching if ankle < 10° dorsiflexion (knee extended)

III. "Packing" disorders

A. Metatarsus Adductus
   1. Definition: forefoot adductus, normal ankle/hindfoot, talonavicular relation
   2. Natural history: >85% spontaneous correction, rare disability with persistent deformity
   3. Classification (Bleck)
      a. spontaneously correctable to neutral (passively hypercorrectable)
      b. passively correctable to neutral
      c. not passively correctable
   4. Differential diagnosis: skewfoot (lateral subluxation talonavicular joint, hindfoot hypervalgus)
   5. Non-operative treatment:
      a. Spontaneously correctable: none
      b. Passively correctable: stretching & straight/reverse last shoes, casting, or observation
      c. Not passively correctable: casting (short vs long leg) or surgery (sloping medial cuneiform)

B. Flexible calcaneovalgus of infancy
   1. Definition: marked dorsiflexion, limited inversion/plantarflexion,"foot on shin"
   2. Natural history: spontaneous correction 3-6 months
   3. Classification: plantarflexion/inversion beyond neutral or not
   4. Differential diagnosis : posteromedial bow tibia
   5. treatment: none or serial casting/stretching

IV. Osteochondroses

A. Kohler's (navicular)
   1. presentation: midfoot pain in 2-7 yo, limp, red bump dorsal midfoot.
   2. pathogenesis: unknown (last bone to ossify in midfoot)
   3. diagnosis: Xray: sclerotic, flat, irregular lucency navicular
   4. natural history: resolves 1_-3 yrs
   5. differential diagnosis: infection/foreign body
   6. treatment: restricted WB, short leg walking cast

B. Frieberg's infraction (2nd or 3rd metatarsal head)
   1. presentation: painful swelling of 2nd MT joint, decr ROM in athletic female10-18.
   2. pathogenesis: AVN vs repetitive stress. Possible factor: long MT
   3. diagnosis: Xray: subchondral fx, wide joint, sclerosis/flat MT head. early: MRI or bone scan +
   4. natural history: resolution of pain in majority of cases over months-years
   5. differential diagnosis: stress fx MT
   6. treatment:
      a. early: activity restriction, stiff rocker-bottom shoe, MT bar/pad, SL walking cast, steroid
      b. late: occasional surgery

V. Apophysitis

A. Sever's (calcaneal)
   1. presentation: heel pain, 7-15 yo, sports, limp, no swelling, normal heel radiographs
   2. natural history: self-limiting by secondary ossification center fusion (15 yo)
   3. differential diagnosis: Achilles tendonitis, stress fx calcaneus, UBC calcaneus, plantar fascitis
   4. treatment: rest, ice, massage, activity restriction; possible heel cord stretching, heel cushions, medial arch supports, short leg walking cast

B. Accessory Navicular
   1. presentation: pain, red "bump" medial arch in 8-14 yo, rubs on shoe
   2. pathogenesis: microfx near/in synchondrosis, chronic inflammation
   3. diagnosis: medial oblique foot radiograph diagnostic, bone scan or MRI + if symptomatic
   4. natural history: common, most asymptomatic, pain at synchondrosis resolves with skeletal maturity, prominence persists
   5. classification (Grogan)
      a. type I small ossicle in PTT (os tibiale externum)
      b. type II 1cm ossicle separate from medial plantar navicular, cartilaginous synchondrosis
      c. type III cornuate navicular (fused type II)
   6. differential diagnosis: stress fx, PTT tendonitis
   7. treatment: shoe modifications, medial arch supports, steroid injection into synchondrosis, short leg walking cast.

REFERENCES

Flexible Flatfoot

1. Echarri JJ, Forriol F. The development in footprint morphology in 1851 Congolese children from urban and rural areas, and the relationship between this and wearing shoes. J Pediatr Orthop B. 2003;12:141-146.
2. Garcia-Rodriguez A, Martin-Jimenez F, Carnero-Varo M, Gomez-Gracia E, Gomez-Aracena J, Fernandez-Crehuet J. Flexible flat feet in children: a real problem? Pediatrics 1999;103:e84.

Metatarsus Adductus

1. Bleck EE. Metatarsus adductus: classification and relationship to outcomes of treatment. J Pediatr Orthop. 1983;3:2-9.
2. Farcetti P, Weinstein SL, Ponseti IV. The long-term functional and radiographic outcomes of untreated and non-operatively treated metatarsus adductus. J Bone Joint Surg Am 1994;76:257-265.
3. Morcuende J, Ponseti IV. Congenital metatarsus adductus in early human fetal development: a histologic study. Clin Orthop. 1996;333:261-6.

Flexible Calcaneovalgus of Infancy

1. Edwards ER, Menelaus MB. Reverse club foot. Rigid and recalcitrant talipes calcaneovalgus. J Bone Joint Surg Br 1987;69:330-334.
2. Wynne-Davies R. Familial studies of the cause of congenital clubfoot-talipes equinovarus, talipes calcaneovalgus and metatarsus varus. J Bone Joint Surg Br 1964;46:445-463.
3. Yu, GV, Hladik J. Residual calcaneovalgus deformity: review of the literature and case study. J. Foot Ankle Surg 1994;33:228-238.

Kohler's Disease

1. Borges JL, Guille JT, Bowen JR. Kohler's bone disease of the tarsal navicular. J Pediatr Orthop 1995;15:596-598.
2. Willliams GA, Cowell HR. Kohler's disease of the tarsal navicular. Clin Orthop 1981;158:53-58.

Freiberg's Infraction

1. Katcherian DA. Treatment of Freiberg's disease. Orthop Clin North Am 1994;25:69-81.

Sever's apophysitis

1. Liberson A, Lieberson S, Mendex DG, Shajrawi I, Ben Haim Y, Boss JH. Remodeling of the calcaneus apophysis in the growing child. J Pediatr Orthop B 1995;4:74-79.

Accessory Navicular

1. Grogan DP, Gasser SI, Ogden JA. The painful accessory navicular: a clinical and histopathological study. Foot Ankle 1989;10:164-169.
2. Miller TT, Staron RB, Feldman F, Parisien M, Glucksman WJ, Gandolfo LH.The symptomatic accessory tarsal navicular bone: assessment with MR imaging. Radiology 1995;195:849-853.
3. Ponseti IV, Becker JR. Sullivan JA, Miller WA. The relationship of the accessory navicular to the development of the flat foot. Clin Orthop 1979;144:233-7.

OPERATIVE TREATMENT OF FOOT DISORDERS

James G. Wright, MD, MPH, FRCSC

Topics
- Tarsal coalition
- Recurrent/residual clubfoot
- Bunions
- Cavus
- Flat foot

Tarsal Coalition: Calcaneonavicular and Talocalcaneal
- Up to 20% have more than one bar (Clarke 1997) – all need CT scan and oblique views of foot
- CT better than MRI (Emery 1998)
- Operative treatment is patient/family choice based on pain non-responsive to modification of activity, orthotics, casting

Excision Calcaneonavicular Coalition
- Excise just beyond margins of joints
- Interposition can be EDB (Moyes 1994), fat, or bone wax
- Postoperative care: early weight-bearing and early motion (cast for 1-2 weeks)

Excision of Talocalcaneal Bar
- "Coalition must be <50% cross-sectional area of subtalar joint"
- Approach from medial side, find joint front and back of medial facet, excise with Hall drill or osteotomy
- Interpose fat, FHL (Raikin 1999), bone wax
- For associated deformity, calcaneal lengthening or arthroereisis (Giannini 2003)
- Early weight-bearing and early motion

Fusion for Talocalcaneal Bar
- At 25 years after triple fusion for any cause , 32% had arthritis and 45% had pain (Saltzman 1999)
- At 5 years after subtalar fusion for all causes, 36-41% had progression of radiographic OA (Mann 1998)

Clubfoot - Residual
- Incomplete correction in children 4-8 years can be treated with repeat soft tissue release ± calcaneocuboid fusion (Lehman 1999)
- Soft tissue coverage becomes issue in children>2-4 years and often requires plastic surgery (for local flap, tissue expander, free gracilis free flap)

Clubfoot - Recurrence
- Multiple osteotomies to correct all aspects of deformity including Dwyer/calcaneal shift, cuboid decancellisation, medial cuneiform open wedge osteotomy, tibialis anterior full or split transfer (Kuo 2001), posterior release
- If equinus is part of recurrence, use prolonged (> 2yr) articulated AFO with plantar flexion stop at neutral

Clubfoot – Recurrence (cont.)
- Soft tissue distraction (Grill 1987)
- Talectomy for arthrogryposis; at 20 years only 33% "good" with pain and recurrence of deformity (Legaspi 2001)
- Tibial osteotomy for recurrent equinus (Napiontek 1994)

Bunions
- RCT of foot orthosis; MP angle increased more in orthotic group (Kilmartin 1994)
- Recurrence rate is higher in adolescents than adults: 21 years after Mitchell, initial 95% good/excellent drops to 64% due to recurrence/pain (Fokter 1999)
- RCT of adding adductor release to Chevron showed no difference (Resch 1994)
- Soft tissue (McBride) vs. osteotomy (Mitchell) similar results 16 years later (Schwitalle 1998)
- "Use basal osteotomies for intermetatarsal angle >15°" (Koop 1992)
- Problems of lateral closing wedge based osteotomy include hallux varus (19%), dorsal bunion (18%), and pain (16%)(Trnka 1999)

Metatarsus Adductus
- Watch for skew foot (examine radiographs for midfoot abduction)(Berg 1986)
- Medial capsulotomy and abductor release < 5 years, all 29 "improved" (Asirvatham 1997)
- After age 4 yrs, can use midfoot osteotomies (Napiontek 2003) or metatarsal osteotomies

Cavus Foot
- Children should receive MRI/EMGs
- Early surgery: first metatarsal osteotomy ± plantar release ± tendon transfer
- Late surgery: osteotomies to correct all aspects of deformity including Dwyer/shift calcaneal osteotomy, first metatarsal osteotomy (or metatarsal-cuneiform fusion), midfoot osteotomy, tendon transfer (Sammarco 2001)
- Claw toes: transfer, flexor release, Jones transfer (Breusch 2000)(corrected deformity but "catch" big toe, transfer pain, hallux flexus)

Midfoot Osteotomies
- Japas: Midfoot "V" osteotomy
- Cole: Wedge tarsectomy
- Tarsometatarsal excisional fusion (Jahss)

Flat Feet
- Operative treatment is child/family choice
- Flatfoot not significant problem overall (Garcia-Rodriguez 1999) but may cause pain and disability in subset (Lin 2001, Luhmann 2000)
- Surgery: tendo-Achilles lengthening, calcaneal lengthening (Mosca 1995), calcaneocuboid distraction arthrodesis (Thomas 2001), metatarsal osteotomy, arthroereisis (Giannini 2001), Kidner procedure (Prichasuk 1995)

REFERENCES

1. Senaris-Rodriguez J, Martinez-Serrano A, Rodruguez-Durantez JA, Soleto-Martinez J, Gonzalez-Lopez JL. Surgical treatment for bunions in adolescents. J Pediatr Orthoped B 1998; 7:210-216.
2. Schwitalle M, Karbowski A, Eckardt A. Hallux valgus in young patients: Comparison of soft-tissue realignment and metatarsal osteotomy. Eur J Pediatri Surg 1998; 8:42-46.
3. Resch S, Stenstrom A, Reynisson K, Jonsson K. Chevron osteotomy for hallux valgus not improved by additional adductor tenotomy. A prospective, randomized study of 84 patients. Acta Orthop Scand 1994; 65:541-544.
4. Kilmartin TE, Barrington RL, Wallace WA. A controlled prospective trial of a foot orthosis for juvenile hallux valgus. J Bone Joint Surg Br 1994; 76:210-214.
5. Talab YA. Hallux valgus in children: A 5-14-year follow-up study of 30 feet treated with a modified Mitchell osteotomy. Acta Orthop Scand 2002; 73:195-198.

6. Davids JR, Mason TA, Danko A, Banks D, Blackhurst D. Surgical management of hallux valgus deformity in children with cerebral palsy. J Pediatr Orthoped 2001; 21:89-94.
7. Lin CJ, Lai KA, Kuan TS, Chou YL. Correlating factors and clinical significance of flexible flatfoot in preschool children. J Pediatr Orthop 2001; 21:378-382.
8. Thomas RL, Wells BC, Garrison RL, Prada SA. Preliminary results comparing two methods of lateral column lengthening. Foot Ankle Int 2001; 2:107-119.
9. Akcali O, Tiner M, Ozaksoy D. Effects of lower extremity rotation on prognosis of flexible flatfoot in children. Foot Ankle Int 2000; 21:772-774.
10. Luhmann SJ, Rich MM, Schoenecker PL. Painful idiopathic rigid flatfoot in children and adolescents. Foot Ankle Int 2000; 21:59-66.
11. Bruyn JM, Cerniglia MW, Chaney DM. Combination of Evans calcaneal osteotomy and STA-Peg arthroreisis for correction of the severe pes valgo planus deformity. Foot Ankle Int 1999; 38:339-346.
12. Garcia-Rodriguez A, Martin-Jimenez F, Carnero-Varo M, Gomez-Gracia E, Gomez-Aracena J, Fernandex-Crehuet J. Flexible flat feet in children: A real problem? Pediatrics 1999; 103:e84.
13. Coleman SS. Complex foot deformities in children. Philadelphia: Lea & Febiger, 1983.
14. Tachdjian MO. The child's foot. Philadelphia: W.B. Saunders Company, 1985.
15. The child's foot and ankle. In: Drennan JC, ed. New York: Raven Press, 1992.
16. Grill F, Franke J. The Ilizarov distractor for the correction of relapsed or neglected clubfoot. J Bone Joint Surg 1987; 69:593-597.
17. Kuo KN, Hennigan SP, Hastings ME. Anterior tibial tendon transfer in residual dynamic clubfoot deformity. J Pediatr Orthop 2001; 21:35-41.
18. Hintermann B, Gachter A. The first metatarsal rise sign: A simple, sensitive sign of tibialis posterior tendon dysfunction. Foot Ankle Int 1996; 17:236-241.
19. Prichasuk S, Sinphurmsukskul O. Kidner procedure for symptomatic accessory navicular and its relation to pes planus. Foot Ankle Int 1995; 16:500-503.
20. Fraser RK, Menelaus MB, Williams PF, Cole WG. The Miller procedure for mobile flat feet. J Bone Joint Surg 1995; 77:396-399.
21. Mosca VS. Calcaneal lengthening for valgus deformity of the hindfoot. Results in children who had severe, symptomatic flatfoot and skewfoot. J Bone Joint Surg 1995; 77:500-512.
22. Sachithanandam V, Joseph B. The influence of footwear on the prevalence of flat foot. A survey of 1846 skeletally mature persons. J Bone Joint Surg 1995; 77:254-257.
23. Moyes ST, Crawfurd EJ, Aichroth PM. The interposition of extensor digitorum brevis in the resection of calcaneonavicular bars. J Pediatr Orthop 1994; 14:387-388.
24. Napiontek M, Kotwicki T, Tomaszewski M. Opening wedge osteotomy of the medial cuneiform before age 4 years in the treatment of forefoot adduction. J Pediatr Orthop 2003; 23:65-69.
25. Napiontek M, Nazar J. Tibial osteotomy as a salvage procedure in the treatment of congenital talipes equinovarus. J Pediatr Orthop 1994; 14:763-767.
26. Galindo MJJ, Siff SJ, Butler JE, Cain TE. Triple arthrodesis in young children: a salvage procedure after failed releases in severely affected feet. Foot Ankle Int 1987; 7:319-325.
27. Benard MA. Treatment of skewfoot by multiple lesser tarsal osteotomies and calcaneal osteotomy. J Foot Surg 1990; 29:504-509.
28. Berg EE. A reappraisal of metatarsus adductus and skewfoot. J Bone Joint Surg 1986; 68:1185-1196.
29. Peterson HA. Skewfoot (forefoot adduction with heel valgus). J Pediatr Orthop 1986; 6:24-30.
30. Legaspi J, Li YH, Chow W, Leong JC. Talectomy in patients with recurrent deformity in club foot. A long-term follow-up study. J Bone Joint Surg 2001; 83:384-387.
31. Lehman WB, Atar D, Bash J, et al. Results of complete soft tissue clubfoot release combined with calcaneocuboid fusion in the 4-year to 8-year age group following failed clubfoot release. J Pediatr Orthop 1999; 8:181-186.
32. Aronson J, Nguyen LL, Aronson EA. Early results of the modified Peterson bunion procedure for adolescent hallux valgus. J Pediatr Orthop 2001; 21:65-69.
33. Coughlin MJ, Carlson RE. Treatment of hallux valgus with an increased distal metatarsal articular angle: evaluation of double and triple first ray osteotomies. Foot Ankle Int 1999; 20:762-770.
34. Raikin S, Cooperman DR, Thompson GH. Interposition of the split flexor hallucis longus tendon after resection of a coalition of the middle facet of the talocalcaneal joint. J Bone Joint Surg 1999; 81:11-19.
35. Mann RA, Beaman DN, Horton GA. Isolated subtalar arthrodesis. Foot Ankle Int 1998; 19:511-519.
36. Emery KH, Bisset GSr, Johnson ND, Nunan PJ. Tarsal coalition: a blinded comparison of MRI and CT. Pediatr Radiol 1998; 28:612-616.
37. Clarke DM. Multiple tarsal coalitions in the same foot. J Pediatr Orthop 1997; 17:777-780.
38. Olney BW, Asher MA. Excision of symptomatic coalition of the middle facet of the talocalcaneal joint. J Bone Joint Surg 1987; 69:539-544.
39. Giannini S, Ceccarelli F, Vannini F, Baldi E. Operative treatment of flatfoot with talocalcaneal coalition. Clin Orthop 2003; 411:178-187.
40. Asirvatham R, Stevens PM. Idiopathic forefoot-adduction deformity: medial capsulotomy and abductor hallucis lengthening for resistant and severe deformities. J Pediatr Orthop 1997; 17:496-500.
41. Sammarco GJ, Taylor R. Cavovarus foot treated with combined calcaneus and metatarsal osteotomies. Foot Ankle Int 2001; 22:19-30.
42. Kilmartin TE, Barrington RL, Wallace WA. Metatarsus primus varus. A statistical study. J Bone Joint Surg 1991; 73:937-940.
43. Breusch SJ, Wenz W, Doderlein L. Function after correction of a clawed great toe by a modified Robert Jones transfer. J Bone Joint Surg 2000; 82:250-254.
44. Watanabe RS. Metatarsal osteotomy for the cavus foot. Clin Orthop 1990; 252:217-230.
45. Johnson WL, Lester EL. Transposition of the posterior tibial tendon. Clin Orthop 1989; 245:223-227.
46. Giannini S, Ceccarelli F, Benedetti G, Catani F, Faldini C. Surgical treatment of flexible flatfoot in children. J Bone Joint Surg 2001; 83:S73-79.

PEDIATRIC FOOT FRACTURES

Robert M. Kay, MD

I. Introduction
- A. Frequency
  - i. 5-8% of pediatric fratures (~7% of physeal fractures)
- B. Often associated with polytrauma (ABC's/Orthopedic survey)
- C. Peds foot fractures almost always do well with closed treatment

II. Anatomy
- A. Much of the pediatric foot is cartilage (More resistant to fracture)
- B. Ossification centers
  - i. Must be aware of accessory ossification centers
  - ii. Timing of appearance is variable

III. Talus fractures and dislocations
- A. ~2% of peds foot fractures
- B. Fractures
  - i. Avulsion fractures (up to 56%)
  - ii. Osteochondral fractures (~ 20%)
  - iii. Talar neck (~20%)
    1. Hawkins classification (as in adults)
  - iv. Talar body (~5%)
    - Pediatric talar neck and body fractures are caused by a fall from height or MVA in 70-90% of cases (Look for associated injuries)
    - Pain is common at long-term follow-up
- C. Peritalar dislocations (~ 4% of talar injuries)

IV. OCD of the talus
- A. Facts:
  - i. 2nd most common site (Knee)
  - ii. Age: Most commonly 13-14 years old
  - iii. ~ 50% report ankle trauma
- B. Berndt and Harty classification
- C. Results appear somewhat better in children (especially when younger)
  - Usually start with non-operative treatment except in type IV lesions

V. Calcaneal fractures
- A. General
  - i. 5% of calcaneal fractures occur in children
  - ii. ~2% of pediatric foot injuries
  - iii. Frequently missed initially (26% in one series)
- B. Falls from height (40%) and MVA (15%) are most common causes
  - Associated injuries in ~ 1/3 of patients (inc. spine fx's in up to 5%)
- C. Results are much more favorable than in adults
- D. •Closed treatment is used for the vast majority (may need to operate on adolescents with displaced intra-articular fractures)

VI. Other tarsal fractures
- A. General
  - i. 1% of pediatric fractures
  - ii. Fx's of navicular, cuneiforms and cuboid account for ~2-7% of pediatric foot fractures
- B. Most are avulsion or stress fractures (Treat with SLWC x 2-3 weeks)
- C. Complete, displaced tarsal fractures are often associated with high energy trauma – may need surgery since much of tarsal bones are intra-articular

VII. Lisfranc injuries
- A. General
  - i. Rare in children
  - ii. Often result from high energy trauma
  - iii. May be harder to detect due to large amount of cartilage in child's foot
- B. Anatomy
  - i. Roman arch and keystone
    - Check for compartment syndrome
    - Long-term pain appears common

VIII. Metatarsal fractures
- A. General
  - i. 1-2% of all physeal fractures
  - ii. Up to 60% of all peds foot fx's (5th MT base up to 22%)
- B. Mechanism may be direct or indirect
  - 1st MT physis is proximal (all others are distal)
  - Surgery rarely needed (May be needed if marked sagittal malalignment)

IX. 5th metatarsal base fractures
- A. General
  - i. ~ 40% of metatarsal fractures
- B. Fractures distal to metaphyseal-diaphyseal junction have worse results
  - Antecedent pain or sclerosis on initial films (sign of chronic injury) are indicators of poor prognosis – consider early surgery

X. Phalangeal fractures
- A. General
  - i. Up to 18% of pediatric foot fractures (and 3-7% of all physeal fractures)
  - ii. Commonly treated by patients/families or primary care physicians
- B. Buddy taping is generally sufficient
  - Check for open fractures and nail bed injuries

XI. Lawn mower injuries
- A. General
  - i. ~ 2,000 children with permanent injuries annually
  - ii. Vast majority (up to 72%) of children injured as bystanders
    - Careful examination of the entire child mandatory (many have associated head and eye injuries and/or upper extremity injuries)
- B. Treatment
  - i. Repeated I & D's
  - ii. Triple antibiotics
    - Despite optimal treatment amputations (partial or complete) are common

XII. Occult foot fractures
- A. General
  - i. Most common in toddlers
  - ii. Has been reported to account for up 29% of LE pain or limping of unknown etiology in preschoolers
    - Think of foot or lower leg pathology if a child crawls without difficulty but limps when walking (or refuses to walk)

References:

1. Jensen I, Wester JU, Rasmussen F, Lindequist S, Schantz K: Prognosis of fracture of the talus in children. 21 (7-34)-year follow- up of 14 cases. Acta Orthop Scand 1994;65:398-400.
2. Kay RM, Tang CW: Pediatric foot fractures: evaluation and treatment. J Am Acad Orthop Surg 9:308-319, 2001.
3. San Giovani TP, Gross RH: Fractures and dislocations of the foot. In Beaty JH and Kasser JR (eds): Rockwood and Wilkin's Fractures in Children, 5th ed. Philadelphia: Lippincott, Williams & Wilkins, 2001, vol. 3, pp. 1169-1222.
4. Schantz K, Rasmussen F: Good prognosis after calcaneal fracture in childhood. Acta Orthop Scand 1988;59:560-3.
5. Wiley JJ: Tarso-metatarsal joint injuries in children. J Pediatr Orthop 1981;1:255-60.

TREATMENT OF THE CLUBFOOT: NORTH AMERICAN EXPERIENCE

Wallace B. Lehman, MD

I. Introduction

- In the 20th century the majority of clubfoot patients in the United States were treated with surgical releases that resulted in a 15-30% recurrent rate.
- The Ponseti conservative method of treating clubfeet reports a success rate of over 90%.
- The Hospital for Joint Diseases (HJD) Clubfoot Center was established to systematically reproduce the Ponseti technique and scientifically document patient outcomes.

II. HJD Clubfoot Center Protocol

- Pediatric examination and family history (pediatrician)
- Clubfoot history and treatment to date
- Photo (plus video if child walking)
- Preoperative x-rays – AP and forced dorsiflexion lateral of the foot
- Classification of clubfoot (three methods):
  — Dimeglio/Bensahel (French)
  — Catterall/Pirani (English)
  — HJD Functional Rating System (USA)
- Assignment of treatment method
  — Casting
  — Continuous passive motion machine (CPM); physical therapy
  — Casting and percutaneous Achilles tenotomy
  — Soft tissue release
  — Tendon transfer
  — Bone surgery – osteotomy, fusion
- Evaluation post-treatment
  — After casting and/or percutaneous tenotomy - Dimeglio/Bensahel and Catterall/Pirani classifications
  — After soft tissue release or bony surgery – HJD Functional Rating System

III. The Iowa (Ponseti) Clubfoot Casting Technique

- Treatment for newborn to one year of age (whether previously treated or not)
  1. First Cast
     a. Gently manipulate foot
     b. Keep foot in supination
     c. Abduct foot
     d. Always maintain pressure on head of talus
     e. Keep cast on for one week
  2. Second Cast
     a. Gently manipulate foot
     b. Keep foot in supination, but less than in first cast
     c. Abduct foot
     d. Always maintain pressure on head of talus
     e. Keep cast on for one week
  3. Third Cast
     a. Gently manipulate foot
     b. Maintain foot in supination, but less than in second cast
     c. Abduct foot to neutral position concerning abduction and adduction
     d. Always maintain pressure on head of talus
     e. Keep cast on for one week
  4. Fourth Cast
     a. Gently manipulate foot
     b. Keep foot in neutral position concerning supination and pronation
     c. Keep foot in 20-30 degrees of abduction
     d. Always maintain pressure on head of talus
     e. Keep cast on for one week
  5. Fifth Cast
     a. Gently manipulate foot
     b. Before performing tenotomy, measure foot and order shoes and foot abduction orthosis
     c. Perform percutaneous Achilles tendon tenotomy
     d. Place foot in 70 degrees of external rotation
     e. Keep foot in neutral position concerning supination and pronation
     f. Always maintain pressure on head of talus
     g. Keep cast on for three weeks
  6. Additional Points
- All casts above knee with knee at 90∞
- Some patients will require additional casts
- Foot abduction orthosis is used full-time (23-24 hr) with foot in 70∞ of external rotation and 15∞ of dorsiflexion for three months
- After first three months foot abduction orthosis is used at sleep time up to age two or three

IV. Advantages of the Iowa (Ponseti) Casting Technique

- Flexibility of technique
- 6-8 week treatment period
- Lower medical costs
- Results
  – Less foot pain
  – Better functioning foot
  – Fewer recurrences
- Key Point – The HJD Clubfoot Center has consistently achieved a 92% success rate using the Iowa (Ponseti) method.

REFERENCES

1. Catterall A: A method of assessment of the clubfoot deformity. Clin Orth Mar 1991;264:48-53.

2. Cooper DM, Dietz FR: Treatment of idiopathic clubfoot. A thirty year follow-up note. J Bone Joint Surg (Am) 1995; 77(10):1477-1489.

3. Cummings RJ, Davidson RS, Armstrong PF, Lehman WB: Congenital clubfoot. AAOS Instructional Course Lecture. J Bone Joint Surg 2002;84A(2):290-308.

4. Dimeglio A, Bensahel H, Souchet P, Mazeau P, Bonnet F: Classification of clubfoot. J Pediatr Orthop B 1995; 4:129-136.

5. Dobbs MB, Morcuende JA, Gurnett CA, Ponseti IV: Treatment of idiopathic clubfoot: an historical review. Iowa Orthop J 2000;20:59-64.

6. Herzenberg JE, Radler C, Bar N: Ponseti versus traditional methods of casting for idiopathic clubfoot. J Pediatr Orthop 2002;22(4):517-521.

7. Kite JH: The non-operative treatment of congenital clubfoot. South Med J 1930;23:337.

8. Lehman WB: The Clubfoot. Philadelphia, PA, JB Lippincott, 1980.

9. Lehman WB, Atar D: Complications in the Management of Talipes Equinovarus. In Drennan J (ed): The Child's Foot and Ankle. New York, Raven Press, 1992, pp 135-153.

10. Lehman WB, Mohaideen A, Madan S, Scher DM, van Bosse JVP, Iannacone M, Bazzi JS, Feldman DS: A method for the early evaluation of the Ponseti (Iowa) technique for the treatment of idiopathic clubfoot. J Pediatr Orthop B 2003;12(2):133-140.

11. Pirani S: The Vancouver and East Africa experience with the Iowa (Ponseti) technique. Hospital for Joint Diseases Clubfoot Workshop, New York, April 25, 2001.

12. Ponseti IV: Current concepts review: treatment of congenital clubfoot. J Bone Joint Surg (Am) 1992;74:448-454.

13. Ponseti IV: Congenital clubfoot. Fundamentals of treatment. Oxford, Oxford University Press, 1996.

TREATMENT OF CLUBFOOT: THE EUROPEAN EXPERIENCE

Henri Bensahel, MD

Talipes EquinoVarus -TEV-, also named **ClubFoot**, remains a very intriguing deformity. It is still a field of mystery and we still have a lot to learn. Modern studies have improved our knowledge in its etiology. Clubfoot can express as a neurologic or muscular disease, but the majority of deformities are idiopathic.

Currently, the pathophysiology is better understood. The midtarsal joint , mainly the talo-navicular joint,- is the keypoint of the correction of deformities. In order to prevent recurrence of deformity in the course of growth, it is best to obtain the alignment of the talo-navicular joint and the calcaneo-forefoot unit - CFFU.

With an evolving understanding of talipes equinovarus, treatment must be undertaken with great care. The initial treatment must avoid various pitfalls that may compromise the function of the foot. This treatment may also complicate any recurrence of deformity during growth or the subsequent correction of the residual deformities. In my treatment of clubfoot, I have concentrated on the function of the foot with respect to the morphological correction of clubfoot deformities.

I have had the privilege to conceive **a method of conservative/non operative treatment based on physical therapy with manipulations alone and without any rigid immobilization.** Since 1972, I have used this method and it has stood the test of time with long term follow up of patients(average 18 years).One of the main goals of this functional method is to avoid surgical treatment and the subsequent fibrosis that can occur in the connective tissues. Hundreds of patients with clubfoot at our institution, which include all idiopathic (with the various degrees of severity)and non-idiopathic, have been treated with my method of physical therapy . The first series of 600 clubfeet has been published in the French literature in 1980 (1); then a new series has been published in the English literature in 1990 (2) .A third series is in press(3).

For the classification of clubfoot in babies at birth, I use the **Dimeglio-Bensahel classification** published in 1995 (4). However, the International ClubFoot Study Group (ICFSG)is updating this classification in order to enable its use as a Pre-Treatment Classification at any stage of growth when the child presents for the first visit.

The diagnosis of clubfoot is easily determined; but we must stress that true clubfeet are only those feet in which the deformities cannot be completely reduced at birth.(the others being named as postural feet). Each clubfoot in our series was checked with objective data at birth. The score at birth has allowed us to distribute the clubfeet into one of the 4 following groups :

A (0-5)	Mild
B (6-10)	Moderate
C (11-15)	Severe
D (16-20)	Rigid

Our method of functional physical therapy consists of a succession of gentle manipulations during the time the baby is relaxed or asleep after having been fed. These manipulations start with gentle tractions of the joints, followed by progressive reduction of each deformity. These gentle manipulations should not be painful and the baby should not cry during the various stages of the physical therapy session.

Our functional treatment consists of the following steps :

- at first,correction of the deformities of the midtarsal foot and ,above all, reduction of the talo-navicular joint subluxation;
- correction of the varus of the hindfoot and partial correction of the equinus of os calcis;
- progressive reduction of the talus in the tibiotalar joint as the posterior soft tissues of the heel become flexible;
- progressive lateral derotation of the calcaneo-forefoot unit (CFFU)
- lastly, achievement of correction of the hindfoot equinus.

Each session of physical therapy uses the same ritual and progresses according to the rate of improvement of the deformities. Active physical therapy ends each session.

A simple splint is applied between the sessions of manipulations. This below-knee splint is light and flexible. It allows spontaneous movements of the baby and self-physiotherapy of the foot .

At birth, the manipulations (around 30 minutes per foot) are performed daily. But, after 2-3 weeks, the manipulations will be 5 sessions per week. Then, it will be decreased progressively to 2 sessions per week. This method can be performed by the therapists, pediatric orthopaedists or, even, by the families.

The timing for reduction of deformities is:

- hindfoot varus correction, talo-navicular reduction ,calcaneo-forefoot unit (CFFU) derotation - from 6 to 8 weeks;
- hindfoot equinus - approximately 50% can be reduced from 6 to 8 weeks ; residual equinus is more demanding, with 4 more weeks required if the Achillis tendon is the alone cause of the deformity or longer if it is due to the whole posterior soft tissue (connective tissue) contracture.

This treatment is continued as long as it is effective . In the case when all deformities of the clubfoot are not reduced, a limited surgery will be performed in order to complete the realignment of the foot. It is what I have named the "à la carte" surgery (5). After this surgery, the functional method is used again to stabilize the reduction of the foot and to strengthen and balance the muscles.

When treatment is over, we follow the child until the end of growth and allow the child to have a normal life , including all kinds of sports activities and normal shoes wear.

In Europe(7) , a number of pediatric orthopaedists have accepted use of this functional method of clubfoot treatment with the same principles. There are some differences in splint use , but this is not contradictory to our philosophy of treatment.

Recently, the International ClubFoot Study Group (ICFSG)has set up and published a Rating System to be used as an outcome evaluation (6). There are objective parameters to this Rating System with scores from 0 point (best result) to 60 points (worst result) . The detailed scores for assessment includes : up to12 points for the morphology of each part of the foot , ankle and lower limb alignment; up to 36points for foot function ,including passive range of motion, dynamic muscular function, gait observation and pain; and up to 12 points for X-rays. This evaluation is used by the end of the treatment ,then at 6 years old and at the end of the growth of the foot.

The results of the European experience with the functional method as conservative/non operative treatment of clubfoot improved with time and experience . Many institutions have reached a true expertise in the method. In good hands, the rate of "excellent " and good results is 77% and these feet do not require any surgery (3). This percentage is distributed widely amongst the four groups of severity of clubfoot, as assessed before the onset of treatment. Long -term follow- up is invaluable to assess the end result. It will likely confirm the "excellent" and good results of our method.

As we compare the outcome of our functional method to the birth classification, we observe that 50% of Group B led to a" very good "outcome. All patients in Group C improved to a "moderate" outcome. All patients in Group D also improved and 40% were stabilized in this "severe" group.

In summary, our functional method of clubfoot treatment decreased the degree of deformity in all patients, despite their severity. There was a progressive reduction of the Chopart joint subluxation, and correction of hindfoot varus, calcaneo-forefoot medial rotation and equinus deformity.

Our functional method for treatment of Clubfoot is "state of the art". The European experience with this method of clubfoot treatment has demonstrated to give the best function to feet during growth and into adulthood.

REFERENCES

1. Bensahel, H., et al., Comments about 600 club feet (author's transl). Chir Pediatr, 1980. 21(5): p. 335-42
2. Bensahel, H., et al., Results of physical therapy for idiopathic clubfoot: a long-term follow- up study. J Pediatr Orthop, 1990. 10(2): p. 189-92
3. Souchet P., Bensahel H., et al.: Functional Treatment of Clubfoot : a New Series of 350 cases with a Long Term Follow Up., J. Ped. Orthop. B, in press
4. Dimeglio, A.-Bensahel H. et al., Classification of clubfoot. J Pediatr Orthop B, 1995. 4(2): p. 129-36.
5. Bensahel, H., et al., Surgery in residual clubfoot: one-stage medioposterior release "a la carte". J Ped. Orthop, 1987. 7(2): p. 145-8.
6. Bensahel H., Kuo K. , Duhaime M. and ICFSG : Outcome Evaluation of Treatment of Clubfoot, J. Ped. Orthop.B, 2003, 12 (4),p.269.
7. Exner, G.U. & al. :Manuelle and operative Behandlung auf patho-anatomischer Basis, Clubfoot-book at Steinkoppff-Darmstadt in press 2004.

MILITARY ORTHOPAEDICS IN SUPPORT OF OPERATION IRAQI FREEDOM AND OPERATION ENDURING FREEDOM (M)

Moderator: Mark R. Bagg, Ft. San Houston, TX (*)

Since the horrific events of September 11, 2001, the US Military has been engaged in a global war on terrorism. As a result, a significant number of military orthopaedic surgeons have been deployed to various parts of Central Asia in support of Operation Iraqi Freedom and Operation Enduring Freedom. During this symposium, experiences and lessons learned will be discussed as they relate to the demographics of both battle and non-battle injury patterns; the treatment of wounded soldiers from initial management in the theater to definitive management in the United States; the treatment of injured civilians and Enemy Prisoner of War; current amputee care; air evacuation policy; and the doctrinal evolution of our current Forward Surgical Teams and Combat Support Hospitals.

I. Current Military Unique Training for Battlefield Surgery
David B. Carmack, MD, Baltimore, MD(*)

II. Forward Surgical Teams: Role of the Orthopaedic Surgeon
Edward D. Arrington, MD, University Place, WA (n)

III. Forward Surgical Teams: One Orthopaedic Surgeon's Experience during Operation Iraqi Freedom
Richard Pope, MD, Adelaide, Australia (*)

IV. Combat Surgical Hospitals: Experience of the 21st CSH
Clark P. Searle, MD, Clarksville, TN (n)

V. Combat Surgical Hosptials: Experience of the 26th CSH
Robert R. Granville, MD, San Antonio, TX (n)

VI. The Role of the USS Comfort in Providing Forward Reconstructive Orthopaedic Care in Theater
Mike J. Phipps, MD, Bethesda, MD (*)

VII. The Landstuhl Experience
Joachim Tenuta, MD (*)

VIII. The Walter Reed Experience
Richard B. Islinger, MD, Silver Springs, MD (n)

IX. The US Army Amputee Program
William C. Doukas, MD, Bethesda, MD (n)

ORTHOPAEDIC SURGERY IN SUPPORT OF OPERATION IRAQI FREEDOM- 21ST COMBAT SUPPORT HOSPITAL EXPERIENCE

MAJ Clark P. Searle, LTC Kim Kesling, COL Robert Lyons

Combat Support Hospital (CSH) capabilities
- Primary mission is battlefield trauma care, not routine peacetime care
- Internal fixation is troublesome due to sanitation/sterility issues
- Very limited Ortho and General Surgery staff (at 21st CSH in particular)
- No Intensivists, Pediatricians, Spine Surgeons, Neurosurgeons, Ophthalmologists
- Very limited pediatric supplies

21st CSH Deployment
- Departed Ft. Hood 19 March 2003 for Kuwait
- Convoys departed Kuwait for Iraq 20 April
- Bravo company to Mosul to support 101st Airborne Div
- Alpha company to Balad to support 4th Infantry Div

Staffing- significant differences between various CSH's
- 21st CSH in each location
- 1 Orthopaedic Surgeon, 1 General Surgeon and 3-4 additional surgeons
- Urologists, OB/GYN's, Plastic Surgeon, OMFS as additional Surgeons

Workload
- At least 65% Orthopaedic
- Not feasible for 1 Orthopaedic Surgeon and 1 General Surgeon to see all patients
- Critical that the other Surgeons took primary Orthopaedic and General Surgery call to screen and work up patients
- Primary care physicians and PT handled large proportion of outpatient Ortho patients

Patient Categories
- Coalition soldiers- treated and returned to duty or evacuated to Europe
- Enemy Prisoners of War (EPW) - definitive care at CSH's
- Iraqi civilians- injured by coalition forces or life / limb threatening injuries
- Third country nationals – contract workers, NGO's

Sources of Coalition Casualties
- Typical peacetime sources
- MVA's, sports, falls, pre-existing conditions, heavy equipment accidents, illnesses
- Combat related

Issues with Civilian Care
- Combat Support Hospital not designed for long-term care
- Local population perceives an "American hospital" as better than Iraqi hospitals
- Not necessarily true- tibia fracture example
- They expect a tertiary care center, not a combat hospital
- Soldiers and leadership want to help injured locals
- Injured and ill locals came to our base gate, potentially compromising security
- Potential for bad press and damaged morale- chronic medical problems, old burns
- Civilian medical needs extremely high, and require rebuilding infrastructure

Iraqi Civilian Medical Care
- Initially no Iraqi facilities were available to accept civilians
- Medical infrastructure long neglected under previous regime
- Hospitals critically short on supplies, equipment
- Iraqi physicians very well educated and enthusiastic
- Very limited CME for years
- COL Bob Lyons, Deputy Commander for Clinical Services organized and established the 21st CSH relationship with the local hospital in Balad
- For the first visit, we took several surgeons, several civilian surgical patients and generous medical supplies to care for those patients
- 21st CSH conducted combined grand rounds, invited Iraqi physicians to visit CSH
- This arrangement was probably the single biggest success of the 21st CSH
- It allowed us to care for the civilians who needed it and then to transfer when stable
- Allowed us to keep beds open in ICU's/wards for mass casualty situations
- Provided supplies/education to local Iraqi hospital
- Facilitated rebuilding medical infrastructure

Successes
- Cooperation with Balad Hospital
- When the local situation became dangerous, Iraqi doctors sent a courier to postpone our visits to Balad
- 21st CSH medical staff selflessly supported one another
- Evacuation system worked very well
- Coalition soldiers left theater very rapidly, so temptation to do too much surgery was very low
- Body armor works!

Difficulties
- Staffing
- Orthopaedic staffing inadequate
- Large number of General Surgeons and Orthopaedic Surgeons in FST's
- Very little work after initial combat phase
- If CSH's are to be used for area support (sick call), must staff for it
- Severe supply problems at outset
- No Hoffman II combat external fixators, Hoffman II "tub" sets or drills
- Environment
- CSH's are VERY DIRTY- including the Operating Room
- Routinely had flies in OR
- Air conditioner reversed flow and blew dust into OR
- Power problems- extreme heat (140+') - very hard on generators- frequent power failures
- Training
- Overall, few lessons from previous wars were re-learned
- But temptation to close dirty wounds was too much for some

Lessons
- Designate one facility as tertiary referral facility for long term EPW and civilian care and staff and equip appropriately
- Place priority on moving hospitals into fixed facilities
- Crucial to coordinate with local medical facilities

-Staff CSH's by workload- much more Ortho staffing
-Allow FST's to augment CSH's after combat phase

MILITARY ORTHOPAEDICS IN SUPPORT OF OPERATION IRAQI FREEDOM AND OPERATION ENDURING FREEDOM

Robert Granville, MD, Keith Albertson, MD, James Oliverio, MD, and Lee McFadden, MD

I. Introduction
- Combat Support Hospital (CSH) is doctrinally the first echelon to provide simple definitive surgery
- Fully configured it has 296 beds: 48 ICU, 80 "Intermediate Care", 168 "Minimal Care" staffed by 565 soldiers
- Surgical staff consists of 3 Orthopaedic, 6 General, 2 Urologic, 2 Ob/Gyn, and 1 Oromaxillofacial surgeons, 2 Anesthesiologists and 8 CRNAs
- Augmentation for Neurosurgery and Ophthalmology is available
- Four 2-bed ORs, lab, X-ray, and medical maintenance are housed in hard-walled, expandable shelters, the remainder of the hospital is in tentage
- 72 hour patient holding capability
- Organic transportation assets can move less than 20% of the hospital

II. 28th CSH—deployment phase
- Supports the XVIIIth Airborne Corps from Fort Bragg, North Carolina
- Deployed to Camp Doha, Kuwait on March 11, 2003 without equipment
- "Fell in" on pre-positioned equipment set stored on USS Gibson in the Mediterranean since 1994
- Mission changes necessitated 3 re-packs before moving into Iraq
- "Crossed the berm" into Iraq on March 29, 2003, moving 64 beds and 135 personnel in 3 marches of more than 20 hours over 10 days to FLB Dogwood, SW of Baghdad

III. Combat operation phase
- "Major operations" ended 1 May
- From 11 April to 30 May, 303 surgeries were performed on 217 patients
- Records were reviewed for 280 surgeries on 198 patients
- 49.5% were US soldiers, 11.1% were enemy prisoners of war (EPW), and 39.4% were civilian wounded (CW)
- 48.9% of anesthetics were given for orthopaedic injuries only, 21.8% for orthopaedic and other injuries, and 29.3% for non-orthopaedic procedures (11.1% were for atraumatic conditions)
- Excluding cases not involving trauma (appendectomies, cystoscopies, etc.) 63.9% of cases were orthopaedic
- Length of stay averaged 2.36 days for US (due to efficient air evacuation), 9.29 for EPW, and 8.33 for CW
- Number of surgeries averaged 1.07 for US, 1.68 for EPW, and 1.76 for CW
- There were 11 (5.6%) deaths: 4 burns, 3 blunt head trauma, 3 multiple-injury, and 1 presumed PE following limb salvage attempt

IV. Post-combat phase
- Split operations—32-bed "slice" moved to Tikrit and began operations 7 June in support of the 4th ID w/1 orthopaedist, 1 urologist, and 1 general surgeon, 3 CRNAs and 1 two-bed OR
- Remainder of personnel and equipment moved up to FLB Dogwood from Kuwait
- Fixed facility—FLB Dogwood operations moved into former Baath Party facility (Ibn Sina Hospital) on 23 August
- Augmentation first by Neuro (during combat ops), then Eye teams
- Iraqi health care system gradually became able to deliver at least custodial care, in part through 28th CSH efforts
- Over 2400 cases performed to date, over 1200 of which have been orthopaedic

V. Successes
- Protective equipment—ceramic body armor supplied to infantrymen has defeated high-velocity weapon hits to protected body areas in large numbers
- Evacuation—formal and "ad-hoc" Critical Care Air Transport teams have allowed rapid evacuation of unstable critically wounded soldiers
- Training—learning curve has been negligible compared to previous conflicts, with essentially none of the classic errors in war wound management being repeated
- Vascular repair—the high percentage of CT and vascular surgeons who deployed in general surgical billets and the vascular skills of the deployed general surgeons resulted in the successful revasculization of almost every limb in which it was attempted
- External fixation—Hoffman II fixator has proved excellent for transport stabilization of femoral fractures stabilized by traction and hip spica casting in previous wars
- Burn care—excess general surgical expertise and available intensive care beds improved survival of high-BSA burns in non-US patients

VI. Problems
- EPWs and CWs—a CSH is not equipped or staffed for definitive war fracture treatment, pediatric, or long-term care despite the tactical and political realities—patients were even "reverse evacuated" when the USS Mercy redeployed
- Disproportionate workload—effective body armor decreases the requirement for general surgeons, relatively increasing the demand for orthopaedic care (20% of the surgeons performed 50% of the surgery)
- Medical logistics—complete reliance was placed on external fixation for long bone stabilization for transport without the medical logistic system ensuring an adequate supply
- Lost training opportunity—in not giving them front line combat surgical experience AMEDD is missing the chanceto ensure a generation of young o rthopaedic surgeons become "military orthopaedists" instead of "orthopaedists in the military"
- Skill degradation—primarily senior surgeons deployed initially and have remained deployed, with concomitant loss of their non-military surgical skills over time

VII. Solutions
- Designate one facility for long-term, definitive orthopaedic treatment for EPW and CW care, equipping and staffing it appropriately, to act as a referral center for the other CSHs in theater
- Provide security for those NGOs attempting to assist in humanitarian care—freeing military medical assets to provide military medical care
- Change the CSH surgical staffing to reflect the preponderance of musculoskeletal trauma, accepting the modern real-

ity that general surgeons no longer receive training in treating orthopaedic injuries during or after residency
- Revise the medical logistic system to have nomenclature understandable to surgeons and provide military surgeons with training that enables them to understand the system sufficiently to be able to force it to respond to patient needs in a timely manner
- Limit surgeon deployments to six months, preventing perishable skill loss and providing combat experience to a larger number of military surgeons

BIBLIOGRAPHY

1. Rutkow, IM, James Thacher and His Military Journal During the American Revolutionary War, Arch. Surg. 2001; 136: 837.
2. Bilski TR, Baker BC, Grove JR, et al, Battlefield Casualties Treated at Camp Rhino, Afghanistan: Lessons Learned, JTrauma 2003; 54: 814-22.
3. Bowen TE, Bellamy RF, eds, Emergency War Surgery, 2 Ed., US Government Printing Office, Wash, DC, 1988; p8.
4. Skolnick A, Medicine and War: Recognizing Common Vulnerability of Friend and Foe, JAMA 1991; 265: 834-35.
5. Gunby P, Another War…and More Lessons for Medicine to Ponder in Aftermath, JAMA 1991; 266: 619-21.
6. Longmire AW, Deshmukh N, The Medical Care of Iraqi Enemy Prisoners of War, Milit Med 1991; 165: 645-48.
7. Keenan WF, Non-Surgical Medical Care of Enemy Prisoners of War during Operation Desert Storm, Milit Med 1991; 165: 648-51.
8. Wintermeyer SF, Pina JS, Cremins JE, Heier JS, Medical Care of Iraqis at a Forwardly Deployed U.S. Army Hospital during Operation Desert Storm, Milit Med 1996; 161: 294-97.
9. Spalding TJW, Stewart MPM, Tulloch DN, Stephens KM, Penetrating missile injuries in the Gulf war 1991, Br J Surg 1991; 78: 1102-04.
10. Batty CG, Changes in the Care of the Battle Casualty: Lessons Learned from the Falklands Campaign, Milit Med 1999; 164: 336-40.
11. Oglesby JE, Twenty-Two Months' War Surgery in Vietnam, Arch Surg 1971; 102: 607-613.
12. Byerly WG, Pendse PD, War Surgery in a Forward Surgical Hospital in Vietnam: A Continuing Report, Milit Med 1971; 136: 221-26.
13. Oreck SL, Orthopedic Surgery in the Combat Zone, Milit Med 1996; 161: 458-61.
14. Wintermeyer SF, Pina JS, Cremins JE, Heier JS, The Inpatient Experience of a U.S. Army Combat Support Hospital in the Persian Gulf during Non-Combat and Combat Periods, Milit Med 1994; 159: 746-51.
15. Rautio J, Paavolainen P, Delayed treatment of complicated fractures in war wounded, Injury 1987; 18: 238-40.
16. Gertsch P, Assessment of hospital workload in war surgery, Br J Surg 1987; 74: 831-33.
17. Pratt JW, Rush RM, The military surgeon and the war on terrorism: a Zollinger legacy, Am J Surg 2003; 186: 292-95.
18. Gasko OD, Surgery in the Field During the Lebanon War, 1982: Doctrine, Experience and Prospects for Future Changes, Israel J of Med Sci 1984; 20: 350-54.
19. Carey ME, Analysis of Wounds Incurred by U.S. Army Seventh Corps Personnel Treated in Corps Hospitals during Operation Desert Storm, February 20 to March 10, 1991, J Trauma 1996; 40: S165-69.
20. Leedham CS, Blood CG, Newland C, A Descriptive Analysis of Wounds among U.S. Marines Treated at Second-Echelon Facilities in the Kuwaiti Theater of Operations, Milit Med 1993; 158: 508-12.
21. Batinica J, Batinica S, War Wounds in the Sibenik Area during the 1991-1992 War Against Croatia, Milit Med 1995; 160: 124-28.
22. Mabry RL, Holcomb JB, Baker AM, et al, United States Army Rangers in Somalia: An Analysis of Combat Casualties on an Urban Battlefield, J Trauma 2000; 49: 515-29.
23. Garfield RM, Neugut AI, Epidemiologic Analysis of Warfare: A Historical Review, JAMA 1991; 266: 688-92.

OUTCOMES AND INCOMES: CLINICAL APPLICATION OF EVIDENCE-BASED PRACTICE (U)

Moderator: Michael J. Goldberg, MD, Boston, MA (d – Data Harbor Inc)

The purpose of this symposium is to educate the clinician on the importance of an evidence-based approach to clinical practice. This symposium will provide current clinical applications of evidence in practice and help the clinician understand the use of outcome instruments, application of performance measures, and utilization of a clinical reasoning cycle in the pursuit of best practice.

I. Introduction and Opening Remarks
Michael J. Goldberg, MD, Boston, MA (d – Data Harbor Inc)

II. Total Joint Registries: A Current Perspective
Robert B. Bourne, MD, London, ON, Canada (n)

III. MODEMS: Lessons Learned and Implications for a Total Joint Registry
Khaled J. Saleh, MD, Minneapolis, MN (a, e – Smith & Nephew, Howmedica Osteonics)

IV. Applications of Current Best Literature in Practice
James G. Wright, MD, Toronto, ON, Canada (a – Canadian Institute for Health Department)

V. Spine Outcome Research Trial: A Successful Outcome Project
William A. Abdu, MD, Lebanon, NH (n)

VI. Application of EBP in a Community Setting
Michael P. Dohm, MD, Grand Junction, CO (n)

TOTAL JOINT REGISTRIES: A CURRENT PERSPECTIVE

Robert B. Bourne, MD

Introduction and Aims

The purpose of this presentation is to demonstrate how a national joint replacement registry can promote evidence-based surgical practice. The Canadian Joint Replacement Registry (CJRR) determines trends in the 43,000 total hip and knee replacement surgeries performed annually in Canada. This data will promote improved access to care, a lower need for revision surgery and evidence-based surgical practice.

Method

The Canadian Joint Replacement Registry is conducted by orthopaedic surgeons under the umbrella of the Canadian Orthopaedic Association, funded by Health Canada and administered by the Canadian Institute of Health Information. Inaugurated in 2000, the Canadian Joint Replacement Registry has issued three annual reports, which highlight trends in total hip and knee replacement in Canada over the past decade. Data from this voluntary Registry provide the data for this study.

Results

1. THR and TKR utilization in Canada increased by 34% from 1994-5 to 2000-01.
2. Total knee replacement utilization exceeded total hip replacement rates in the mid-1990's and increased TKR use continues to grow.
3. Considerable provincial area variations exist with regards THR and TKR utilization in Canada.
4. THR and TKR are more commonly performed in female patients with peak utilization being between 65 – 74 years of age. One third of THR's and TKR's are now performed on patients <65 years of age.
5. Average length of stay has dropped precipitously over the last two decades. Average length of stay is now approximately five days for THR's and TKR's.
6. In-hospital mortality is higher for THR's (1.51%) as compared to TKR's (0.54%).
7. Complications leading to readmission are more common in THR's.
8. Age-standardized rates of THR and TKR/100,000 population have increased from 1994-5 to present, but still are lower than other countries.
9. Waiting times for surgery remain a problem with most patients waiting more than six months for surgery.
10. One year post-operatively, 96% of patients would have their primary or revision total hip or knee replacement performed again.
11. Patients are more satisfied with the outcome of primary procedures as compared to revisions.
12. THR patients have a higher level of satisfaction than TKR patients.

Conclusions

THR and TKR utilization are dynamic in nature. A national registry such as the CJRR is important in pooling large data sets, allowing trends to be recognized, influencing health care providers and promoting evidence-based surgical practice.

REFERENCES

1. Health Care in Canada 2003, Canadian Institute of Health, Ottawa
2. 2002 Report, Total Hip and Knee Replacements in Canada, Canadian Institute of Health, Ottawa
3. 2003 Report, Total Hip and Knee Replacements in Canada, Canadian Institute of Health, Ottawa

APPLICATION OF CURRENT BEST LITERATURE IN PRACTICE

James G. Wright, MD, MPH, FRCSC

Goals of Clinical Practice
- Choice of treatment for individual patients must do more good than harm and result in the greatest improvement in health compared to no treatment or alternative treatments

Treatment Options: Femoral Fractures
- Traction/casting
- Early casting
- External fixation
- Flexible nails
- Internal fixation

Evidence in Surgery
- Best evidence leads to best practice
- Best evidence are from randomized clinical trials

Definition of Evidence-based Medicine
"the conscientious, explicit, judicious use of current best evidence in making decisions about the care of individual patients. The practice of evidence-based medicine means integrating individual expertise with the best available external clinical evidence from systematic research." *Sackett 1996*

Process of EBP
- Ask question
- Find evidence
- Appraise evidence
- Integrate into clinical situation

Evidence and the Practicing Surgeon
- Need "best" evidence
- Easily available
- Comprehensive
- Timely fashion

Formulate Question
- Identify disease
- Identify treatment (or non-treatment) options

Identify Evidence
- Texts/CD ROMs
- Medline: studies, meta-analyses
- Practice guidelines
- Evidence-based Journals
- Cochrane data-base

Medline Search: Paediatric Femoral Fractures
- Search for "Femoral Fracture" limited by 0-18 years, human, English language identified 2297 articles from 1966-Dec 2003

Evaluate Evidence
- Grade levels of evidence
- Critically appraise evidence

Levels of Evidence
- Level 1: meta-analyses and/or RCT
- Level 2: non-randomized cohort studies
- Level 3: case-control studies
- Level 4: case series
- Level 5: expert opinion

Critical Appraisal (JAMA)
- Study population should be explicitly described
- Patients being compared should be similar
- Treatments should be delivered proficiently without other treatments
- Outcome should be determined at same time and in same fashion

Journal of Bone and Joint Surgery: Evidence-based Orthopaedics
- McMaster University reviews 42 journals to identify level I evidence
- Quarterly section of three structured abstracts with solicited commentaries

Journal of Bone and Joint Surgery: Levels of Evidence
- All submitted clinical papers will have rating for LOE on primary research question
- Oxford Center for Evidence-based Medicine
- Articles published with LOE

Levels of Evidence For Primary Research Question

	Therapeutic Studies – Investigating the results of treatment	Prognostic Studies – Investigating the outcome of disease	Diagnostic Studies – Investigating a diagnostic test	Economic and Decision Analyses – Developing an economic or decision model
Level I	1. Randomized Trial a) Statistically significant difference. b) No statistically significant difference but narrow confidence intervals 2. Systematic Review[2] of Level I RCTs (and studies were homogenous)	1. Prospective study[1] 2. Systematic review[2] of Level I studies	1. Testing of previously developed diagnostic criteria on consecutive patients (with universally applied reference "gold" standard) 2. Systematic review[2] of Level I studies	Economic and Decision Analyses – Developing an economic or decision model
Level II	1. Prospective cohort study[3] 2. Poor quality RCT (e.g. < 80% follow-up) 3. Systematic review[2] (a) Level II studies (b) non-homogeneous Level 1 studies	1. Retrospective[4] study 2. Untreated controls from an RCT 3. Systematic review[2] of Level II studies	1. Development of diagnostic criteria on consecutive patients (with universally applied reference "gold" standard) 2. Systematic review[2] of Level II studies	1. Clinically sensible costs and alternatives; values obtained from limited studies; with multiway sensitivity analyses 2. Systematic review[2] of Level II studies
Level III	1. Case control study[5] 2. Retrospective[4] cohort study 3. Systematic review[2] of Level III studies		1. Study of non-consecutive patients; without consistently applied reference "gold" standard 2. Systematic review[2] of Level III studies	1. Analyses based on limited alternatives and costs; and poor estimates 2. Systematic review2 of Level III studies
Level IV	Case Series (no, or historical, control group)	Case series	1. Case-control study 2. Poor reference standard	Analyses with no sensitivity analyses

1. All patients were enrolled at the same point in their disease (inception cohort) with ≥ 80% follow-up of enrolled patients
2. A combination of results from two or more prior studies.
3. Patients compared with a control group of patients treated at same time and institution.
4. The study was initiated after treatment performed.
5. Patients with a particular outcome called "cases"; e.g. failed total arthroplasty compared to those who did not have outcome called "controls", e.g. non-failed total hip arthroplasty.

Restrict Medline to "Clinical Trials"
- Bar-On et al. JBJS 1998
- 19 patients randomized to external fixation and flexible nails
- No statistical analyses

Meta-Analysis (Wright et al. CJS 2000)
- Average mean quality score was 4.1 (out of a possible 15)

Table IV

Results of Treatment

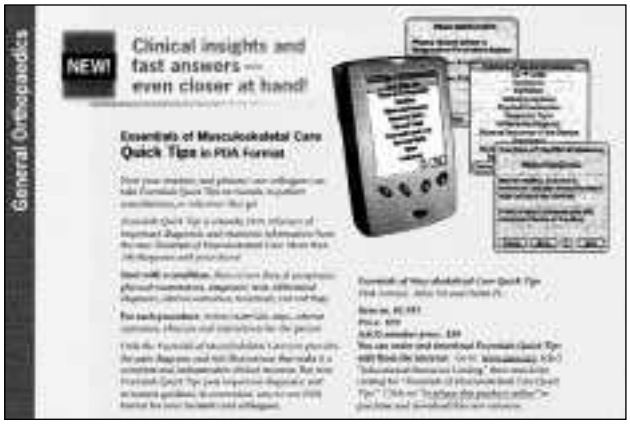
Outcome measure	Treatment, mean (and range)		
	Early application of hip spica	Traction with or without spica	Internal fixation
LLD ≥ 2 cm, %	3 (0–25)	10 (0–28)	25 (5–100)
Varus or valgus > 10°, %	9 (3–19)	16 (8–29)	0
Anterior or posterior angulation > 10°, %	8 (0–19)	16 (8–23)	0
Malrotation > 10°, %	13 (0–25)	21 (3–36)	25 (11–32)
Hospital stay, d	11 (5–29)	34 (22–40)	24 (5–42)
Immobilization, d	45 (40–51)	39 (39–39)	—
Cost or charges, $	5 784 (590–11 800)	10 410 (2 514–18 307)	8 708

LLD = leg-length discrepancy

Evidence-based Working Group Recommendations (6 to 9 years)
- Traction/spica cast
- Flexible nails
- Plate/screws
- External fixator

Canadian Task Force Grade of Recommendations

A: Good evidence for
B: Fair evidence for
C: Conflicting evidence
D: Fair evidence against
E: Good evidence against
I: Insufficient evidence



Apply Evidence
- Shared decision making
- Re-evaluate decision

Problems with EBP (Straus et al. CMAJ 2002)
- Shortage of evidence
- Difficulty applying to individual patient
- Gap between demand and resources
- Need for new skills
- Limited time
- Uncertain it works
- Misrepresentations

Conclusions
- Best practice based on best evidence
- Multiple sources for best evidence
- Ideal method to deliver evidence to surgeons unknown

REFERENCES

1. Doig GS, Simpson F. Efficient literature searching: A core skill for the practice of evidence-based medicine. Intensive Care Med 2003.
2. McAlister FA. Applying evidence to patient care: From black and white to shades of grey. Ann Intern Med 2003; 138:938-939.
3. Ramos K, Linscheid R, Schafer S. Real-time information-seeking behavior of residency physicians. Fam Med 2003; 35:257-260.
4. Ross R, Verdieck A. Introducing an evidence-based medicine curriculum into a family practice residence -- is it effective? Acad Med 2003; 78:412-417.
5. Campbell SM, Braspenning J, Hutchinson A, Marshall MN. Education and debate. Improving the quality of health care. Research methods used in developing and applying quality indicators in primary care. BMJ 2003; 326:816-819.
6. Mabrey JD. A PDA orthopaedic library. AAOS Bulletin 2002; 50.
7. Davis D, Evans M, Jadad A, et al. Learning in practice. The case for knowledge translation: Shortening the journey from evidence to effect. BMJ 2003; 327:33-35.
8. Devereaux PJ, Yusuf S. The evolution of the randomized controlled trial and its role in evidence-based decision making. J Intern Med 2003; 254:105-113.
9. New grades for recommendations from the Canadian Task Force on Preventive Health Care. Can Med Assoc J 2003; 169:213-214.

A Office-Based Electronic Data Collection System for Prospective Longitudinal and Real Time use in Spine Patients

Experience at the Spine Center

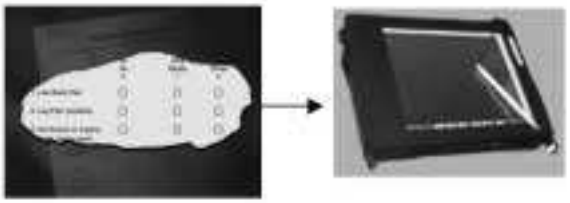
Dartmouth-Hitchcock Medical Center

Dartmouth Medical School

Hanover NH

William A. Abdu MD MS

Moving from paper to electronic data collection in a clinical setting



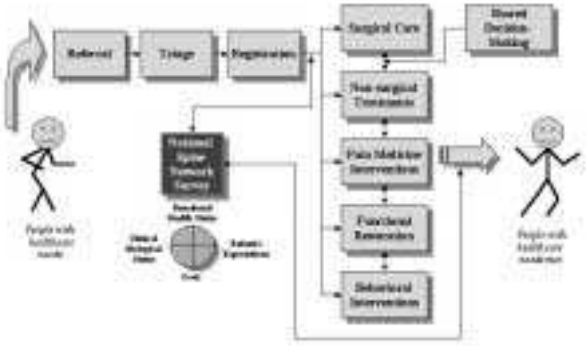
1. Initialize survey with patient information.

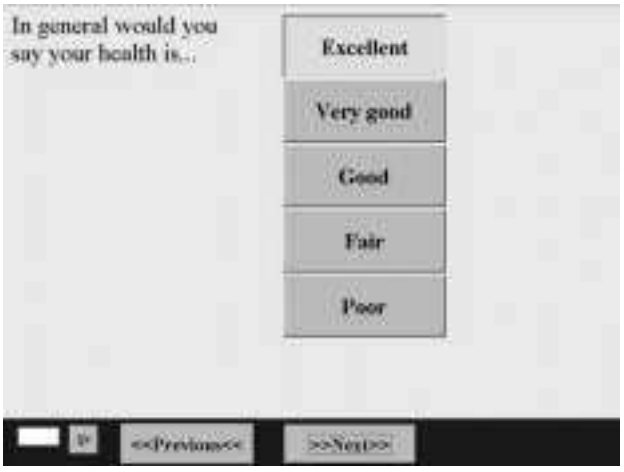
Current Technology

Patient Completes the Survey

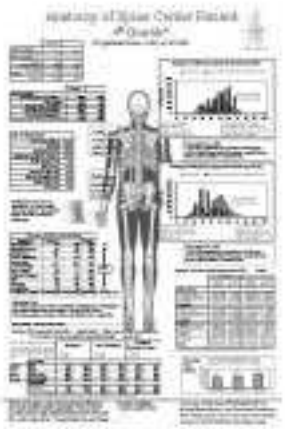
...And returns it to the receptionist

DHMC Spine Center
Panel Management Process: Clinical Laboratory





Wireless download and printing of the Patient Summary Report



What can we learn from the data ?

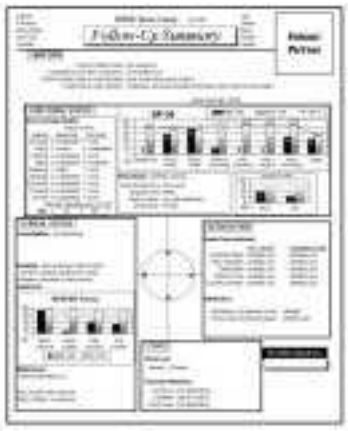
Today

- Point of care (real time use) for each visit
- Process of delivering care
- Benchmarking
- Research: Feedback to the clinical practice (SPORT)

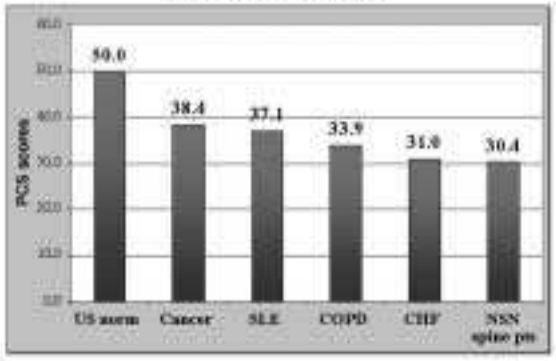
Future

- Web based surveys
- Improve triage efficiency
- Collaboration
- Public reporting of health outcomes

'Real-Time' Patient Summary Reports



PCS in medical conditions reported in the literature



SPORT: Study Design

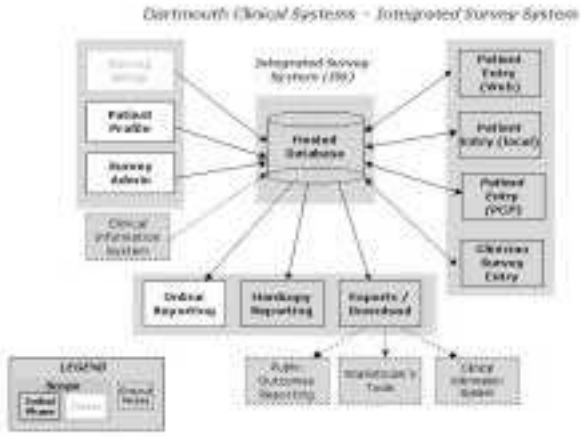
Multi-center prospective clinical trial

- **Randomized cohort**
- **Observational cohort**

Surgical vs. Non-surgical treatment for disorders of the Lumbar Spine

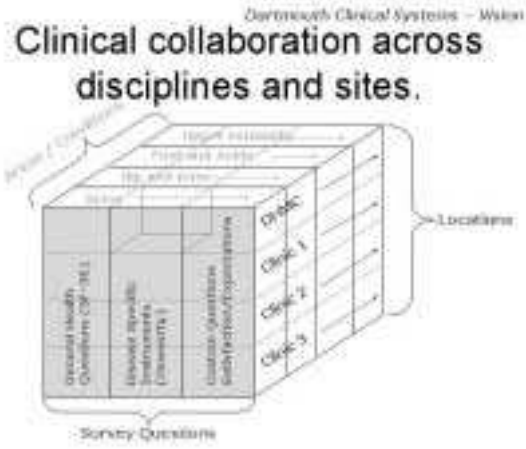
Intervertebral disc herniation (IDH), spinal stenosis (SS), degenerative spondylolisthesis (DS)


Pt eligibility criteria for inclusion in IDH, SpS, or DS cohorts
View videotape for IDH or SPS (DS)
Consent to participate in RCT or Observational Cohort?
No
Yes
Observational Cohort
Randomized Cohort
IDH, DS & SpS Choose
IDH, DS & SpS Randomize
Surgery
Non-surgical therapy
Surgery
Non-surgical therapy

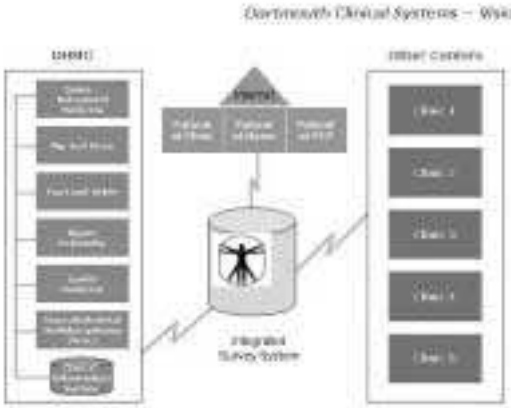

Dartmouth Clinical Systems – Integrated Survey System
Integrated Survey System (ISS)
Hosted Database
Patient Profile
Survey Admin
Clinical Information System
Patient Entry (Web)
Patient Entry (Local)
Patient Entry (PCP)
Clinician Survey Entry
Online Reporting
Hardcopy Reporting
Reports / Download
LEGEND
Script
Stored Values
Output Files
Public Outcomes Reporting
Statistical & Trends
Clinical Information System


Web-Based


It Doesn't Compute
Boston's Field Boss Should Lack Silicon


Dartmouth Clinical Systems – Vision
Clinical collaboration across disciplines and sites.
Clinic
Clinic 1
Clinic 2
Clinic 3
Localities
Survey Questions


Thank-You


Dartmouth Clinical Systems – Vision
IDH(1)
Other Centers
Integrated Survey System

TORT REFORM (V)

Moderator: Stuart L. Weinstein, MD, Iowa City, IA (n)

This symposium will include discussions on the current tort reform crisis, the federal legislative landscape, and successful state models where reform has occurred.

I. Overview of Tort Reform, AAOS actions including its National Campaign, Fundraising Efforts, Coalition Activities and Grants
Stuart L. Weinstein, MD, Iowa City, IA (n)

II. Tort Reform in Texas – tactics, obstacles and succcesses
David D. Teuscher, MD, Beaumont, TX (n)

III. National Efforts in Tort Reform, AMA activities, efforts at federal reform and successes in particular states
Donald J. Palmisano, MD, Chicago, IL (n)

IV. Bridging state and federal efforts at tort reform. Why the Texas tort reform success is unique and the possibility of federal reform
Victor E. Schwartz, Washington, DC (n)

DIFFICULT ELBOW FRACTURES: PEARLS AND PITFALLS (D)

Moderator: Shawn W. O'Driscoll, MD, Rochester, MN (c – Acumed)

Difficult elbow fractures are defined as those posing challenges relating to diagnosis, exposure, treatment, or serious uncertainly regarding prognosis. These include comminuted fractures of the distal humerus with bone loss, complex fracture patterns of the articular surfaces such as shearing injuries, as well as certain fractures of the coronoid and the radial head. This symposium will greatly help the attendees to manage these challenging injuries.

I. Comminuted Distal Humerus Fractures
Shawn W. O'Driscoll, MD, Rochester, MN (c – Acumed)

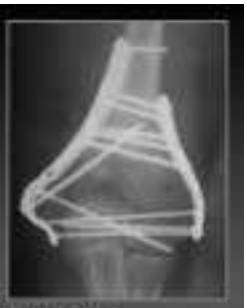
II. Coronal Shear Fractures of the Capitellum and Trochlea
Jesse B. Jupiter, MD, Boston, MA (a – AO Foundatrion)

III. Complex Coronoid Fractures
Mark S. Cohen, MD, Chicago, IL (n)

IV. Olecranon Fracture Dislocations
David Ring, MD, Boston, MA (a – AO Foundation)

V. Radial Head and Neck Fractures
Michael D. McKee, MD, Toronto, Canada (a – Stryker Biotech, e – Zimmer)

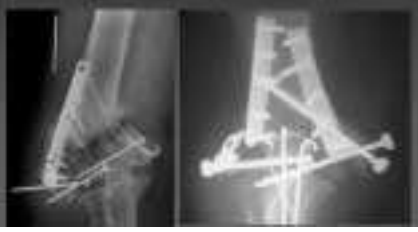
Comminuted Distal Humerus Fractures



Shawn W. O'Driscoll, PhD, MD
Mayo Clinic, Rochester MN

What is the current problems with treatment of these fractures ?

- Problem is fixation of distal fragment
- Failure is at the supracondylar level



Outline

- Challenges & current problems
- Principle-based approach
- Technical Objectives
- Concepts in plating

Principles To Be Satisfied

Because failure occurs at the supracondylar level…

1. Maximize fixation of distal fragments
2. All fixation in distal fragments should contribute to supracondylar stability

Disappointing Results

1. Stiffness (due to immobilization for inadequate fixation)
2. Nonunion - at the supracondylar level

8 Technical Objectives

- 6 Concerning the screws in the distal fragments
- 2 concerning the plates

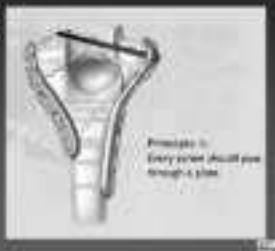
Goals & Philosophy

Goals:	Prerequisites:
• Preserve joint motion & function	• Start active & passive ROM 1-2 days postop. * - CPM - Splints (May be needed)
• Obtain union	• Adequate stability to prevent nonunion

Technical Objective # 1

Every screw should:

pass through a plate



Technical Objective # 2

Every screw should:

be anchored in a fragment on the opposite side that is fixed by a plate

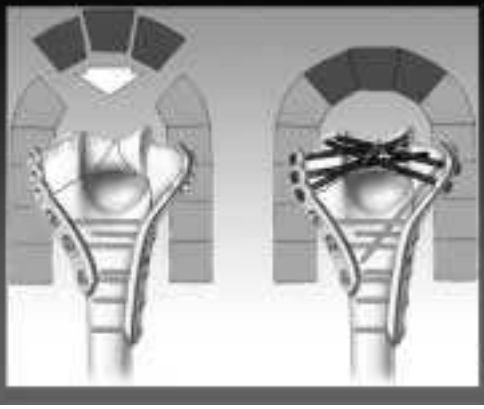
Technical Objective # 6

The screws in the distal fragments should lock together by interdigitation, creating a "fixed angle" structure

"Complete the arch" / "Close the loop"

Technical Objective # 3

As many screws as possible should be placed in the distal fragments



Technical Objective # 4

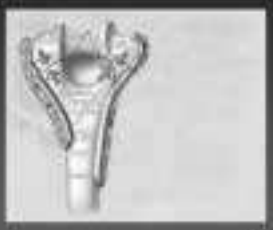
Every screw should:

be as long as possible

Technical Objective # 7

The plates should be:

applied with compression at the supracondylar level



Technical Objective # 5

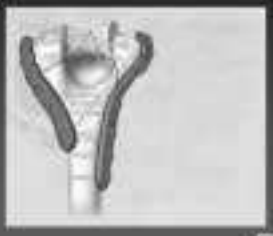
Every screw should:

engage as many articular fragments as possible

Technical Objective # 8

The plates should be:

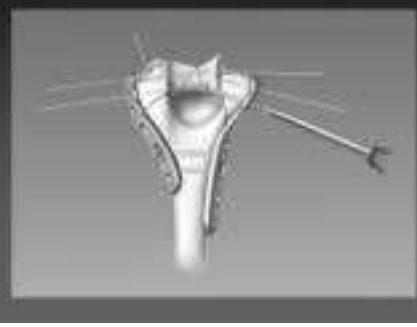
strong enough & stiff enough to resist bending or breakage before union occurs



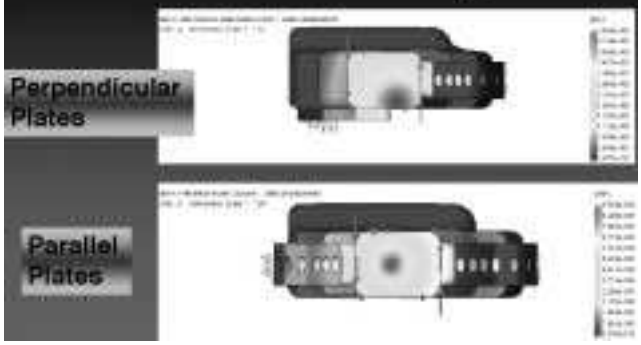
From Principles ... To Plates

- Objectives can be achieved with 'parallel' plates
- Principles can be applied using existing plates and fixation technologies
- However... a dedicated system designed to meet these principles may improve:
  - efficacy
  - efficiency

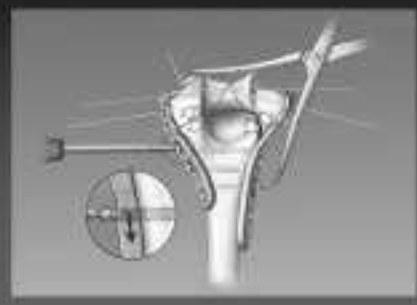
Distal Fixation



Finite Element Analysis



Lateral Supracondylar Compression



Articular Reduction

Medial Supracondylar Compression

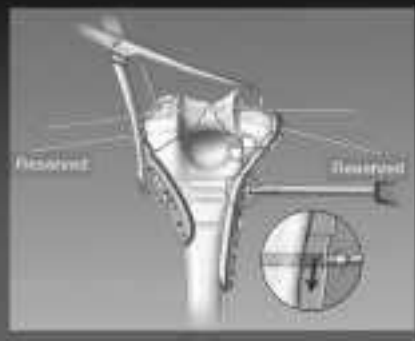
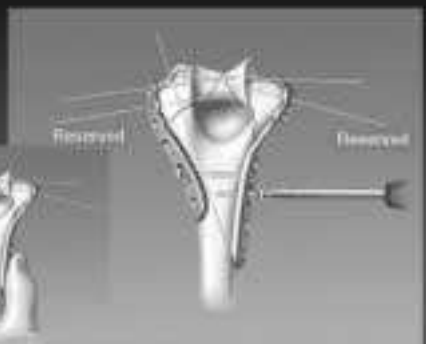
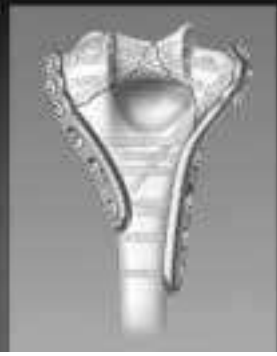


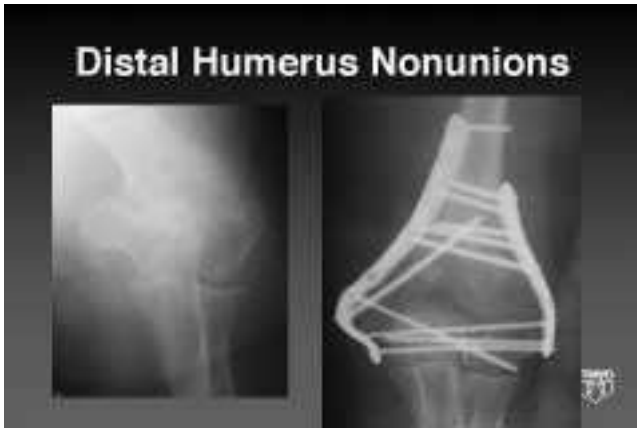
Plate Application & Provisional Fixation

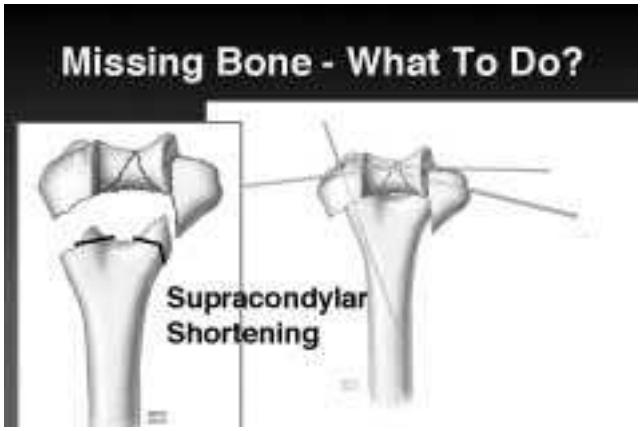


Mayo Clinic Congruent Plates




Distal Humerus Fracture

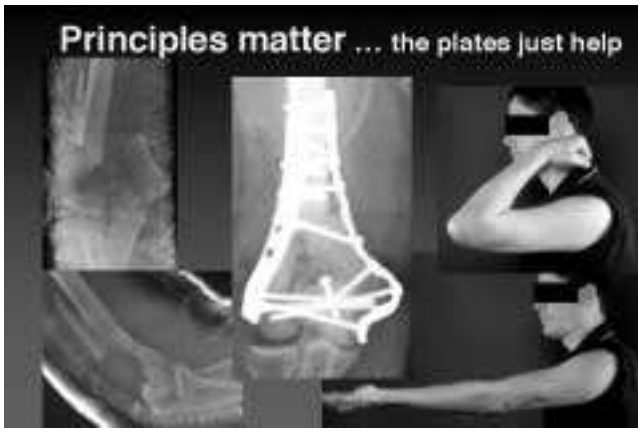

Distal Humerus Nonunions

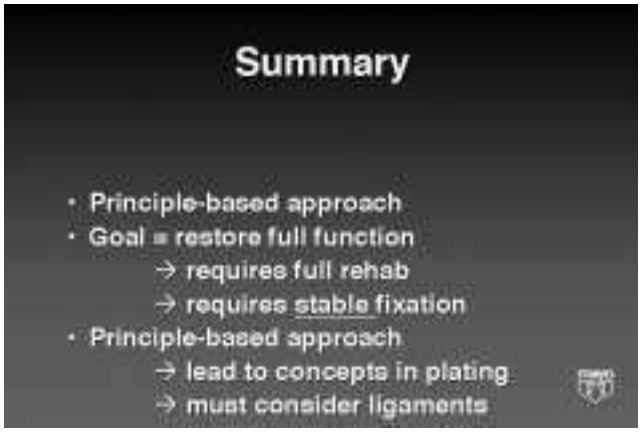

Missing Bone - What To Do?
Supracondylar
Shortening


Non-Union


Smashed Elbow


Revision & HO Excision


Principles matter ... the plates just help


Summary
• Principle-based approach
• Goal = restore full function
→ requires full rehab
→ requires stable fixation
• Principle-based approach
→ lead to concepts in plating
→ must consider ligaments

CORONAL SHEAR FRACTURES OF THE DISTAL HUMERUS—PITFALLS AND PEARLS

Jesse Jupiter, MD

I. Overview
- A. The problem –articular fractures with meager subchondral bony support and limited soft tissue attachments
- B. Pitfalls
  1. Fracture recognition
  2. Decision making
  3. Operative approach
  4. Tactics of internal fixation
  5. Postoperative management
  6. Complications
  7. Outcomes

II. Clinical Case (operative video)

III. Fracture morphology – recognition
- A. Pitfalls

  "We have been treating many such fractures and they are for the most part capitellar lesions with some trochlear involvement:

  Letter to the editor J. Bone Joint Surgery in response to article by Ring and Jupiter "Complex articular fractures of the distal humerus". JBJS 4A:2003
- B. Pearls
  1. Double crescent sign on standard lateral radiograph
  2. CT scanning especially 3-dimensional reconstructions
  3. Fracture patterns important due to individual differences

Type 1 -Standard capitellum fracture
Type 2A -Coronal shear fracture-single fragment
Type 2B -Coronal shear fracture-multifragmented
Type 3 -Coronal shear fracture plus lateral epicondyle fracture
Type 4 -Type 3 fracture with impaction of posterior lateral column
Type 5 -Shearing fracture of anterior and posterior trochlea fragments
Type 6 -Extension to medial epicondyle

IV. Decision making
- A. Operative treatment
  1. Advantages – restore anatomy and stability on permanent basis
  2. Disadvantages – loss of motion, prolonged rehab, loss of fixation
- B. Arthroplasty
  1. Advantages – early return to function and enhanced motion
  2. Disadvantages – permanent limitation on function, risk of loosening and failure
- C. Closed treatment
  1. Advantages – reduction may be applicable for capitellar fracture only
     – Suggested for patients who are infirmed
  2. Disadvantages – block to motion, potential for instability

V. Operative exposure
- A. Pitfalls
  1. Shearing fractures are anterior and often displaced proximally
  2. Ulnar nerve dysfunction may prove difficult postoperatively
- B. Pearls
  1. Straight dorsal incision will permit mobilization of the ulnar nerve 6 cm proximal and distal to the cubital tunnel
  2. Extended lateral approach (will be demonstrated)
  3. Lateral epicondyle osteotomy may enhance lateral exposure and allow elbow to hinge open on medical soft tissue structures

VI. Internal Fixation
- A. Pitfalls
  1. Small articular fragments with little subchondral bone or attached soft tissue
  2. Fixation may be necessary from anterior through the overlying articular cartilage
  3. Underlying osteoporosis will complicate fixation
- B. Pearls
  1. Headless screws are essential for most fracture patterns
  2. Lateral epicondylar fracture and/or osteotomy can be secured with small plate and/or tension wire
  3. Type 6 can benefit from small plate support on the columns

VII. Complications
1. Ulnar nerve dysfunction
2. Loss of fixation
3. Loss of motion
4. Deformity

VIII. Outcomes – Ring D, Jupiter J. JBJS 85A 2003

21 Patients
All united, no instability
10 had second procedure
6 capsular release
2 ulnar nerve transpositions
2 hardware removal
Average arc of motion 96˚ (range 55 – 140˚)

Mayo index	- Excellent	4
	- Good	12
	- Fair	5

BIBILIOGRAPHY

1. McKee MD, Jupiter JB, Bamberger HB. Coronal shear fractures of the distal end of the humerus. J Bone Joint Surg Am 1996; 78: 49–54.
2. Robertson RC, Bogart FB. Fracture of the capitellum and trochlea combined with fracture of the external humeral condyle. J Bone Joint Surg 1933; 15: 206–13.
3. Jupiter JB, Barnes KA, Goodman LJ, Saldana AE. Multiplane fracture of the distal humerus. J Orthop Trauma 1993; 7: 216–20.
4. Faierman E, Wang J, Jupiter JB. Secondary ulnar nerve palsy in adults after elbow trauma: a report of two cases. J Hand Surg (Am) 2001; 26: 675–8.
5. Monsat P, Morrey BF. The column procedure: a limited lateral approach for extrinsic contracture of the elbow. J Bone Joint Surg Am 1998; 80: 1603–15.
6. Husband JB, Hastings H 2nd. The lateral approach for operative release of posttraumatic contracture of the elbow. J Bone Joint Surg Am 1990; 72: 1353–8.
7. Ochner RS, Bloom H, Palumbo RC, Coyle MP. Closed reduction of coronal fractures of the capitellum. J Trauma 1996; 40: 199–203.
8. Ring D, Gulotta L, Jupiter JB. Articular fractures of the distal part of the humerus. J Bone Joint Surg 2003; 85A: 232–8.

CORONOID FRACTURES

Mark S. Cohen, MD

I. ANATOMY
1. Sublime Tubercle
2. Capsular Attachment
3. Brachialis
4. Opening Angle – Normal 30∞
5. Medial Collateral Ligament
6. Anterior Buttress (with Radial Head)

II. INJURY MECHANISM
1. Shear (Dislocation)
2. Impaction
3. Rotatory (Posterolateral and Posteromedial)

III. IMAGING
1. Plain Radiographs (Obliques)
2. Stress Views
3. Tomograms
4. CT Scan (Reformatted Images/3-D Reconstructions)

IV. ASSOCIATED INJURIES
1. Proximal Ulna
2. Joint Subluxation/Dislocation
3. Radial Head
4. Joint Dislocation and Radial Head (terrible triad)
5. Collateral Ligaments

V. CLASSIFICATION (Regan and Morrey)
1. Type I – Chip Fracture
   a. Sign of Dislocation
   b. Not avulsion
   c. Repair not typically necessary
2. Type II – Up to 50% of Coronoid
   a. Elbow usually unstable
   b. Surgery required
3. Type III – Greater than 50%
   a. Ulnohumeral joint unstable
   b. Surgery required
   c. External Fixation for neutralization considered

VI. CLASSIFICATION (O'Driscoll)
1. Type A – Tip (Posterolateral Rotatory Mechanism)
   a. < 2 mm
   b. > 2 mm (seen with terrible triad)
   c. Surgery required if U-H joint unstable
2. Type B – Anteromedial (Varus Posteromedial Rotatory Mechanism)
   a. Anteromedial rim
   b. Anteromedial rim + tip
   c. Anteromedial rim + sublime tubercle (+ tip)
   d. Anteromedial rim + sublime tubercle + tip + body
   e. Rim fracture between tip and sublime tubercle
   f. Subtle joint incongruity can exist
3. Type C – Base
   a. Body alone
   b. Coronoid body + olecranon
   c. Internal fixation required

VII. SURGICAL APPROACH
1. Medial/anterior (through the floor of the cubital tunnel elevating flexor-pronator muscles anteriorly)
2. Posterior along subcutaneous border (medially)
3. Posterior through ulna fracture
4. Lateral (through exposure in fracture-dislocation)

VIII. OPTIONS FOR FIXATION
1. Heavy Suture
2. Wire
3. Screws
4. Plate (buttress)
5. Adjuvant external fixation

BIBLIOGRAPHY

1. Amis AA, Miller JH. The mechanisms of elbow fracture: an investigation using impact tests in vitro. Injury 26: 163-8, 1995.
2. Cage DJ, Abrams RA, Callahan JJ, Botte MJ. Soft-tissue attachments of the ulnar coronoid process. Clin Orthop 320: 154-8, 1995.
3. Cobb TK and Morrey BF. Use of distraction arthroplasty in unstable fracture dislocations of the elbow. Clin Orthop 312: 201-10, 1995.
4. Cohen MS, and Hastings H: Acute Elbow Dislocation: Evaluation and Management, J Amer Acad Orthop Surg 6: 15-23, 1998.
5. Hanks GA, Kottmeier SA. Isolated fracture of the coronoid process of the ulna: a case report and review of the literature. J Orhtop Trauma 4: 193-6, 1990.
6. Morrey BF. Complex Instability of the Elbow, AAOS Instructional Course Lectures 47: 157-64, 1998.
7. Morrey BF. Fractures of the proximal ulna and olecranon. In: B.F. Morrey, ed., The Elbow and Its Disorders, 2nd edition, W.B. Saunders Company, Philadelphia, 405-28, 1993.
8. O'Driscoll SW. Elbow Instability. Hand Clin 10: 405-15, 1994.
9. O'Driscoll SW, Jupiter JB, Cohen MS, Ring D, McKee MD: Difficult Elbow Fractures: Pearls and Pitfalls, IN Instructional Course Lectures, Ed. D.C. Ferlic, American Academy of Orthopaedic Surgeons, Rosemont, 52:113-136, 2003.
10. Regan W and Morrey B. Fractures of the coronoid process of the ulna. J Bone Joint Surg 71A: 1348-54, 1989.

OLECRANON FRACTURE-DISLOCATIONS

David Ring, MD

I. Fracture patterns
- a. Anterior[1-3] vs. posterior displacement[4-6] of the forearm
- b. Also varus instability pattern on occasion with anteromedial facet coronoid fracture[7].
- c. Often very complex fractures
- d. Coronoid fractures common
  - i. ~50% of anterior fracture-dislocations
  - ii. ~80-90% of posterior fracture-dislocations

II. Anterior, or trans-olecranon, fracture-dislocations[1-3]
- a. Distal humerus passes through the trochlear notch of the ulna
- b. Forearm displaced anteriorly
- c. Anterior radio-capitellar dislocation often confused with anterior Monteggia fracture, however:
  - i. Radio-ulnar relationship relatively preserved
  - ii. Injury involved ulnohumeral joint, not radioulnar articulation
  - iii. Anterior olecranon fracture-dislocations are fracture-dislocations of the elbow, not the forearm (true Monteggia).
- d. Coronoid fractures common (~50%)
  - i. Large = at the base (Regan and Morrey[8] Type 3)
  - ii. Occasionally fragmented[7, 9, 10]
- e. Fragmentation of ulna extending to the diaphysis is common
- f. Fragmentation of the olecranon fragment may also occur.
- g. Collateral ligaments usually remain intact.

III. Posterior olecranon fracture-dislocation
- a. Posterior Monteggia variant (Type A, Jupiter, et. al. J.O.T. 1991[6])
  - i. Extent of PRUJ disruption debatable11, but part of the spectrum of posterior Monteggia fractures
  - ii. Apex posterior fracture of ulna
  - iii. Radial head fracture (67%)[4, 6, 12, 13]
  - iv. Coronoid fracture (80-90%)
    1. Usually large (Regan and Morrey Type 3)
    2. Occasionally fragmented.
    3. Often anteromedial facet
  - v. Often LCL injury. Rarely MCL injury.
- b. Most common in older women (osteoporosis related)
- c. High energy in young adult
- d. TRANSITIONAL LESION = threatens stability and function of both the ELBOW and the FOREARM joints6.

IV. Principals of treatment (ulna)
- a. Restore contour and dimensions of trochlear notch
  - i. Relationship of coronoid and olecranon facets/processes
  - ii. Intervening area is relatively non-articular and anatomical reduction less important
- b. ORIF coronoid
  - i. Through the olecranon fracture[7, 9, 14-16]
  - ii. Indirect reduction (distractor)[3, 17]
  - iii. Direct exposure (medial/ lateral)[7, 9, 10, 18]
- c. Bridge fragmentation
  - i. Stable plate fixation
  - ii. Limit elevation of muscle and periosteum
  - iii. Bone graft only necessary with absolute defects (usually open fracture)
- d. Fixation of olecranon
  - i. Dorsal plate contoured to wrap around olecranon
    1. More screws in fragment
    2. Orthogonally oriented screws.
    3. Long screw into coronoid or down ulnar shaft
  - ii. Tension band wire engaging triceps insertion if olecranon fragmented/ poor bone quality
- e. Fragmentation of shaft
  - i. Use long plate
    1. Dorsal plate extends onto apex of ulna distally
    2. Very little muscle elevation required.
    3. Excellent fixation possible with placement on apex.
- f. Fixation of coronoid fracture
  - i. Screws for large fragments.
  - ii. Some anteromedial fractures best treated with a second plate[7, 10]
  - iii. Some small fractures benefit from suture through attached capsule[7, 9, 10].

V. Principals of treatment: collateral ligaments
- a. Anterior trans-olecranon fracture dislocations
  - i. Collateral ligaments relatively spared
  - ii. Insertions onto large coronoid fragment preserved
  - iii. Stable fixation of coronoid restores function of ligaments
- b. Posterior olecranon fracture-dislocation
  - i. Anterior band of MCL attaches to large or medially based coronoid fracture and fixation restores its function
  - ii. LCL often avulsed from lateral epicondlyle and can contribute to ulnohumeral instability.
  - iii. Reattach LCL origin to epicondyle (suture anchors or drill holes)

VI. Principals of treatment: radial head
- a. Potential for ulnohumeral instability, diminished forearm rotation
  - i. Strongly consider ORIF or prosthetic replacement

VII. Complications
- a. Instability
- b. Arthrosis
- c. Nonunion
- d. Heterotopic ossification

REFERENCES

1. Balakim G, Wippula E. Fractures of the olecranon complicated by forward dislocation of the forearm. Ann Chir Gyn Fenn 1971;60:105-108.
2. Biga N, Thomine JM. La luxation trans-olecranienne du coude. Rev Chir Orthop 1974;60:557-567.
3. Ring D, Jupiter JB, Sanders RW, Mast J, Simpson NS. Trans-olecranon fracture-dislocation of the elbow. J Orthop Trauma 1997;11:545-550.
4. Ring D, Jupiter JB, Simpson NS. Monteggia fractures in adults. J Bone Joint Surg 1998;80A:1733-1744.
5. Ring D, Jupiter JB. Fracture-dislocation of the elbow. J Bone Joint Surg 1998;80A:566-580.
6. Jupiter JB, Leibovic SJ, Ribbans W, Wllk RM. The posterior Monteggia lesion. J Orthop Trauma 1991;5:395-402.

7. Ring D, Jupiter JB. Surgical Exposure of Coronoid Fractures. Tech Should Elbow Surg 2002;3:48-56.
8. Regan W, Morrey BF. Fractures of the coronoid process of the ulna. J Bone Joint Surg 1990;71A:1348-1354.
9. Ring D, Jupiter JB. Operative fixation and reconstruction of the coronoid. Tech Orthop 2000;15(2).
10. O'Driscoll SW, Jupiter JB, Cohen M, Ring D, McKee MD. Difficult Elbow Fractures: Pearls and Pitfalls. Instructional Course Lectures 2003;52:113-134.
11. Bruce HE, Harvey JP, Wilson JC. Monteggia fractures. J Bone Joint Surg 1974;56A:1563-1576.
12. Pavel A, Pittman JM, Lance EM, Wade PA. The posterior Monteggia fracture. A clinical study. J Trauma 1965;5:185-199.
13. Penrose JH. The Monteggia fracture with posterior dislocation of the radial head. J Bone Joint Surg 1951;33B:65-73.
14. Heim U. Kombinierte Verletzungen von Radius und Ulna im proximalen Unterarmsegment. Hefte Unfallchir 1994;241:61-79.
15. Heim U. Combined fractures of the upper end of the ulna and the radius in adults: a series of 120 cases. Rev Chir Orthop 1998;84:142-153.
16. O'Driscoll SW. Technique for unstable olecranon fracture-subluxations. Oper Tech Orthop 1994;4:49-53.
17. Mast J, Jakob RP, Ganz R. Planning and Reduction Techniques in Fracture Surgery. Heidelberg: Springer-Verlag; 1979.
18. Patterson SD, Bain GI, Mehta JA. Surgical approaches to the elbow. Clin Orthop 2000;370:19-33.

PRINCIPLES AND PROCEDURES FOR ANTERIOR GLENOHUMERAL INSTABILITY: AN INTERNATIONAL PERSPECTIVE (E)

Moderator: Frederick A. Matsen, III, MD, Seattle, WA (n)

To provide an international perspective on the evaluation and management of simple and complex forms of glenohumeral instability.

I. Mechanics of Glenohumeral Stability
Frederick A. Matsen, III, MD, Seattle, WA (n)

II. Clinical Evaluation of the Unstable Shoulder
Gilles Walch, MD, Lyon, France (n)

III. The Role of imaging and Arthroscopy in the Evaluation of the Unstable Shoulder
Christian Gerber, MD, Zurich, Switzerland (e – Smith & Nephew)

IV. Non-operative Management of Anterior Instability
Eiji Itoi, MD, Akita, Japan (n)

V. Principles and Procedures for the Management of Anterior Instability
Gilles Walch, MD, Lyon, France (n)

VI. Humeral and Glenoid Defects in Anterior Instability
Eiji Itoi, MD, Akita, Japan (n)

VII. Principles and Procedures for the Management of Posterior and Multidirectional Instability
Christian Gerber, MD, Zurich, Switzerland (e – Smith & Nephew)

VIII. Management of Failed Repairs
Frederick A. Matsen, III, Seattle, WA (n)

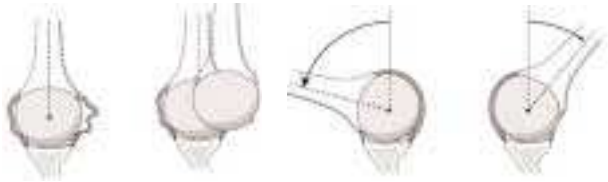
IX. Case Presentations
All faculty

MY VIEW OF THE MECHANICS OF GLENOHUMERAL STABILITY

Frederick A. Matsen III, MD

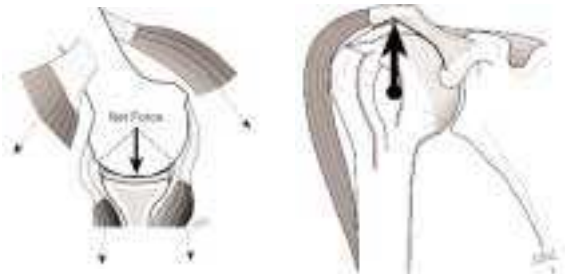
I. Definition: Glenohumeral Stability – the patient's ability to hold the humeral head centered in the glenoid (below left) and in the center of the coracoacromial arch (below right). This stability enables the upper extremity to carry out a huge range of activities requiring precision and strength.

II. Ligaments cannot center the head in the glenoid, they can only limit the maximal translational (below left) and rotational laxity (below right).



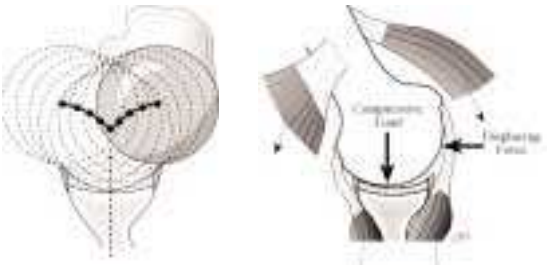
III. The depth and shape of the glenoid is built by the bone, cartilage and labrum, with harder in the middle and softer on the edge so that it can function as a suction cup. The mobility of the scapula allows the glenoid to be positioned beneath the humeral force.

IV. The humeral head is centered by compression of the humeral head into the medial concavity (below left) and the superior concavity (below right).

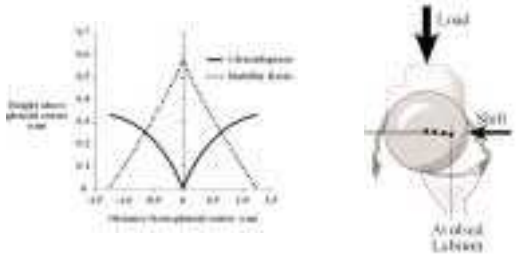


V. The balance stability angle is the maximum angle between the glenoid centerline and the net humeral joint reaction force before dislocation occurs. When the BSA is exceeded the golf ball falls off the tee.

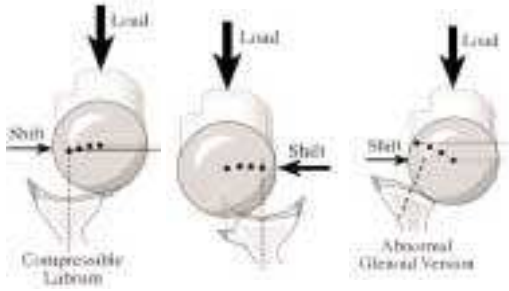
VI. The glenoidogram is the path taken by the center of the humeral head (below left). The stability ratio is the compressive load divided into the displacing force necessary to shift the head from the center (below right).



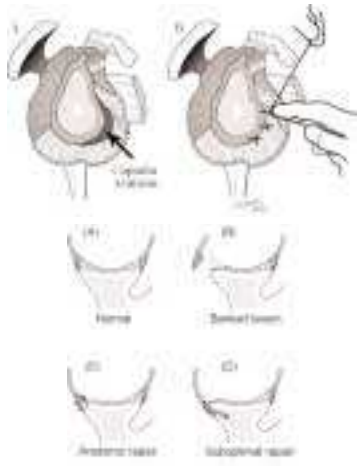
VII. The local stability ratio is the slope of the glenoidogram. It is greatest when the head is in the center of the glenoid. (below left). Once the head is uncentered the local stability ratio drops off rapidly. When the glenoid lip is deficient, the glenoidogram is flattened and the ratio of shift to load (the stability ratio) is lessened (below right).



VIII. Any cause of loss of the function of the glenoid lip can compromise the force necessary to shift the humeral head from the glenoid center and, thus, the stability.



IX. The ideal repair restores the glenoid concavity.



THE ROLE OF IMAGING AND ARTHROSCOPY IN THE EVALUATION OF THE UNSTABLE SHOULDER

Christian Gerber, Zürich, Switzerland

The diagnosis of shoulder instability is made on the base of history and physical examination.

Imaging and diagnostic arthroscopy are used to confirm the clinical diagnosis and to quantitate the type and extent of the responsible lesion(s) in view of the selection of the most appropriate treatment.

The presence of two types of lesions must be ruled out to exclude or documented to proove prior anterior subluxation of dislocation of the glenohumeral joint:

- the posterolateral compression fracture of the humeral head first described anatomically in 1847 by Malgaigne1,2 and radiographically in 1940 by Hill and Sachs3 and
- the lesion of the inferior glenohumeral ligament which occurs most frequently at its insertion site at the antero – inferior glenoid rim which has been described successively by Broca and Hartmann4, Perthes5and Bankart6,7 after whom the lesion is called. It should be noted that a so-called Bankart lesion can only be diagnosed on conventional radiographs if it is associated with bony lesions of the anterior glenoid rim, which are, however, extremely frequent.

The posterolateral humeral compression fracture is anbsolute proof of a prior subluxation and or dislocation. It can be seen in the following conventional radiographic views:

- a true anteroposterior radiograph in full internal rotation
- the Stryker notch view8
- the 20/20 view9,10: The patient is supine , the elbow is flexed to ninety degrees and comes to lie on the abdomen of the supine patient. This implies an approximately 20 degree flexion of the arm in the shoulder joint with respect to the examining table. The X- ray beam is parallel to the examining table and comes from inferiorly- laterally in an angle of 20 degrees towards to superiorly and medially with the beam centered on the humeral head. The X-ray cassette is on top of the shoulder. This view takes the Hill- Sachs lesion exactly in ist axis and determines whether the head is completely spherical or whether a compression fracture can be identified. This is the radiograph which is most reliable and most easy to take for the detection of a Hill Sachs lesion.

The bony Bankart lesion ican be seen on

- a true anteroposterior radiograph as a loss of the subchondral sclerosis of the anterior glenoid rim in the inferior half of the glenoid
- a true lateral (Neer view) as a fracture of the anterior glenoid rim
- a west – point axillary lateral11
- a glenoid profile according to the French radiologist J. Bernageau12,13

A true anteroposterior view in internal rotation, a 20/20 view and a glenoid profile of Bernageau can ascertain the presence or absence of a prior subluxation and / or dislocation with an accuracy of < 90%.

Additional studies depend on the requested additional information:

- arthro - computertomography seems most appropriate if more precise information on bony and possibly cartilage lesions is desired 14-17
- arthro- mri seems most appropriate if additional information on soft tissue lesions is desired.18-20

Diagnostic arthroscopy is not usually used to diagnose anterior recurrent instability. It may be helpful to diagnose associated lesions. 21-23

It is of particular interest for

- associated SLAP lesions and
- associated or isolated HAGL lesions:

The value of arthroscopy for the assessment of the size and the significance of labral or bony lesions is difficult to determine because intra and interobserver variability studies are essentially not available.

In conclusion: The diagnosis of clinical instability is based on history and physical examination. It can ne definietly be confirmed by conventional radiography in over 90% of the cases. For scientic investigations, arthro-CT and arthro-MRI may be justified. Diagnostic arthroscopy without the goal of stabilization during the same operative session does not seem to be justified.

REFERENCES

1. Malgaigne, J. F.: Traité des Fractures et des Luxations. Edited, 841, Paris, Ballière, 1847.
2. Malgaigne, J. F.: Traité des Fractures et des Luxations: Atlas de XXX Planches. Edited, Paris, J.B. Ballière, 1855.
3. Hill , H. A., and Sachs, M. D.: The Grooved Defect of the Humeral Head. A Frequently Unrecognized Complication of Dislocations of the Shoulder Joint. Radiology, 35: 690-700, 1940.
4. Broca, A., and Hartmann, H.: Contribution à l'étude des luxations de l'épaule (luxations dites incomplètes, décollements périostiques, luxations directes et luxations indirectes). Bull. Soc. Anat. Paris, Série 5(4): 312-336, 1890.
5. Perthes, G.: Ueber Operationen bei habitueller Schulterluxation. Deutsch. Zeitschr. Chir., 85: 199-227, 1906.
6. Bankart, A. S. B.: Recurrent or habitual dislocation of the shoulder-joint. Br. med. J., 2: 1132-1133, 1923.
7. Bankart, A. S. B.: The pathology and treatment of recurrent dislocation of the shoulder joint. Br. J. Surg., 26(July): 23-29, 1938.
8. Hall, R. H.; Isaac, F.; and Booth, C. P.: Dislocation of the shoulder with special reference to accompanying small fractures. J. Bone Joint Surg., 41-A: 489-494, 1959.
9. DeAnquin: Recurrent Dislocation of the Shoulder - Roentgenographic Study. J. Bone Joint Surg., 47-A: 1085,, 1965.
10. Johner , R. T.; Joz - Roland, P.; and Burch, H. B.: Luxation antérieure de l`épaule: Nouveaux aspects diagnostiques et thérapeutiques. Rev. Méd. Suisse Romande, 102: 1143-1150, 1982.
11. Rokous, J. R.; Feagin.J.A.; and Abbott, H. G.: Modified Axillary Roentgenogram. Clin.Orthop.Rel.Res., 82:: 84 --87,, 1972.

12. Bernageau, J.; Patte, D.; Debeyre, J.; and Ferrane, M.: Intérêt du profil génoidien dans les luxations récidivantes de l`épaule. Rev. Chir. Orthop., 62:(suppl II): 142-147, 1975.

13. Patte, D.; Bernageau, J.; and Rodineau, J.: Epaules douloureuses et instables. Rev chir orthop, 66: 157- 165, 1980.

14. Callaghan, J. J.; McNiesh, L. M.; DeHaven, J. P.; Savory, C. G.; and Polly, D. W., Jr.: A prospective comparison study of double contrast computed tomography (CT) arthrography and arthroscopy of the shoulder. Am J Sports Med, 16(1): 13-20, 1988.

15. Dewatre, F.; Cotten, A.; Leblond, D.; Singer, B.; Mestdagh, H.; and Chastanet, P.: (Normal and pathological aspects of the glenoid labrum in opaque arthro-scanner). J.Radiol., 75(8-9): 413-422, 1994.

16. Hodler, J.; Terrier, F.; and Gerber, C.: (Sonography of the shoulder). Ther.Umsch., 46(3): 158-163, 1989.

17. Weishaupt, D.; Zanetti, M.; Nyffeler, R. W.; Gerber, C.; and Hodler, J.: Posterior glenoid rim deficiency in recurrent (atraumatic) posterior shoulder instability. Skeletal Radiol, 29(4): 204-10, 2000.

18. Wischer, T. K.; Bredella, M. A.; Genant, H. K.; Stoller, D. W.; Bost, F. W.; and Tirman, P. F.: Perthes lesion (a variant of the Bankart lesion): MR imaging and MR arthrographic findings with surgical correlation. AJR Am J Roentgenol, 178(1): 233-7, 2002.

19. Massengill, A. D.; Seeger, L. L.; Yao, L.; Gentili, A.; Shnier, R. C.; Shapiro, M. S.; and Gold, R. H.: Labrocapsular ligamentous complex of the shoulder: normal anatomy, anatomic variation, and pitfalls of MR imaging and MR arthrography. Radiographics., 14(6): 1211-1223, 1994.

20. Chandnani, V. P.; Yeager, T. D.; DeBerardino, T.; Christensen, K.; Gagliardi, J. A.; Heitz, D. R.; Baird, D. E.; and Hansen, M. F.: Glenoid labral tears: prospective evaluation with MRI imaging, MR arthrography, and CT arthrography. AJR.Am.J.Roentgenol., 161(6): 1229-1235, 1993.

21. Norlin, R.: Intraarticular pathology in acute, first-time anterior shoulder dislocation: an arthroscopic study (see comments). Arthroscopy., 9(5): 546-549, 1993.

22. Suder, P. A.; Hougaard, K.; Frich, L. H.; Rasmussen, O. S.; and Lundorf, E.: Intraarticular findings in the chronically painful shoulder. A study of 32 posttraumatic cases. Acta Orthop.Scand., 65(3): 339-343, 1994.

23. Warner, J. J., and Beim, G. M.: Combined Bankart and HAGL lesion associated with anterior shoulder instability. Arthroscopy, 13(6): 749-52, 1997.

MY NON-OPERATIVE MANAGEMENT OF ANTERIOR INSTABILITY

Eiji Itoi

I Background
- Shoulder dislocation: the most common dislocation in human body
- Problem of shoulder dislocation: high rate of recurrence
- The younger the patient, the higher the recurrence rate
- Bankart lesion: 94% to 97% of initial dislocation
- Bankart lesion: ability to heal
- Why no healing?
- Something must be wrong with the current immobilization
  - Rigidity of immobilization →No
  - Length of immobilization →No
  - Position of immobilization → ?

II Cadaveric Study1
- Cadaveric shoulders without the cuff muscles
- Relationship between the position of the arm and the coaptation of a simulated Bankart lesion
- Coaptation zone:
  - full IR to 30° of ER in adduction
  - full IR to NR in 30° of abduction or flexion

III MRI Study[2]
- 19 patients with traumatic anterior dislocation
  - 6 initial dislocations
  - 13 recurrent dislocations
- MRI with the arm in IR and ER
- The labrum was less displaced and the capsule less detached with the arm in ER
- Immobilization in ER may be better in terms of coaptation and healing of the Bankart lesion

IV Clinical Study: Preliminary Report in 2003[3]
- 40 patients with traumatic dislocation of the shoulder
  - IR group: 20 patients (avg 38 years old)
  - ER group: 20 patients (avg 40 years old)
- 3 weeks of immobilization
- follow-up: avg 15.5 months
- Compliance: 75% in the IR group, 80% in the ER group
- Recurrence rate
  - IR group: 6/20 (30%)
  - ER group: 0/20 (0%)

IV Clinical Study: Interim Report in 2004[4]
- 80 patients with traumatic dislocation of the shoulder
  - IR group: 40 patients (avg 36 years old)
  - ER group: 40 patients (avg 36 years old)
- 3 weeks of immobilization
- follow-up: avg 12.4 months
- Compliance: 65% in the IR group, 75% in the ER group
- Recurrence rate
  - IR group: 12/40 (30%)
  - ER group: 4/40 (10%)

V Perspective
- Angle of external rotation
- Length of immobilization
- Strategy for initial dislocation
  - Stabilization surgery for initial dislocation may be too much.
- Strategy for recurrent dislocations
  - There is a chance of healing if ER immobilization is applied immediately after the last dislocation.

VI My Preferred Management
- Immobilization in 10° of ER for 3 weeks for initial dislocations
- Same method for recurrent anterior dislocation if immobilization can be started within 3 days of injury

REFERENCES

1. Itoi E, Hatakeyama Y, Urayama M, Pradhan RL, Kido T, Sato K. Position of immobilization after dislocation of the shoulder: a cadaveric study. J Bone Joint Surg Am 1999; 81-A: 385-390.
2. Itoi E, Sashi R, Minagawa H, Shimizu T, Wakabayashi I, Sato K. Position of immobilization after dislocation of the glenohumeral joint: a study with use of magnetic resonance imaging. J Bone Joint Surg Am 2001; 83-A: 661-667.
3. Itoi E, Hatakeyama Y, Kido T, Sato T, Minagawa H, Wakabayashi I, Kobayashi M. A new method of immobilization after traumatic anterior dislocation of the shoulder: a preliminary study. J Shoulder Elbow Surg, 2003; 12: 413-415.
4. Itoi E, Hatakeyama Y, Sato T, Kido T, Minagawa H, Wakabayashi I, Kobayashi M, Saito H, Nozaka K. Immobilization in external rotation after dislocation of the shoulder: an interim report of an ongoing prospective multicenter study. The 71st Annual Meeting, American Academy of Orthopaedic Surgeons, San Francisco, March 11, 2004.

PRINCIPLES AND PROCEDURES FOR THE MANAGEMENT OF ANTERIOR INSTABILITY.

Gilles Walch, MD, T. Bradley Edwards, MD

Many different procedures have been described for anterior shoulder instability including open and arthroscopic capsulolabral reconstructions and coracoid transfer procedures. Although most of these procedures have been successful in restoring normal function, some have been associated with recurrence of instability, loss of shoulder external rotation and development of glenohumeral osteoarthritis.

Recurrence of instability or loss of external rotation may bring an early end to an athlete's career. A procedure that restores glenohumeral stability while preserving external rotation is, therefore desirable.

Additionally, as many as 85% of shoulders with recurrent anterior shoulder instability have bony lesions of the anterior inferior glenoid rim (3). A procedure that can address these lesions would also seem advantageous. The Latarjet procedure successfully restores glenohumeral stability, does not limit external rotation, and can address bony lesions of the glenoid rim in patients with recurrent anterior shoulder instability (1,2,5,7,15). We describe the rationale, indications, and our preferred technique for this procedure (4,14).

I- Historical perspective and rationale.

In 1954, Latarjet described his technique for coracoif transfer performed through a horizontal split in the subscapularis, advocating screw fixation of the coracoid process postioned flush with the anterior inferior margin of the glenoid (8). North American surgeons are more familiar with the Bristow procedure described initially by Helfet in which the tip of the coracoid process is sutured to the capsuloperiosteal tissues through a short horizontal incision in the subscapularis (6). In 1961, McMurray modified the Bristow procedure to include screw fixation of the coracoid process (10). May subsequently explained that the stabilizing mechanism of this procedure was attributable to the bracing role played by the conjoined tendon and the subscapularis tendon in abduction external rotation, rather than by the bone block itself (9).

The terms "buttress" or "bone block" are not appropriate for this procedure. The efficacy of the Latarjet procedure is explained by the "triple blocking" effect as described by Patte (11).

- Stable screw fixation of a bone block laid flat in a subequatorial position, flush to the anterior margin of the glenoid. The bone block is the horizontal limb of the coracoid process.
- Preservation of the musculotendinous fibres of the inferior third of the subscapularis.
- Suturing of the lateral capsular flap to the medial centimeter of the coracoacromial ligament which remains attached to the coracoid.

The technique described in this article is a combination of the original techniques described by Latarjet, May and Bankart, plus some modifications such as the preservation of the continuity of the subscapularis fibers. Preservation of the subscapularis tendon fibers has a dual role. First, range of motion exercises in external rotation can be begun immediately after the operation. Second, the integrity of the fibers of the subscapularis tendon is preserved. Damage to the subscapularis tendon fibers is precisely what Rowe did not like about bone blocks, because it makes surgical revision (when necessary) more difficult. We further modified the procedure to include a fixation method, which provides good stability and reliable healing while avoiding secondary osteolysis of the coracoid transfer.

II- Indications and contraindications

This procedure is indicated in all cases of traumatic and atraumatic recurrent anterior instability with or without hyperlaxity and painful shoulders with anatomic lesions attesting that the pain is related to instability and not to an other etiology. In the rare case where the ligamentous instability lesion is located on the humeral side (HAGL lesion), the Latarjet procedure is not used and we suture the inferior glenohumeral ligament back to the anatomical neck of the humerus using suture anchors.

The reasons for our almost exclusive use of this technique are:

- better results in terms of stability and postoperative range of motion than with a Bankart type repair;
- extensive experience with this procedure making the procedure easy, safe, and quick;
- no need for postoperative immobilization or any motion limitation during rehabilitation;
- patients are able to resume activities of daily living and sports quicker (3 months) than with a capsular repair.

Contraindications include "subtle" anterior instability without a Bankart lesion (painful shoulder in the throwing athlete) and voluntary habitual anterior instability.

III- Technique

IV- Results

Between 1985 and 2002, we performed 1568 Latarjet procedures. One hundred sixty of these procedures used in the treatment of recurrent anterior instability with a mean follow-up of three years are reported here.

This series included 79% male patients. Mean age at surgery was 28 years (range, 18 to 40 years). The dominant side was involved in 66% of cases; 88% participated in sports. Instabilities were classified as recurrent dislocation (84%), recurrent subluxation (12%), and isolated painful shoulder (4%).

Radiographic osseous lesions were present in 95% of cases (Hill-Sachs lesions in 73 % and/or glenoid lesions in 87 %).

Clinical results: Stability was rated excellent in 72% of cases, although 22% of patients were apprehensive during athletic activities and 5% were apprehensive in activities of daily living. One percent of patients experienced recurrent instability.

Pain was present in 41% of patients, generally during athletic activities, seldom during activities of daily living. In one half of the cases, this pain resulted from an overhanging coracoid

block. The patients often complained of arm fatigue. Rotation was moderately limited in 38% of cases, more often in internal (25%) than external (13%).

Eighty-three percent of patients were able to resume their athletic activities at the same level, while 9% switched to another type of sport or participated at a lower level because of their shoulder. Eighty-one percent of patients were very satisfied, 17% were satisfied and 2% were disappointed with their result. The disappointed group included patients who had shoulder pain during sports or were apprehensive during activities of daily living. Overall, 38% of results were excellent, 38% were good, 17% were fair and 7% were poor.

Radiographic results: Pseudarthrosis of the coracoid process occurred in 2.4% of cases; it was related to unicortical screw fixation but had no statistical influence on the outcome. Fracture of the coracoid process occurred in 2.4% of cases and always occurred within three months of surgery as a result of intraoperative overtightening of the screws. In our series, they had no statistical influence on the clinical result. Partial resorption of the coracoid occurred more frequently (9 %). Only resorption of greater than two thirds of the coracoid led to persistent apprehension and decreased athletic participation. The position of the coracoid had no influence on partial resorption. No glenohumeral joint space narrowing was observed, although an inferior humeral osteophyte was present in 11.6% of cases (< 7 mm). Presence of an osteophyte correlated with a laterally overhanging coracoid process.

Surgical recommendations to avoid complications: Successful union of the coracoid transfer is critical to avoid complications:

- place the coracoid process in the "lying position" rather than in "standing" position to have a better contact at the bone interface and avoid pseudarthrosis;
- use a 3.2 mm drill bit for both the coracoid and the scapula and malleolar screws to provide interfragmentary compression;
- the two screws must be bicortical;
- do not use washer to avoid impingement with the humeral head;
- never accept a lateral overhanging coracoid, which is responsible for rapid degenerative joint disease (the coracoid should be flush with the articular margin of the glenoid). Conversely, if the coracoid is 1 or 2 mm medial to the glenoid articular margin, there is no pejorative effect.

Conclusion

Although many different procedures are able to carry out good to excellent results, the Latarjet procedure is a reliable operative technique in the treatment of recurrent anterior instability. However meticulous attention to technique is imperative to avoid complications that have been previously reported.

REFERENCES

1. Allain J, Goutallier D, Glorion C. Long-term results of the Latarjet procedure for the treatment of anterior instability of the shoulder. J Bone Joint Surg 1998;80-A:841-852.
2. Coudane H, Walch G. L'instabilité antérieure chronique de l'épaule chez l'adulte. Rev Chir Orthop 2000;86:91-150.
3. Edwards TB, Boulahia A, Walch G. Radiographic analysis of chronic anterior shoulder instability. Arthroscopy 2003;19:735-739.
4. Edwards TB, Walch G. The Latarjet procedure for recurrent anterior shoulder instability: rationale and technique. Operative Techniques in Sports Medicine 2002;10:25-32.
5. Ferlic DC, Digiovone NM. A long-term retrospective study of the modified Bristow procedure. Am J Sports Med 1988;16:469-474.
6. Helfet AJ. Coracoid transplantation for recurring dislocation of the shoulder. J Bone Joint Surg 1958;40-B:198-202
7. Hovelius L, Korner L, Lundberg B, et al. The coracoid transfer for recurrent dislocation of the shoulder: technical aspects of the Bristow-Latarjet procedure. J Bone Joint Surg 1983;65A:926-934.
8. Latarjet M. A propos du traitement des luxations récidivantes de l'épaule. Lyon Chir 1954;49:994-1003.
9. May VR. A modified Bristow operation for anterior recurrent dislocation of the shoulder. J Bone Joint Surg 1970;52A:1010-1016.
10. McMurray TB. Recurrent dislocation of the shoulder (proceedings). J Bone Joint Surg 1961;43B:402-405.
11. Patte D, Bernageau J, Bancel P. The antero-inferior vulnerable point of the glenoid rim, in Bateman JE, Welsh RP (eds) : Surgery of the Shoulder. New York, NY, Marcel Dekker. 1985:pp94-99.
12. Rowe CR, Patel D, Southmayd WW. The Bankart procedure: a long-term end-result study. J Bone Joint Surg 1978;60A:1-16
13. Thomas SC, Matsen FA III. An approach to the repair of avulsion of the gleno-humeral ligaments in the management of traumatic anterior gleno-humeral instability. J Bone Joint Surg 1989;71A:506-513.
14. Walch G, Boileau P. Latarjet-Bristow procedure for recurrent anterior instability. Techniques in Shoulder and Elbow Surgery 2000;1:256-261.
15. Walch G. La luxation récidivante antérieure de l'épaule. Rev Chir Orthop 1991;77:177-191.

MY MANAGEMENT OF HUMERAL AND GLENOID DEFECTS IN ANTERIOR INSTABILITY

Eiji Itoi

I Background
- Humeral defects
  - Malgaigne 1855
  - Hill & Sachs 1940
- Glenoid defects (bony Bankart lesion)
  - Fracture
  - Erosion

II Humeral Defects
- Incidence: 25% - 100%
- Anatomical studies: x-ray, CT, MRI
- No biomechanical study
- Indication:
  - Involvement of articular surface :20% - 50% (reverse Hill Sachs) 3
    40% < (Hill Sachs) 4
  - Volume > 1000 mm3 or depth > 16% of humeral head diameter5
- Management: bone graft1, rotational humeral osteotomy10, soft tissue tightening2,3

III Glenoid Defects
- Incidence: 8% - 90%
- erosion 40%, fragment 50% assessed by 3D-CT9
- How large a defect should be when bone grafting is necessary?

IV Cadaveric Study6
- Standardization of glenoid defect size
  - Area: difficult to measure
  - Length: easy to measure
- Created anteroinferior defect stepwise with a width of 12.5%, 25%, 37.5%, and 50% of the glenoid length (diameter of the circumcircle of the glenoid)
- Stability & ER motion: significantly affected when
  - remnant glenoid arc < 25% (glenoid defect > 21%)

V X-ray and CT Assessment of the Defect Size7
- Axillary view: not appropriate
- West Point view: 21% defect appears as 20% defect of the glenoid
- CT: 21% defect appears as 50% defect of the glenoid in a slice at the inferior 1/4 level of the glenoid

V CT Assessment of the Defect Location8
- 93 shoulders with recurrent anterior dislocations
- 3D-CT/MRI assessment of location and direction of the defect
- Scapular inclination: 30.5 degrees
- Location of the defect: 3:40 (1:08 – 5:40)
- Direction of dislocation:
  - 3:10 relative to the glenoid
  - 4:10 relative to the trunk

V My Preferred Management
- Humeral defect
  - Assessment: CT
  - Indication: chronic dislocation, seizures with a large Hill Sachs lesion
  - Bone graft: greater tuberosity transfer
- Glenoid defect
  - Assessment: 3D-CT, MRI
  - Indication: remnant arc < 25% of the glenoid length
  - Bone graft: coracoid transfer (Latarjet)

REFERENCES

1. Buhler M, Gerber C. Shoulder instability related to epileptic seizures. J Shoulder Elbow Surg. 2002; 11: 339-344.
2. Burkhart SS, Danaceau SM. Articular arc length mismatch as a cause of failed bankart repair. Arthroscopy. 2000; 16: 740-744.
3. Connolly JF. Humeral head defects associated with shoulder dislocation: their diagnostic and surgical significance. Instr Course Lect 1972; 21: 42-54.
4. Gerber C, Lambert SM. Allograft reconstruction of segmental defects of the humeral head for the treatment of chronic locked posterior dislocation of the shoulder. J Bone Joint Surg Am. 1996; 78: 376-382.
5. Hardy PP. Symposium: Shoulder instability – Limits of arthroscopic surgery. 2003 ISAKOS Congress, Auckland, March 10-14, 2003.
6. Itoi E, Lee SB, Berglund LJ, Berge LL, An KN. The effect of a glenoid defect on anteroinferior stability of the shoulder after Bankart repair: A cadaveric study. J Bone Joint Surg Am 2000; 82-A: 35-46
7. Itoi E, Lee SB, Amrami KK, Wenger DE, An KN. Quantitative assessment of classic anteroinferior bony Bankart lesions using radiography and computed tomography. Am J Sports Med, 2003; 31: 112-118.
8. Saito H, Itoi E, Minagawa H, Kobayashi M, Wakabayashi I, Nozaka K, Kamata T. Location of the glenoid defect in shoulders with recurrent anterior dislocation. J Jpn Orthop Assoc 2003; 77: S291.
9. Sugaya H, Moriishi J, Dohi M, Kon Y, Tsuchiya A. Glenoid rim morphology in recurrent anterior glenohumeral instability. J Bone Joint Surg Am. 2003; 85-A: 878-884.
10. Weber BG, Simpson LA, Hardegger F. Rotational humeral osteotomy for recurrent anterior dislocation of the shoulder associated with a large Hill-Sachs lesion. J Bone Joint Surg Am. 1984; 66: 1443-1450.

PRINCIPLES AND PROCEDURES FOR POSTERIOR AND MULTIDIRECTIONAL INSTABILITY

Christian Gerber

The principles and procedures for posterior and multidirectional instability do not substantially differ from those involved in anterior instability. The separate assessment of instability and hyperlaxity, however, is of key importance[1]:

The prerequisites for correct management are recognition of the following facts

- correct diagnosis is difficult but crucial: posterior subluxation and apprehension must be differentiated from the anterior variant. The coexistence of instability in more than one direction must be diagnosed prior to any procedure
- Whereas hyperlaxity is a trait of biological character, instability is pathological and always associated with a structural lesion. This lesion must be looked for in physical examination[2-4] and at imaging, arthroscopy or surgery.
- The lesions may be insertional (capsulolabral at the glenoid insertion, at the humeral insertion (hagl) or they may be intraligamentous and then especially difficult to identify.
- Bony lesions may be absent or minimal.

Physical examination must identify differences of passive ranges of motion between the hyperlax asymptomatic and the unstable and hyperlax symptomatic shoulder. Recurrent posterior instabilities often exhibit more internal rotation in ninety degrees of abduction and persistence of a sulcus sign in internal rotation whereas these two findings are not present in the contralateral hyperlax but stable shoulder. Inferior and anteroinferior instabilities with hyperlaxity may exhibit a more important hyperabduction test than the asymptomatic contralateral side[3].

Imaging may reveal mild abnormalities of uncertain relevance[5,6]

Treatment options include

- Conservative management may be successful and should be attempted before any surgical therapy is undertaken[7].
- Open surgical treatment using the inferior capsular shift procedure[8] is the gold standard of treatment. It is almost as successful as procedures for unidirectional instability if carried out properly. In posterior instability it is also successful except for revision situations[9]. As opposed to former medio – lateral plication, the capsule is reefed in the supero-inferior direction. Whereas inferior capsular shift is known to be clinically successful[10,11,] its biomechanics remain poorly understood [11,12]
- Arthroscopic stabilization using plication procedures[13] becomes more and more popular and appears as successful as open capsular reefing for posterior and multidirectional instability. As opposed to large bony lesion, it appears that arthroscopic procedures are able to satisfactorily address excessive length of capsular ligaments. As opposed to capsular plication procedures, the thermal capsulorrhaphies have not yet been successful and should not have a place in the current management of the multidirectionally unstable shoulder

REFERENCES

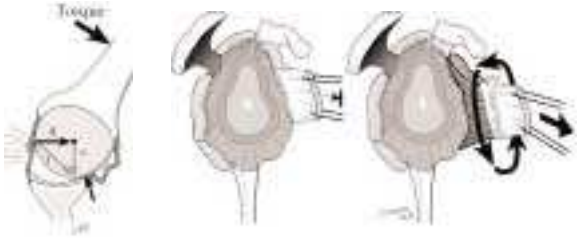
1. Gerber, C., and Nyffeler, R. W.: Classification of glenohumeral joint instability. Clin Orthop, (400): 65-76., 2002.
2. Gerber, C.: Observations on the Classification of Instability. In Complex and Revision Problems in Shoulder Surgery, pp. 9-18. Edited by Warner, J. J. P., Iannotti, J.P., Gerber, C., 9-18, Philadelphia, Lippincott- Raven,, 1997.
3. Gagey, O. J., Gagey,N.: The hyperabduction test. An assessment of the laxity of the inferior glenohumeral ligament. J Bone Joint Surg, 82-B(1): 69-74, 2001.
4. Neer, C. S.: Shoulder Reconstruction. Edited, 551, Philadelphia, W.B. Saunders Comp, 1990.
5. Zanetti, M.; Carstensen, T.; Weishaupt, D.; Jost, B.; and Hodler, J.: MR arthrographic variability of the arthroscopically normal glenoid labrum: qualitative and quantitative assessment. Eur Radiol, 11(4): 559-66, 2001.
6. Weishaupt, D.; Zanetti, M.; Nyffeler, R. W.; Gerber, C.; and Hodler, J.: Posterior glenoid rim deficiency in recurrent (atraumatic) posterior shoulder instability. Skeletal Radiol, 29(4): 204-10, 2000.
7. Burkhead, W. Z., and Rockwood, C. A.: Treatment of Instability of the Shoulder with an Exercise Program. J. Bone Joint Surg., 74-A(6): 890-896, 1992.
8. Neer, C. S., and Foster, C. R.: Inferior Capsular Shift for Involuntary Inferior and Multidirectional Instability of the Shoulder. A Preliminary Report. J. Bone Joint Surg., 62-A(6): 897-908, 1980.
9. Bigliani, L. U.; Pollock, R. G.; McIlveen, S. J.; Endrizzi, D. P.; and Flatow, E. L.: Shift of the Posteroinferior Aspect of the Capsule for Recurrent Posterior Glenohumeral Instability. J.Bone Joint Surg, 77-A(7): 1011-1020, 1995.
10. Pollock, R. G.; Owens, J. M.; Flatow, E. L.; and Bigliani, L. U.: Operative results of the inferior capsular shift procedure for multidirectional instability of the shoulder. J Bone Joint Surg Am, 82-A(7): 919-28., 2000.
11. Gerber, C.; Werner, C. M.; Macy, J. C.; Jacob, H. A.; and Nyffeler, R. W.: Effect of selective capsulorrhaphy on the passive range of motion of the glenohumeral joint. J Bone Joint Surg Am, 85-A(1): 48-55, 2003.
12. Werner, C. M. L.; Nyffeler, R. W.; Jacob, H. A. C.; and Gerber, C.: Effect of Capsular Tightening on Humeral Head Translations. J. Orthop. Res. in print, 2003.
13. Wolf, E. M., and Eakin, C. L.: Arthroscopic capsular plication for posterior shoulder instability. Arthroscopy, 14(2): 153-63, 1998.

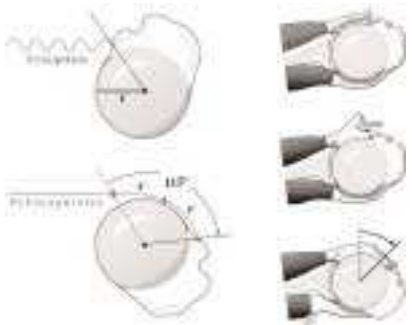
MY MANAGEMENT OF FAILED REPAIRS

Frederick A. Matsen III, MD

I. My rule # 1 Identify the cause of the failure before considering operative treatment (Is it stiffness? Is it recurrent instability? Is it hardware problems? Is it non-specific pain?). My rule #2 Do not do surgery unless a mechanic cause of failure can be identified preoperatively (Don't rely on examination under anesthesia or arthroscopy). My rule #3 Do not do surgery unless the mechanical problem can be fixed surgically.

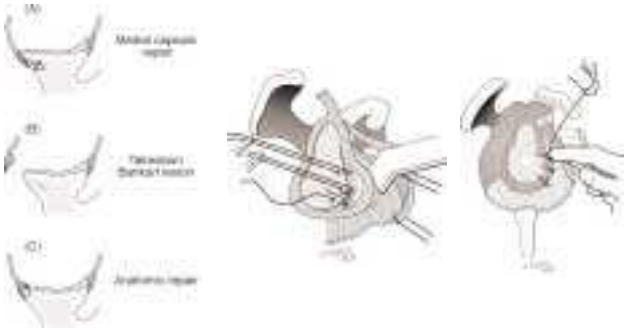
II. If the problem is stiffness, for example an over tightened anterior capsule risking capsulorraphy arthropathy (below left), consider an anterior capsular release and subscapularis lengthening (below left). If the humeral head radius is r, increasing the length of the subscapularis by r, increases the external rotation by 57 degrees (next page).



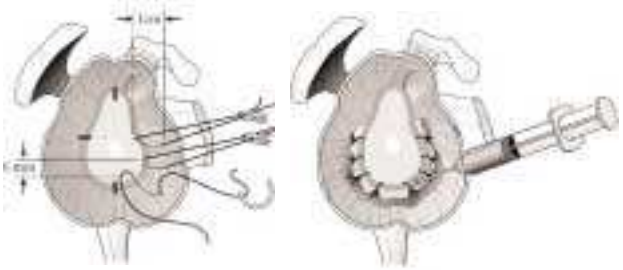


III. If the problem is capsular deficiency (e.g. after thermal damage), reconstruct by capsuloplasty or, if no tissue is left, with a hamstring graft woven from glenoid to humerus.

IV. If the problem is an unrepaired, unhealed or malunited Bankart lesion, repair it right.

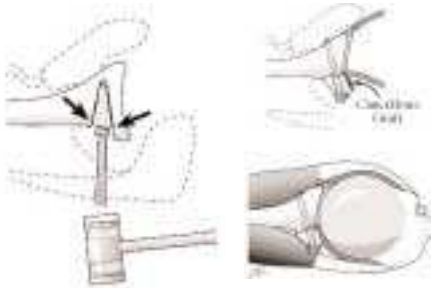


V. If the problem is a flat labrum, augment by imbrication and injection.

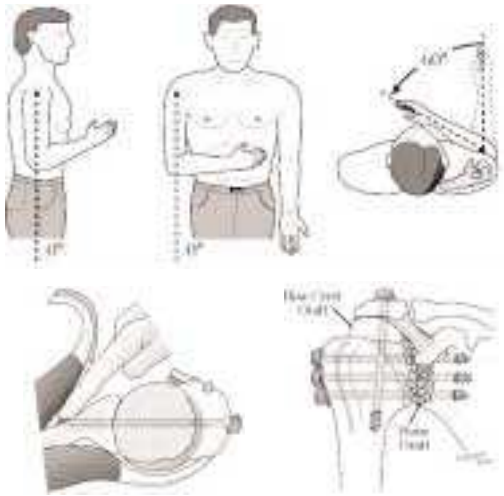


VI. If the problem is a deficient anterior glenoid, augment with extracapsular iliac crest.

VII. If the problem is an inadequate posterior glenoid lip, augment with posterior glenoid osteoplasty or extracapsular graft.



VIII. If the instability is refractor to all traditional methods, consider 0,0,60 arthrodesis.



◆ MANAGEMENT OF ROTATOR CUFF DISEASE: SCIENCE, TECHNIQUE AND TECHNOLOGY (N)

Moderator: Jon J. P. Warner, MD, Boston, MA (n)

This symposium will present not only the scientific basis for best methods of rotator cuff repair, but also the spectrum of applicable surgical techniques including arthroscopic and open repair, tendon transfer, and prosthetic replacement.

I. Introduction/The Use of Tendon Transfers for Treatment of Irreparable Rotator Cuff Tears
Jon J. P. Warner, MD, Boston, MA (n)

II. The Scientific Basis for Current Methods of Rotator Cuff Repair
Christian Gerber, MD, Zurich, Switzerland (n)

III. The Dilemma of the Partial and Delaminated Rotator Cuff Tendon Tear: Debridement or Arthroscopic or Open Repair
Ralph Hertel, MD, Berne, Switzerland (n)

IV. Arthroscopic Rotator Cuff Repair: Are there Limits to Technology and Technique?
Laurent Lafosse, MD, Annecy, France (n)

V. Management of Tears of the Subscapularis and Biceps Disease
Gilles Walch, MD, Lyon, France (n)

VI. The Irreparable Tendon Tear: Hemiarthroplasty versus Delta (Reverse Ball-in-Socket) Arthroplasty
Daniel Mole, MD, Nancy, France (n)

TREATMENT OPTIONS FOR MASSIVE IRREPARABLE RCT: DEBRIDEMENT OR TENDON TRANSFER

Jon J. P. Warner, MD

Definitions
- Massive
  - >5 cm (Cofield)
  - >2 tendon involvement after debridement (Gerber)
- Irreparable
  - A defect that cannot be repaired primarily , after debridement of avascular tissue, by reattachment of the tendons to the region of the greater tuberosity unless the upper extremity is immobilized in adbuction (Rockwood)
  - Static subluxation of the humeral head (acromiohumeral distance < 5mm)
  - Fatty degeneration stage III to IV (Goutallier) and/or severe atrophy on parasagital MR imaging scans (Zanetti, Gerber)
- Irreparable does not mean massive, massive does not mean irreparable!
  - Reparable (symptomatic) ruptures should be repaired, excepted in eldery, low demand patient with biomechanically compensated massive RCT and poor candidate for morbidity of formal open repair
  - Interpretation of results difficult because of poor differentiation between those categories especially in arthroscopic studies!
- Configuration of tendon tear
  - Posterior-superior (Supraspinatus + Infraspinatus)
  - Anterior-superior (Subscapularis + Supraspinatus)

Epidemiology
- Small percentage of all RCT
  - Neer 1992: 145 of 340 RCT over 13 yrs
  - Bigliani 1992: 61 cases over 6 years
  - Ellman 1986: 9 of 50 RCT over 12 years
  - Harryman 1991: 28 of 100 RCT over 5 years
  - Hawkins 1985: 27 of 100 RCT over 5 years
  - Warner 2000: 92 of 470 over 6 years
- Anterior-superior tears less common than posterior-superior tears

Therapeutic options for massive irreparable tears
- Débridement: see below
- Partial repair: Repair of the posterior and anterior reparable parts of the tear without transposition and with a residual defect of 1-3 cm2 can lead to good function (Burkhart). See also clinical outcome after structural failure of RCR (Jost, Gerber)
- Rotator cuff allografts: no reproducible results
- Synthetic materials: no reproducible results
- Local tendon transfer or muscle slide: destruction of the cornal plane force couple and danger of nerve injury
- Tendon transfer: see below
- Hemiarthroplasty: no improvment of function
- Fusion: salvage procedure

Pathomechanical considerations
- Balanced force couple concept :
  - Coronal force couple: superior-inferior balance: Deltoid – Inferior parts of the cuff
  - Transverse force couple: antero-posterior balance: Subscapularis- Infraspinatus/Teres minor
  - In order to have a stable fulcrum of glenohumeral motion, the force couples in both the coronal and transverse planes must be intact. This is compatible with a RCT
- Role of coracacromial arch: stabilizer against unchecked anterosuperior movement of the humeral head in tears involving the supraspinatus and at least one other tendon.

Tendon Transfer for irreparable cuff tears
- Which tendon?
  - Supraspinatus: Trapezius, Deltoid
  - Infraspinatus/Teres minor: Teres major, Latissimus dorsi
  - Subscapularis: Pectoralis minor, Pectoralis major
- State of the art
  - Latissimus dorsi transfer for irreparable posterior-superior cuff tears
  - Pectoralis major transfer for irreparable anterior-superior cuff tears
- Clinical experience:
  - Latissimus
    - Gerber(1992): good to excellent results in 80 % of patients stable over 10 years
    - Miniaci (1999): satisfactory results in 80 % of patients after failed RCR
    - Warner (2000): significant poorer results in transfer after RCR and 30% of transfer rupture
  - Pectolaris major
    - Wirth, Rockwood (1997): satisfactory results in 10/13 patients
    - Resch (2000): good and excellent results in 9/12 patients
    - Warner (2000): 10 complex cases after failed surgery with less predictable results
- Technical considerations: see literature
- Indications for tendon transfer
  - Painful irreparable RCT with poor function in high demand patient
  - Compliant patient and physiotherapist (long and difficult rehabilitation)

Débridement of irreparable cuff tears:
- Clinical experience
  - Apoil, Augereau 1990 poor long-term results after open subacromial débridement and resection of the coracoacromial ligament
  - Rockwood, Williams, Burkhead 1995: decrease of pain and impovement of function and strength in 83% patients after open acromioplasty, subacromial decompression, tear débridement without deterioration with time
  - Gartsman, 1997: decrease of pain, improve of function but decrease of strength after open débridement and subacromial decoompression, overall results inferior than Rockwood's results
  - Esch et al. 1988: 3 from 6 failures after arthroscopic decompression in case of cranial migration of the humeral head
  - Burkart, 1991: good and stable results in biomechanical compensated irreparable tears after arthroscopic

acromioplasty
  - Ellman, Kay, Wirth 1993 : significant reduction of pain but no improvment in function and strength after arthroscopic débridement
  - Zvijac, Lévy, Lemak, 1994: Deterioration of function and strength over time espacially in massive tears after arthroscopic débridement and subacromial decompression
  - Kempf et al , 1999: long rehabilitation and non significant improvement in overall Constant score in patients with massive tears after arthroscopic débridement.
- Technical considerations
  - Open versus arthroscopic: for massive irreparable tears no difference, but arthroscopic procedure less invasive for patient
  - Biceps: controversy about preservation (Rockwood) or tenotomy(Kempf, Walch)
  - Débridement of the tear seems not to be essential as far as acromioplasty is performed (Kempf)
  - Loss of the coracoacromial arch means loss of the shoulder
- Indication
  - The best patient for débridement is an eldery low demanding patient with a painful compensated massive (rep or irrep) cuff tear
  - In case of poor preoperative function this procedure cannot guarantee durable pain relief or recovery of function. Consider alternatives like partial repair of the tear if possible, hemiarthroplasty or the implantation a Delta III reversed prosthesis
  - Osteoarthrosis and previous operations like acromioplasty or cuff repair are negative factors

Recommendations: Transfer versus Débridement

- Overall disability of patient (pain> functional deficit) usually (young patient excepted) establishes indication for surgery
- Individualized treatment depending on:
  - Work/Sport requirements
  - Patient expectations, compliance
  - Preexisting medical conditions
  - Bilateral or dominant site involvement

REFERENCES

1. Apoil, A. and B. Augereau (1990). Antero-superior arthrolysis of the shoulder for rotator cuff degenerative lesions. In M. Post, B. Morrey and R. Hawkins, eds: Surgery of the shoulder. St Louis, Mosby Year Book 267-270.
2. Bigliani, L., S. McIlveen, et al. (1992). Operative repair of massive rotator cuff tears: long-term results. J Shoulder Elbow Surg(1): 120-130.
3. Burkhart, S. (1991). Arthroscopic treatment of massive rotator cuff tears. Clin Orthop 267: 45-56.
4. Burkhart, S. (1994). Reconciling the paradox of rotator cuff repair versus débridement: A unified biomechanical rationale for the treatment of rotator cuff tears. Arthroscopy 10: 4-19.
5. Cofield, R. (1985). Rotator cuff disease of the shoulder. J Bone Joint Surg 67A: 974-979.
6. Ellman, H. (1987). Arthroscopic subacromial decompression: analysis of one- to three year results. Arthroscopy 3: 173-181.
7. Ellman, H., G. Hanker, et al. (1986). Repair of the rotator cuff: end results study of factors influencing reconstruction. J Bone Joint Surg 68A: 1135-1144.
8. Ellman, H., S. Kay, et al. (1993). Arthroscopic treatment of full-thickness rotator cuff tears: 2 to 7 years follow up study. Arthroscopy 9: 195-200.
9. Esch JC, Ozerkis ZR, et al. (1988). Arthroscopic sub-acromial decompression: Results according to the degree of rotator cuff tear. Arthroscopy(4): 241-249.
10. Gartsman, G. (1997). Massive, Irreparable Tears of the Rotator Cuff. Results of Operative Debridement and Subacromial Decompression. J Bone Joint Surg 79A(May): 715-721.
11. Gerber, C. (1992). Latissimus dorsi transfer for the treatment of irreparable tears of the rotator cuff. Clin Orthop 275(february): 152-160.
12. Gerber, C. and O. Hersche (1997). Tendon transfers for the treatment of irreparable rotator cuff defects. Orthop Clin North Am 28(2): 195-203.
13. Gerber, C., T. Vinh, et al. (1988). Latissimus dorsi transfer for the treatment of massive tears of the rotator cuff. A preliminary report. Clin Orthop 232: 51-61.
14. Goutallier, D., J. Postel, et al. (1994). Fatty muscle degeneration in cuff ruptures: pre- and postoperative evaluation by CT scan. Clin Orthop 304: 7-83.
15. Harrymann, D., L. Mack, et al. (1991). Repair of the rotator cuff: correlation of functional results withn the integrity of the cuff. J Bone Joint Surg 73A: 982-989.
16. Jost, B., C. Pfirrmann, et al. (2000). Clinical outcome after structural failure of rotator cuff repairs. J Bone Joint Surg 82A: 304-314.
17. Kempf, J.-F., P. Gleyze, et al. (1999). A Multicenter Study of 210 Rotator Cuff Tears Treated by Arthroscopic Acromioplasty. Arthroscopy 1: 56-62.
18. Miniaci, A. and M. MacLeod (1999). Transfer of the Latissimus dorsi muscle after failed repair of a massive tear of the rotator cuff. J Bone Joint Surg 81A: 1120-1127.
19. Nevasier, J., R. Nevasier, et al. (1978). The repair of chronic massive ruptures of the rotator cuff of the shoulder by the use of freeze-dried rotator cuff. J Bone Joint Surg 60A: 681-686.
20. Resch, H., P. Povacz, et al. (2000). Transfer of the pectoralis major muscle for the treatment of irreparable rupture of the subscapularis tendon. J Bone Joint Surg 82A: 372-382.
21. Rockwood, C., G. Williams, et al. (1995). Débridement of degenerative irreparable lesions of the rotator cuff. J Bone Joint Surg 77A(6): 857-866.
22. Warner, J. (2000). Managment of massive irreparable rotator cuff tears: the role of tendon transfers. Instructional course lectures. J Bone Joint Surg in press.
23. Wirth, M. and C. R. Jr (1997). The operative treatment of irreparable rupture of the subscapularis. J Bone Joint Surg 79A: 722-733.
24. Zvijac, J., H. Levy, et al. (1994). Arthroscopic sub-acromial decompression in the treatment of full thickness rotator cuff tears. A 3 to 6 year follow-up. Arthroscopy(10): 518-523.

THE SCIENTIFIC BASIS OF ROTATOR CUFF REPAIR

Christian Gerber, MD

CHANGES IN THE MUSCLE – TENDON – BONE UNIT ASSOCIATED WITH CHRONIC ROTATOR CUFF TENDON FAILURE

If rotator cuff tendons fail, the respective muscles retract, atrophy, undergo interfibrillar fatty infiltration and loose elasticity and strength. The tendons degenerate, thin out, become brittle and weak. The greater tuberosity becomes osteopenic and mechanically weak.

Experimental release of a rotator cuff tendon from its insertion and prevention of spontaneous healing for a period of up to 40 weeks are associated with musculotendinous retraction, progressive muscular atrophy, fatty infiltration of the interfibrillar space (until muscle contains at least as much fat as contractile elements), interstitial fibrosis, loss of contractile strength and elasticity[1-9]. Analogous changes characterize the human rotator cuff muscles after long standing tear of their tendons[4,10-15].

- Rotator cuff tendons do not fail in the absence of substantial degenerative structural alterations[16-20] .
- The insertion site of the tendons and the underlying bone undergo osteopenia so that the bone to which a tendon is repaired must be considered to be weak[21,22].

THE EFFECTS OF OPERATIVE REPAIR ON THE STRUCTURAL PROPERTIES OF THE MUSCLE – TENDON - BONE UNIT

Successful operative repair as currently performed often restores structural and functional continuity between tendon and bone but does not revert fatty infiltration and only exceptionally reverts atrophy of the muscle

durable structural continuity of the muscle – tendon – bone unit in 50 – 90% of the repairs[23-29], in the remaining cases, the repair fails most frequently early after the repair[3,14]

If structural continuity can be maintained until healing (approximately for 6 to 9 months) the probability for durable structural integrity and a good clinical long-term result is high[24,28-33].

Whereas the degenerative changes in the tendon may be improved and a good tendon to bone insertion site may be restored, the fatty infiltration of the muscle is not and the muscular atrophy is most frequently not reversible[8,9,34,35].

THE EFFECT OF OPERATIVE REPAIR ON OUTCOME AFTER ROTATOR CUFF TEARING

Patients with low functional demands may not need surgery. Various surgical concepts at least temporarily relieve pain. Functional recovery is significantly better if a repair results in structural tendon – to bone continuity.

Operative repair of rotator cuff tendon tears significantly improves patients with respect to pain, ability to perform activities of daily living, function and overall perception of their health status[36-39]

If the repair heals successfully, the functional outcome is significantly better than if the tear is not repaired or if the repair fails[14,25,26,29,40]

THE GOALS OF OPERATIVE REPAIR OF ROTATOR CUFF TENDONS

If operation with the goal to not only relieve pain but also restore function is undertaken, the first goal is to restore muscle – tendon – bone continuity without further injury to the nerve – muscle – tendon – bone unit and to ascertain that this continuity is maintained until healing.

For the future, the goal is to become able to revert fatty degeneration and atrophy.

In the absence of functional musculotendinous units, mucle – tendon transfers or other salvage operations may become necessary.

TECHNICAL CONSIDERATIONS FOR OBTAINING SUCCESSFUL REPAIRS

Currently, the following steps appear optimal to obtain a successful repair:

- mobilization of the musculotendinous unit without neurovascular injury
- grasping a sufficently strong tendon stump with an adapted tendon grasping technique and/or a large number of sutures
- fixation of the tendon transosseoulsy to the greater tuberosity using as little tension as possible
- No creation of a trough at the tendon footprint but augmentation of the suture fixation on or in the bone to prevent cutting of the suture through bone
- postoperative protection and adapted mechanical stimulation of the repair

Lateral advancement of the musculotendinous units of the rotator cuff may be extremely limited. A normal supraspinatus or infraspinatus can be advanced by no more than 1cm unless the muscle is released from its fossa[41]. The more chronic the tear, the more fibrotic and the less elastic the musculotendinous unit and the less can it be advanced laterally without undo tension[8,9,15,42,43.]

The suture material must be adapted: Elastic sutures are probably less suited than braided less elastic suture materials which avoid gapping. Number two suture of a braided polyester invariably remains the weakest link in the repair chain. Number three is probably better suited unless newer, stronger materials are utilized. The more sutures are passed through the tendon, the less load is absorbed by each individual suture. Number of sutures and grasping technique are therefore interdependent[44]. They should consider viability of tissue and repair strength.

Tendon grasping techniques greatly affect the holding power of a repair. Special grasping techniques (such as modified Mason Allen Stitches) should have a short course within the tendon to avoid elastic gapping at the reinsertion site and if possible compress a fiber bundle when loaded rather than being loaded in the direction of the fiber bundles. The grasping techniques must be strong on single as well as on repetitive loading and allow preservation of vascularity at the repair site[3,44]

The creation of a bony trough on the footprint of the tendon is mechanically detrimental as it results in need of a longer tendon to reach the insertion site, weakens the insertion site[22] and has biologically not been proven to be of any advantage[45]

Transosseous fixation yields highest pull out strength because both strands of the suture the greater tuberosity, cortical bone augmentation may be necessary to prevent cutting of the knot through the bone upon loading[44].

The use of anchors is an attractive alternative: Holding power of the anchor in bone is usually not a problem. If anchors are utilized, however, the load is fully on the one strand which goes through the eyelet. With the sharpness of the eyelet, the strength of the suture is reduced[46] and as the strand carries double load as compared to a transosseous repair so that the holding power of the same suture is substantially less than with standard transosseous repairs. In fact the load on the suture is so high, that there is no benefit of using a Mason Allen stitch if braided polyester sutures are used[47]. If absorbable sutures are utilized it should be remembered that failure of the anchor material at the eyelet under tension is a potential complication[48.]

Postoperative protection should not be confused with postoperative immobilization. Experimental work has shown that failure to protect a tendon to bone repair will result in structural failure whereas this can be at least in part prevented by avoiding the positions which impose a high load on the repair. There fore we use an abduction brace in as little as 20 degrees of abduction as this seems to be the position which relieves tension sufficiently for the cuffs which can repaired with the arm at the side.[3,14,49]

REFERENCES

1. Crawford, G. N. C.: Some effects of tenotomy on adult striated muscle. J. Anat., 123(2): 389-396, 1977.
2. Josza, L., Kannus, P., Thöring, J., Reffy, A., Järvinen, M., Kvist, H.: The effect of tenotomy and immobilisation on intramuscular connective tissue. J Bone Joint Surg, 72-B: 293-297,, 1990.
3. Gerber, C.; Schneeberger, A. G.; Perren, S. M.; and Nyffeler, R. W.: Experimental Rotator Cuff Repair. A Preliminary Study. J. Bone Joint Surg., 81-A(9): 1281-1290, 1999.
4. Jozsa, L.; Balint, J. B.; and Demel, S.: Histochemical and ultrastructural study of human muscles after spontaneous rupture of its tendon. Acta histochem, 63: 61-73, 1978.
5. McMinn, R., and Vrbova, G.: Morphological Changes in Red and Pale Muscles following Tenotomy. Nature, 195: 509, 1962.
6. Fabis, J.; Kordek, P.; Bogucki, A.; Synder, M.; and Kolczynska, H.: Function of the rabbit supraspinatus muscle after detachment of its tendon from the greater tubercle - Observations up to 6 month. Acta Orthopaedica Scandinavica, 69(6): 570-574, 1998.
7. Fabis, J.; Kordek, P.; Bogucki, A.; and Mazanowska-Gajadowicz, J.: Function of the rabbit supraspinatus muscle after large detachment of its tendon: 6-week, 3-month and 6-month observation. Journal of Shoulder and Elbow Surgery, 9: 211-6, 2000.
8. Meyer, D.; Pfirrmann, C.; von Rechenberg, B.; Hoppeler, H.; Lajtai, G.; and Gerber, C.: Adaptation of the musculotendinous junction to tendon retraction after rotator cuff tear with delayed repair. An experimental study in sheep. submitted, 2002.
9. Gerber, C.; Meyer, D.; Schneeberger, A.; Hoppeler, H.; and von Rechenberg, B.: The effect of tendon release and delayed repair on the structure of the rotator cuff musculature. An experimental study using a new animal model. submitted, 2002.
10. Fuchs, B.; Weishaput, D.; Zanetti, M.; Hodler, J.; and Gerber, C.: Fatty degeneration of the muscles of the rotator cuff: Assessment by computed tomography versus magnetic resonance imaging. J Shoulder Elbow Surg, 8(6): 599-605, 1999.
11. Goutallier, D.; Postel, J.-M.; Bernageau, J.; Lavau, L.; and Voisin, M.-C.: Fatty Muscle Degeneration in Cuff Ruptures. Clin.Orthop. Rel Res., 304(304): 78-83, 1994.
12. Nakagaki, K.; Ozaki, J.; Tomita, Y.; and Tamai, S.: Alterations in the supraspinatus muscle belly with rotator cuff tearing: Evaluation with magnetic resonance imaging. J. Shoulder Elbow Surg., 3: 88-93, 1994.
13. Nakagaki, K.; Ozaki, J.; Tomita, Y.; and Tamai, S.: Fatty degeneration in the supraspinatus muscle after rotator cuff tear. J Shoulder Elbow Surg, 5: 194-200, 1996.
14. Gerber, C., Fuchs,B., Hodler,J.: The Results of Repair of Massive Tears of the Rotator Cuff. J. Bone Joint Surg., 82-A: 505-515, 2000.
15. Hersche, O., and Gerber, C.: Passive tension in the supraspinatus musculotendinous unit after long- standing rupture of its tendon: a preliminary report. J Shoulder Elbow Surg, 7(4): 393-6., 1998.
16. Kannus, P., Kozsa, L.: Histopathological Changes Preceding Spontaneous Rupture of a Tendon. J. Bone Joint Surg., 73-A(10): 1507-1525, 1991.
17. Uhthoff, H. K., and Sarkar, K.: The pathogenesis of rotator cuff disease with special reference to changes at the tendon insertion. In Surgery of the Shoulder, pp. 59-63. Edited by Vastamäki, M., and Jalovaara, P., 59-63, Amsterdam, Elsevier, 1995.
18. Uhthoff, H. K., and Sano, H.: Pathology of failure of the rotator cuff tendon. Orthop Clin North Am, 28(1): 31-41., 1997.
19. Sano, H.; Ishii, H.; Trudel, G.; and Uhthoff, H. K.: Histologic evidence of degeneration at the insertion of 3 rotator cuff tendons: a comparative study with human cadaveric shoulders. J Shoulder Elbow Surg, 8(6): 574-9., 1999.
20. Sano, H.; Uhthoff, H. K.; Backman, D. S.; Brunet, J. A.; Trudel, G.; Pham, B.; and Ishii, H.: Structural disorders at the insertion of the supraspinatus tendon. Relation to tensile strength. J Bone Joint Surg, 80-B(4): 720-5., 1998.
21. Kannus, P.; Leppälä, J.; Lehto, M.; Sievänen, H.; Heinonen, A.; and Järvinen, M.: A Rotator Cuff Rupture Produces Permanent Osteoporosis in the Affected Extremity, but Not in Those with whom Shoulder Function Has Returned to Normal. J Bone Miner Res, 10(8): 1263-1271, 1995.
22. Meyer, D.; Fucentese, S.; Koller, B.; and Gerber, C.: Association of osteopenia of the humeral head with full thickness rotator cuff tears. submitted, 2002.
23. Gazielly, D. F.; Gleyze, P.; and Montagnon, C.: Functional and Anatomical Results After Rotator Cuff Repair. Clin.Orthop.Rel.Res., 304: 43-53, 1994.
24. Gerber, C.; Fuchs, B.; and Hodler, J.: The Results of Repair of Massive Tears of the Rotator Cuff. J.Bone Joint Surg, 82-A: 505-515, 2000.
25. Harryman, D. T.; Mack, L. A.; Wang, K. Y.; Jackins, S. E.; Richardson, M. L.; and Matsen, F. A.: Repairs of the Rotator Cuff. Correlation of Functional Results with Integrity of the Cuff. J. Bone Joint Surg., 73-A(7): 982-989, 1991.
26. Jost, B.; Pfirrmann, C. A. W.; and Gerber, C.: Clinical Outcome After Structural Failure of Rotator Cuff Repairs. J. Bone Joint Surg., 82-A(3): 304-314, 2000.
27. Thomazeau, H., Boukobza, E., Morcet, N., Chaperon, J., Langlais, F.: Prediction of Rotator Cuff Repair Result by Magnetic Resonance Imaging. Clin. Orthop. Rel. Res., 344: 275-283, 1997.
28. Walch, G.; Maréchal, E.; Maupas, J.; and Liotard, J. P.: Traitement des ruptures de la coiffe des rotateurs. Facteurs de pronostic. Rev.Chir.Orthop.Reparatrice.Appar.Mot., 78(6): 379-388, 1992.
29. Postel, J. M.; Goutallier, D.; Lavau, L.; and Bernageau, J.: Anatomical Results of Rotator Cuff Repairs: Study of 57 Cases Controlled by Arthrography. J.Shoulder Elbow Surg., 3: 20,, 1994.
30. Bigliani, L. U.; McIlveen, S. J.; Cordasco, F.; and Musso, E.: Operative Repair of Massive Rotator Cuff Tears: Long Term Results. J. Shoulder Elbow Surg., 1(3): 120-130, 1992.
31. Ellman, H.; Hanker, G.; and Bayer, M.: Repair of the Rotator Cuff. End-Result Study of Factors Influencing Reconstruction. J. Bone Joint Surg., 68-A:: 1136 -- 1144,, 1986.
32. Neer, C. S.; Flatow, E. L.; and Lech, O.: Tears of the Rotator Cuff. Long Term Results of Anterior Acromioplasty and Repair. Orthop.Trans., 12:: 735,, 1988.
33. Adamson, G. J., and Tibone, J. E.: Ten - year assessment of primary rotator cuff repairs. J. Shoulder Elbow Surg., 2(2): 57-63, 1993.
34. Goutallier, D., Postel,J.M., Lavau,L., Bernageau,J.: Influence de la dégénérescence graisseuse des muscles supraépineux et infraépineux sur le pronostic des réparations chirurgicales de la coiffe des rotateurs. Rev. Chir. Orthop., 85: 668-676, 1999.
35. Matsumoto, F.; Uhthoff, H. K.; Trudel, G.; and Loehr, J. F.: Delayed tendon reattachment does not reverse atrophy and fat accumulation of the supraspinatus - an experimental study in rabbits. J Orthop Res, 20: 357-363, 2002.
36. Gartsman, G. M.; Khan, M.; and Hammerman, S. M.: Arthroscopic repair of full-thickness tears of the rotator cuff. J Bone Joint Surg Am, 80(6): 832-40, 1998.
37. Watson, M.: Major Ruptures of the Rotator Cuff. The Results of Surgical Repair in 89 Patients. J Bone Joint Surg, 67-B:: 618 --624,, 1985.
38. Cofield, R. H., Parvizi, J., Hoffmeyer, P., Lanzer, W.L., Ilstrup, D.M., Rowland, C.M.: Surgical Repair of Chonic Rotator Cuff Tears. J Bone Joint Surg, 83-A(1): 71-77, 2001.
39. Rokito, A. S., Cuomo, F., Gallagher, M.A., Zuckerman, J.D.: Long-Term Functional Outcome of Repair of Large and Masive Chronic Tears of the Rotator Cuff. J. Bone Joint Surg., 81-A(7): 991-997, 1999.
40. Montgomery, T. J.; Yerger, B.; and Savoie, F. H.: Management of rotator cuff tears:Comparison of arthroscopic debridement and surgical repair. J. Shoulder Elbow Surg., 3(2): 71-78, 1994.
41. Warner, J. J. P.; Krushell, R. J.; Masquelet, A. C.; and Gerber, C.: Anatomy and Relationsships of the Suprascapular Nerve: Anatomical Constraints to Mobilization of the Supraspinatus and Infaspinatus Muscles in the Management of Massive Rotator Cuff Tears. J. Bone Joint Surg, 74-A: 36-45, 1992.
42. Gerber, C.; Vinh, T. S.; Hertel, R.; and Hess, C. W.: Latissimus Dorsi Transfer for the Treatment of Massive Tears of the Rotator Cuff. A Preliminary Report. Clin.Orthop.Rel.Res., 232:: 51 --61,, 1988.
43. Meyer, D.; Hoppeler, H.; von Rechenberg, B.; and Gerber, C.: Association of fatty muscle infiltration with increase of pennation angle following tendon tear of pennate muscle. Experimental observations in sheep. submitted, 2002.
44. Gerber, C.; Schneeberger, A. G.; Beck, M.; and Schlegel, U.: Mechanical Strength of Repairs of The Rotator Cuff. J. Bone Joint Surg., 76-B: 371-380, 1994.
45. St.Pierre, P., Olson, E.J., Elliott, J.J., O'Hair, K.C., McKinney L.A., Ryan, J.: Tendon - Healing to Cortical Bone Compared with Healing to a Cancelous Trough. A Biomechanical and Histological Evaluation in Goats. J. Bone Joint Surg., 77-A(12): 1858 - 1866, 1995.
46. Meyer, D.; Nyffeler, R.; Fucentese, S.; and Gerber, C.: Failure of suture material at suture anchor eyelets. Arthroscopy, in print, 2002.
47. Schneeberger, A. G.; von Roll, A.; Kalberer, F.; Jacob, H. A. C.; and Gerber, C.: The Mechanical Strength of Arthroscopic Rotator Cuff Repairs. J Bone Joint Surg A: In Print, 2002.
48. Meyer, D.; Felix, E.; Ruffieux, K.; and Gerber, C.: Influence of test-temperature and test-speed on the mechanical strength of absorbable suture anchors. Arthroscopy, in print, 2002.
49. Silva, M. J.; Boyer, M. I.; and Gelberman, R. H.: Recent progress in flexor tendon healing. J Orthop Sci, 7(4): 508-14, 2002.

THE DILEMMA OF THE PARTIAL AND DELAMINATED TENDON TEAR: ARTHROSCOPIC OR OPEN REPAIR?

Ralph Hertel, MD

Partial tears are difficult to fully appreciate and best treatment is uncertain. The first difficulty relates to the wide spectrum of symptoms that are due to or can be associated with partial tears of the rotator cuff. Other problems are the heterogeneous and often multifactorial etiology of the lesion and the difficulty to recognize the relevant patho-anatomy.

The following check-list serves as a reminder and a categorizer:

- Aetiology (ranging from traumatic, microtraumatic to atraumatic);
- Size (tendon thickness involved, antero-posterior extension);
- Location (articular side, bursal side, intratendinous; starting from x mm and ending y mm behind the bicipital groove, extension in the lateral to medial direction);
- Retraction of the deep layer or, less frequently, of the superficial layer in mm;
- Size and extent of the cleavage lesion[1-3] (also called intratendinous delamination);
- Involvement of the superior articular cartilage (chondromalacia;
- Involvement of the biceps tendon (posterior poulie lesion, instability, partial rupture);
- Involvement of the labrum (postero-superior and antero-inferior);
- Involvement of the capsule (distesion, contracture);
- Degree of the inflammatory synovial reaction;
- Condition of the subacromial bursa;
- Shape of the acromion (C-A enthesophyte?);
- Condition of the A-C joint (inferior ostheophytes?).

Preoperative imaging and arthroscopy are often inadequate to reveal the full extent of the lesion[4]. Unless the surgeon actively searches for lesions such as delaminations, the chances of missing them are high.

As a general rule treatment should be causative, not palliative! Therefore debridement and "simple" reinsertion cannot be a lasting solution for most shoulders. To obtain lasting results it is important that the patient changes habits and adapts to the disease.

Technical difficulties of reinsertion of the deep layer further jeopardize the desirable outcome. The problem is to mobilize the deep layer without damage to the superficial, generally intact layer. Another challenge is to readapt the intratendinous cleavage plane.

The postoperative course varies considerably. Tedious rehabilitation should be expected in shoulders presenting capsular inflammatory reaction and a discrepancy between the size of the lesion and the symptoms.

Best outcomes can be expected in patients with moderate inflammatory synovial reaction, large acromial enthesophytes, and well-delimitated lesions with minimal cleavage component. Although strong evidence is still missing, tendon repair seems to offer better results than debridement and acromioplasty alone in patients with partial tears comprising more than 50% of the tendon[5, 6].

REFERENCES

1. Reilly P, Amis AA, Wallace AL, Emery RJ. Supraspinatus tears: propagation and strain alteration. J Shoulder Elbow Surg 2003;12(2):134-8.
2. Sonnabend DH, Watson EM. Structural factors affecting the outcome of rotator cuff repair. J Shoulder Elbow Surg 2002;11(3):212-8.
3. Bey MJ, Ramsey ML, Soslowsky LJ. Intratendinous strain fields of the supraspinatus tendon: effect of a surgically created articular-surface rotator cuff tear. J Shoulder Elbow Surg 2002;11(6):562-9.
4. Lee SY, Lee JK. Horizontal component of partial-thickness tears of rotator cuff: imaging characteristics and comparison of ABER view with oblique coronal view at MR arthrography initial results. Radiology 2002;224(2):470-6.
5. Fukuda H. The management of partial-thickness tears of the rotator cuff. J Bone Joint Surg Br 2003;85(1):3-11.
6. Cordasco FA, Backer M, Craig EV, Klein D, Warren RF. The partial-thickness rotator cuff tear: is acromioplasty without repair sufficient? Am J Sports Med 2002;30(2):257-60.

ARTHROSCOPIC ROTATOR CUFF REPAIR

Laurent P Lafosse, MD

INTRODUCTION

Actually rotator cuff repair is more currently performed by arthroscopy, with different opinions about indications and the eventual combination with acromioplasty 1,2,3,4. We started arthroscopic technique in 1992 and since 2000 we manage all cuff repairs arthroscopically. It is important to understand the tear shape in order to place the portals, to release the retracted tendons sufficiently and to close the cuff as complete as possible.

PREOPERATIVE ASSESSMENT

Clinical and functional findings with an additional specific neurological examination of the involved and healthy shoulder are classified by the ASES-Score, the Constant-Murley-Score and the UCLA-Score. Preoperative imaging are standard X-rays (true a.p., outlet view and ACJ by Zanca5), arthro-CT-Scan or arthro-MRI. Tendon tear is classified by the Patte classification 6, muscles quality assessed by the Goutallier classification 7.

INDICATIONS

Many factors determine the indication for ARCR: firstly pain, mobility restriction and loss of force. A clinical and functional examination informs about the involved tendons and the tear extend, the AC-joint and the neurological status. Radiological findings help to judge the tear shape and muscle status. Definite decision is taken together with the totally cleared up patient, whose compliance is essentially for an excellent outcome. Since 3 years we perform only ARCR, as open technique does not bring any advantage now.

SURGICAL PRINCIPLES

ANESTHESIA and POSITIONNING

Under interscalenic and axillary block, with or without general anesthesia in beach chair position, the patient's arm is in 30° flexion under a 1.5 to3 kg traction.

PORTALS

We use five portals: the classic posterior "soft spot" portal and the anterior portal through the rotator interval as well as the standard lateral portal as for acromioplasty. Our two additional approaches are a postero-superior portal at the postero-lateral angle of the acromion and an antero-superior portal at the antero-lateral corner of the acromion. The arthroscope and the instruments are often switched from one to an other portal for ideal visualization and access to the lesion.

ARTHROSCOPIC JOINT EVALUATION

Articular and subacromial elements are viewed meticulously statically and dynamically after joint and bursal cleaning by shaving and electrocautery. The tear is classified, then the cuff reducibility is tested and the necessity of a periglenoid, subacromial and subdeltoid release is evaluated. Special care has to be paid for extensive subscapularis release, as the axillary nerve and vessels and the plexus nerves are close and endangered.

Decrescent U-shaped tears are reduced from medial to lateral. L-shaped tears or are closed by pulling the retracted anterior flap posteriorly during internal rotation of the humerus, vice versa for inverse L-shaped tears. V-shaped tears can be understood as a combined L- and inverse L-shaped. When delamination of the tendons, both layers have to be repaired. The status of the long head of biceps is viewed, his anterior and posterior stability in the groove is controlled during internal and external rotation.

Acromioplasty and eventual AC-joint resection is done before repair to have better view and larger subacromial space for the instruments. In cases with persistent anterosuperior head instability no acromioplasty is done for keeping the osteo-ligamentary overhang for joint stabilization.

TECHNICAL PRINCIPALS

Anchor positioning in a footprint technique enlarges the tendon to bone contact area and reduces the traction forces on each thread: one anchor is placed on the cartilage-bone-interface, a second laterally on the greater tuberosity. The first knots are on the lateral anchor to get the tendon under traction, then the medial knots are done to plate the tendon on the abraded bone. The use of metallic or absorbable anchors or screws is determined by the bone quality, the tendons traction forces, the planned localization. We use absorbable anchors only in a position close to the cartilage and for biceps tenodesis, but only with braided non-absorbable suture. It can be shuttled by a PDS suture for 2-step techniques, otherwise it is passed directly by a pointed device or grabbed after having perforated perpendicularly the tendon. Sutures can be done simple or as guy ropes to halve the traction forces on both single threads. Side to side sutures in the "lasso-technique" between the cuff borders or upon an anchor can be added. We do a "doubled first half loop" knot followed by alternated half loops for a high knot-security. We don't use sliding knots nor canula and work quickly with low fluid pressure.

SURGICAL TECHNIQUE

PARTIAL TEAR

We repair superficial tears by a guy-rope technique. Deep tears are often combined with posterior (SSP) instability of the LHB according pulley lesion. We reattach the torn tendon in a parachute technique on an anchor close to the cartilage under intraarticular view and pay attention to not strangulate the biceps tendon by a too tight closure. Any erosion of the LHB is treated by a tenodesis in the groove.

FULL THICKNESS TEAR

We always perform footprint technique as described before. Supraspinatus tears are often U-shaped or V-shaped, infraspinatus tears mostly are L- or inverse L-shaped. Subscapularis tears often involve the upper third, and the repair is facilitated by additional flexion and slight internal rotation. More important SSC-lesions require an extensive release and extra-articular view for good extensive fixation.

When complete cuff closure is not possible, partial repair with tendon refixation at least higher than the humeral head rotation center should be tried in order to keep the static balance of the joint. Side to side sutures often are helpful.

TRICKS AND PITFALLS

Perfect visualization is indispensable for ARCR and needs systematic use of shaver and electrocautery. The flow pressure should be as low as possible to avoid swelling. The surgeon has

to be well experienced in arthroscopy and especially in knot tying before ARCR.

POSTOPERATIV ECARE

Pain free rehabilitation is starting at day 1 out of an 30° abduction brace for the first 6 weeks with only active-assisted motion within the first 3 month to obtain good healing, later active motion is started successively. Shoulder stiffness has never been seen in our clinic after ARCR. Clinical follow-up consists of x-ray control at 6 weeks and 3 month postOP, at 6 month postOP an arthrographic control for supra- and infraspinatus and an arthro-CT-scan for subscapularis estimation and check of fatty degeneration and trophicity of the tendons is performed.

CONCLUSION

Nowadays the use of arthroscopical techniques for rotator cuff repair is widespread. The know-how and the surgical devices have been rapidly developed and allow even the repair of massive and retracted cuff tears. Nevertheless, it is still an extremely difficult surgery even for small sized ruptures because of the morphology of the subacromial space. We are encouraged to invest our efforts in arthroscopy by the excellent clinical and functional results we have in arthroscopic rotator cuff repair.

REFERENCES

1. Hoe-Hansen CE, Palm L, Norlin R: The influence of cuff pathology on shoulder function after arthroscopic subacromial decompression: A 3-and6-year. J Shoulder Elbow Surg 8(6): 585-89, 1999
2. Norlin R: Arthroscopic subacromial decompression versus open acromioplasty. Arthroscopy 5: 321-23, 1989
3. Rockwood CA, Williams GR, Burkhead WZ: Debridement of degenerative, irreparable lesions of the rotator cuff. J Bone Joint Surg 77A: 739-40, 1995
4. Cordasco FA, Backer M, Craig EV, Klein D, Warren RF. The partial-thickness rotator cuff tear: is acromioplasty without repair sufficient? Am J sports Med 2003 Mar-Apr; 31(2); author reply 325
5. Zanca P: Shoulder pain: involvement of the acromioclavicular joint. (Analysis of 1,000 cases). Am J Roentgenol Radium Ther Nucl Med. 1971 Jul;112(3):493-506.
6. Patte D: Classification of rotator cuff lesions. Clin Orthop. 1990 May (254):81
7. Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC: Fatty muscle degeneration in cuff rupture. Clin Orthop 304 : 78-83, 1994

MANAGEMENT OF TEARS OF THE SUBSCAPULARIS AND BICEPS DISEASE

Gilles Walch, MD, T. Bradley Edwards, MD

Introduction

Tears of the subscapularis tendon are much less common than other types of rotator cuff tears. While tears of the posterior superior rotator cuff tend to occur in the older patient population, tears of the subscapularis tend to occur in patients younger than 50 years of age secondary to a traumatic insult[2,7]. An exception to this rule is the older patient sustaining a traumatic anterior shoulder dislocation, which commonly results in an anterior or superior rotator cuff tear involving the subscapularis tendon[12].

Isolated tears of the subscapularis are exceedingly rare[2,7,13]. Most subscapularis disruptions occur with a concomitant injury to the supraspinatus tendon, the rotator interval, or the biceps tendon[10,23]. Additionally, many subscapularis lesions are partial lesions relegated to the superior portion of the subscapularis with the inferior portion remaining intact[13].

Instability of the biceps tendon can result from tears of the subscapularis. Instability can occur as subluxation, a transitory or partial loss of contact between the biceps tendon and the bicipital groove, or dislocation, fixed or complete loss of contact between the biceps tendon and the bicipital groove[24]. With subscapularis tears, biceps subluxation occurs in a medial direction via disruption or distension of the ligamentous pulley resulting in fraying of the medial aspect of the biceps tendon. Dislocation of the biceps tendon can occur with the tendon resting on the lesser tuberosity (partial tear of the subscapularis), the tendon dislocated intra-articularly (complete rupture of the subscapularis), or with the tendon dislocated extra-articularly and resting on the anterior surface of the subscapularis (subscapularis intact, disruption of the rotator interval). When the tendon is resting on the lesser tuberosity, mechanical friction on the tendon will evolve to spontaneous rupture.

With the latter two types of dislocation, absence of mechanical friction prevents spontaneous rupture.

Clinical Features

Most patients with a subscapularis tear will recall a traumatic episode initiating their shoulder problem. The inciting trauma may be violent and involve forced external rotation or forced extension of a partially abducted arm[2]. Older patients may have had an anterior glenohumeral dislocation. A certain subset of patients will recall no traumatic episode and probably have a subscapularis tear that is degenerative in origin much like degenerative tears involving the posterior superior rotator cuff[13].

A variety of findings on physical examination have been reported in patients with complete subscapularis disruption. Many of these findings occur secondary not only to the subscapularis lesion but also to concomitant pathology occurring in the rotator interval, biceps tendon, and/or posterior superior rotator cuff. Physical findings classically occurring secondary to complete subscapularis disruption include increased passive external rotation with the arm at the side, decreased internal rotation strength, a positive lift-off test, and a positive belly-press test[2,6,7,20]. The lift-off test is positive when the patient cannot lift his hand off of his back. The belly-press test is positive when the patient is required to flex his wrist and extend his arm to exert force on his lower abdomen with the affected upper extremity. Partial tears of the subscapularis are more difficult to diagnose and may present with isolated weakness in internal rotation.

Radiographic Findings

Plain radiography is usually normal in patients with a subscapularis disruption[16], although avulsions of the lesser tuberosity have been rarely reported[11,14]. Arthrography may reveal a biceps dislocation highly suggestive of a subscapularis tear. A normal arthrogram however does not rule out a subscapularis tear.

Computed tomographic arthrography and magnetic resonance imaging are the secondary imaging studies of choice in evaluation of the subscapularis[1,17]. Either of these modalities will readily identify a complete subscapularis disruption. A partial subscapularis tear involving the superior portion of the tendon is more difficult to identify. In this scenario, the presence of extravasated contrast medial to the biceps sheath on computed tomographic arthrography is a reliable indicator of subscapularis disruption. These partial lesions may not be apparent on magnetic resonance imaging, however, magnetic resonance arthrography has been successful at identifying such lesions[19].

In addition to evaluating of the subscapularis tendon on secondary imaging studies, the status of the subscapularis musculature should be assessed.

Fatty degeneration of the rotator cuff musculature has been found to be a poor prognosticator for tendon repair. Since this could have clinical implications on the type of treatment selected (repair versus tendon transfer), fatty degeneration of the subscapularis musculature should be assessed prior to considering operative intervention[8]. Fatty degeneration of the rotator cuff musculature is graded according to the method of Goutallier, with grade 0 showing no fat within the muscle belly, grade I showing minimal fatty streaking, grade II showing moderate fatty infiltration but with more muscle than fat present, grade III showing that over half of the volume of the muscle belly has been replaced with fat, and grade IV showing that the entire muscle belly has been replaced by fat[9]. Fatty degeneration is traditionally graded on computed tomography but a similar staging system has been adopted for magnetic resonance imaging[5].

Treatment

The decision of whether or not to surgically repair a subscapularis tear is based on multifactorial criteria. First, the patient must be appropriately motivated to commit to extensive rehabilitation following surgery.

Older patients who lack this motivation may be better treated with arthroscopic debridement with biceps tenotomy[10]. Second, the presence of a concomitant irreparable posterosuperior rotator cuff tear may contraindicate repair. Third, fatty degeneration of the subscapularis musculature of grade III or higher may contraindicate repair[8]. Fourth, fixed anterior subluxation of the humeral head contraindicates repair[15,18]. Finally, any preoperative shoulder stiffness should be addressed with preoperative physical therapy to restore passive mobility prior to performing repair. In the event that the subscapularis is irreparable or has a high

grade of fatty degeneration, pectoralis major transfer can be considered in young motivated patients[20].

Operative repair can be performed using one of three surgical approaches. An all arthroscopic repair can be employed for partial or no retracted tears. An anterior deltoid splitting rotator cuff approach can be utilized for most tears of the subscapularis[4], while a deltopectoral approach may be more suited for retracted tears of the subscapularis[7]. When repairing the subscapularis tendon, the superior aspect of the tendon must be identified to insure that it is reinserted. For retracted tears, it may be necessary to mobilize the subscapularis tendon via transection of the coracohumeral ligament, middle glenohumeral ligament, and/or the inferior glenohumeral ligament. Z-lengthening of the subscapularis tendon is avoided secondary to the thin nature of the tendon. After proper mobilization, tendon reinsertion is accomplished with suture anchors or metallic staples.

In cases of irreparable tears in young motivated patients that have failed a reasonable course of nonoperative treatment, a pectoralis major transfer can be performed using the subcoracoid technique described by Resch et al [20]. Whenever performing open surgery for subscapularis tears, the biceps is systematically tenodesed using an interference screw technique[3].

Postoperative rehabilitation is initiated on postoperative day one with passive mobility exercises. External rotation is limited during the first six postoperative weeks based on how much passive external rotation is possible intraoperatively following repair. Active mobility is allowed starting six weeks postoperative and full return to sports is anticipated six months postoperative.

Results

Results of arthroscopic debridement with biceps tenotomy in appropriately selected patients have been very good. In 11 patients with minimum two year follow-up, the Constant score improved from 48 points to 80 points.

Similarly, results of open repair in properly selected patients have been good. In 84 patients with minimum two year follow-up, the Constant score improved from 55 points to 80 points. In patients undergoing repair, concomitant biceps surgery (tenotomy or tenodesis) improved the results independent of the preoperative condition of the biceps tendon. In patients undergoing pectoral is major transfer for irreparable subscapularis tears, Resch et al. reported improvement in the Constant score from 23 points preoperatively to 54 points postoperatively[20].

REFERENCES

1. Bernageau J, Goutallier D. Isolated lesions of the subscapularis tendon and internal malpositions of the biceps tendon: a propos of 45 cases. Journal de Radiologie 1997;78:1255-1263.
2. Deutsch A, Altchek DW, Veltri DM, et al. Traumatic tears of the subscapularis tendon: clinical diagnosis, magnetic resonance imaging findings, and operative treatment. Am J Sports Med 1997;25:13-22.
3. Edwards TB, Walch G. Biceps tenodesis: indications and techniques. Operative Techniques Sports Medicine. 2002;10:99-104.
4. Edwards TB, Walch G. Repair of tears of the subscapularis tendon. Operative Techniques in Sports Medicine. 2002;10:86-92
5. Fuchs B, Weishaupt D, Zanetti M, et al. Fatty degeneration of the muscles of the rotator cuff: assessment by computed tomography versus magnetic resonance imaging. J Shoulder Elbow Surg 1999;8:599-605.
6. Gerber C, Krushell RJ. Isolated rupture of the subscapularis muscle: clinical features in 16 cases. J Bone Joint Surg 1991;73-B:389-394.
7. Gerber C, Hersche O, Farron A. Isolated rupture of the subscapularis tendon. J Bone Joint Surg 1996;78-A:1015-1023.
8. Goutallier D, Postel JM, Lavau L, et al. Influence de la dégénérescence graisseuse des muscles supra-épineux et infra-épineux sur le pronostic des réparations chirurgicales de la coiffe des rotateurs. Revue Chirurgicale Orthopédique 1999;85:668-676.
9. Goutallier D, Postel JM, Bernageau J, et al. Fatty muscle degeneration in cuff ruptures: pre- and postoperative evaluation by CT scan. Clin Orthop 1994;304:78-83.
10. Kempf JF, Gleyze P, Bonnomet F, et al. A multicenter study of 210 rotator cuff tears treated by arthroscopic acromioplasty. Arthroscopy 1999;15:56-66.
11. McAuliffe TB, Dowd GS. Avulsion of the subscapularis tendon: a case report. J Bone Joint Surg 1987;69-A:1454-1455
12. Neviaser RJ, Neviaser TJ, Neviaser JS. Concurrent rupture of the rotator cuff and anterior dislocation of the shoulder in the older patient. J Bone Joint Surg 1988;70-A:1308-1311.
13. Nove-Josserand L, Levigne C, Noël E, et al. Les lésions isolées du sous scapulaire: a propos de 21 cas. Revue Chirurgicale Orthopédique 1994;80:595-601.
14. Nove-Josserand L, Walch G. Les fractures du trochin chez l'adulte: diagnostic et traitement à propos de 17 cas. J Traumatol. Sport 1995;12:213-217.
15. Nove-Josserand L, Boulahia A, Levigne C, Noel E, Walch G. Coraco-humeral space and rotator cuff tears. Revue Chirurgicale Orthopédique 1999;85:677-683.
16. Nove-Josserand L, Levigne C, Noel E, Walch G. Factors influencing the acromio-humeral height. Revue Chirurgicale Orthopédique 1996;82:379-385.
17. Patten RM. Tears of the anterior portion of the rotator cuff (the subscapularis tendon) : MR imaging findings. Am J Roentgenology 162:351-354, 1994
18. Pisan M, Gerber C. Repair of the subscapularis. Tech Shoulder Elbow Surg 2000;1:146-153.
19. Pfirrmann CW, Zanetti M, Weishaupt D, et al. Subscapularis tendon tears: detection and grading at MR arthrography. Radiology 1999;213:709-714.
20. Resch H, Povacz P, Ritter E, et al. Transfer of the pectoralis major muscle for the treatment of irreparable rupture of the subscapularis tendon. J Bone Joint Surg 2000;82-A:372-382
21. Sakurai G, Ozaki J, Tomita Y, et al. Incomplete tears of the subscapularis tendon associated with tears of the supraspinatus tendon: cadaveric and clinical studies. J Shoulder Elbow Surg 1998;7:510-515.
22. Walch G, Marechal E, Maupas J, et al. The surgical treatment of ruptures of the rotator cuff of the shoulder: prognostic factors. Revue Chirurgicale Orthopédique 1992,78:379-388.
23. Walch G, Nove-Josserand L, Levigne C, et al. Tears of the supraspinatus tendon associated with "hidden" lesions of the rotator interval. J Shoulder Elbow Surg 1994;3:353-360.
24. Walch G, Nove-Josserand L, Boileau P, et al. Subluxations and dislocations of the tendon of the long head of the biceps. J Shoulder Elbow Surgery 1998;7:100-108.

◆ COMPLEX AND REVISION PROBLEMS IN SHOULDER ARTHROPLASTY (BB)

Moderator: David M. Dines, MD, Great Neck, NY (c – Biomet Inc)

With the increasing popularity of shoulder arthroplasty, more complex primary arthroplasties, revision arthroplasties, and even salvage procedures can be expected. The purpose of this symposium is to present current concepts in dealing with soft tissue, bone loss, or deformities in those primary cases indicated for arthroplasty. In addition, current ideas regarding indications, diagnosis and surgical options in revision arthroplasty will be presented.

I. Arthroplasty for Malunion of the Proximal Humerus
David M. Dines, MD, Great Neck, NY (c – Biomet Inc)

II. Treatment of Bone Loss in Primary and Failed Shoulder Arthroplasty
Joseph P. Iannotti, MD, Cleveland, OH (a, b, c, e – DePuy, Johnson & Johnson)

III. Treatment of Soft Tissue Insufficiency in Shoulder Arthroplasty
Evan L. Flatow, MD, New York, NY (a, b, c – Zimmer)

IV. The Use of a Reverse Prosthesis for Cuff Tear Arthropathy (Are we there yet)? Indications, Technique and Results
Christian Gerber, MD, Balgrist, Zurich (c – Centerpulse)

V. Revision Surgery for Instability after Shoulder Arthroplasty
Jon J. P. Warner, MD, Boston, MA (c – Centerpulse)

VI. Glenoid Revision for Loosening or Primary Glenoid Arthrosis after Hemiarthroplasty
Robert H. Cofield, MD, Rochester, MN (c – Smith & Nephew)

ARTHROPLASTY FOR CHRONIC MALUNIONS OF THE PROXIMAL HUMERUS

David Dines, MD

I. Proximal Humeral Malunions
1 .Rare
2. Seen after ORIF or Closed original treatment
3. Degree of original displacement determines complexity of the deformity
4. Complexity determines difficulty of arthroplasty

II. Shoulder Arthroplasty is indicated in malunions of the proximal humerus, which affect the humeral head anatomy, i.e. AVN or joint incongruity
1. 3 or 4 part facture +/- dislocations
2. Humeral head fracture splits- impression fractures
3. Chronic impression fracture dislocation

III.Complex Malunions
1. Bone and soft tissue deformity/ contracture
2. Failed hardware
3. AVN
4. Traumatic arthritis

IV. Evaluation
1. History- previous treatment, complaint, medical history patient compliance
2. Physical Exam- ROM, strength, deformity, NV status
3. Lab studies- r/o infection, metabolic deficiency
4. Imaging
   a. Plain x-rays (trauma series)
   b. CTT
   c. MRI- soft tissue
   d. Scanograms – humeral length
   e. Aspiration arthrogram- r/o infection

V. Classifcation of Malunion
1. Neer Classification System of original fracture
2. Berdjiklian Classification- bone and soft tissue abnormalities

VI. Critical decision making in arthroplasty for malunion
1. Assess humeral height and version
2. Assess tuberosity deformity
3. Assess soft tissue contracture vs tuberosity bone deformity
   —Bone deformity as primary cause of restricted ROM=Tuberosity Osteotomy

VII. Tuberosity Osteotomy- technical considerations
1. Adequate bone and soft tissue releases
2. Decorticate
3. Proper reconstruction around arthroplasty

VIII. Arthroplasty for Malunion
1. Proper positioning, anesthesia, and exposure
2. Release contractures and or tuberosity osteotomy
   >20 degree ER/120 degree FF‡ soft tissue release and tendon length.
   >20 degree ER/ 90 degree FF‡ soft +/- tuberosity osteotomy
   <20 degree ER/90 degree FF ‡ tuberosity osteotomy
3. Humeral Head resection (in cases where tuberosities are maintained)
   Proper cutting guide in appropriate version (20-40 degrees retroversion)
4. Glenoid assessment and replacement when indicated
5. Tuberosity Osteotomy (when indicated)
6. Humeral Component placement
   Proper height and version
7. Humeral Head Component Sizing and Placement
   50% ant/post and inferior override
   >90degree ABD scapula stabilized
8. Tuberosity Reconstruction

IX. Tuberosity Reconstruction
1. Place sutures during exposure
2. Greater Tuberosity place around component at proper height overlap shaft
   a. Suture through medial hole implant + longitudinal suture shaft
   b. Place below humeral head 0.5 cm
   c. Bone graft
3. Lesser Tuberosity fixed
   a. Tuberosity sutures thru fin
   b. Figure of 8 suture
   c. Bone graft
   d. Assess stability of fixation for rehab

X. Rehabilitation
1. Assess stability of tuberosity fixation and ROM at surgery
2. PROM within limits of repair (.> 6wwks tuberosity healed)
3. AAROM
4. AROM and strength – tuberosities healed
5. Continued improvement for more than 1 year

XI. Resultsof Arthroplasty for Malunion
1. Dines etal. – 20 patients
   12/20 osteotomy 90% good to excellent
   < 70 yrs + no osteotomy best results
2. Norris – 23 pts
   Improved ROM and function
   Results inferior to acute reconstruction

REFERENCES

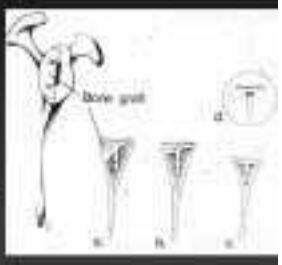
1. Berdjiklian etal,Treatment of Proximal Humeral Fractures with Prosthesis. ICL 47:135-140,1998
2. Berdjikilian etal,Operative Treatment of Malunion for fractures of the Proximal Humerus. JBJS (A) 80:1484-97,'98
3. Dines etal, Posttraumatic Changes of the Proximal Humerus..Treatment with Modular Arthroplasty. JSES 2:11-21,"93
4. Norris,etal, Late Prosthetic Shoulder Arthroplasty for Displaced Proximal Humerus Freactures. JSES 4:271-280,"95

Glenoid Bone Loss in Total Shoulder Arthroplasty

Joseph P. Iannotti MD, PhD
Chairman, Department of Orthopaedic Surgery
The Cleveland Clinic Foundation
Professor, CCF Lerner College of Medicine CWRU

Management Options: Glenoid Bone Loss

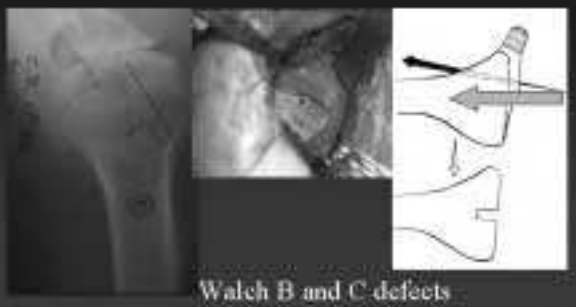
- Reaming (C)
- Bone grafts (A)
  - Cancellous for central contained defects
  - Corticocancellous structural for uncontained defects
- Custom components; wedges (B,D)



Causes Of Bone Loss: Glenoid

- CTA: Superior and CA arch
- RA: Superior, medial, CA arch
- OA, PCA: Posterior
- Chronic Dislocation: Anterior or posterior
- Failed Arthroplasty
- Infection

Glenoid Bone Erosion Up to 1 Centimeter



Walch B and C defects
Uncontained rim loss, vault intact

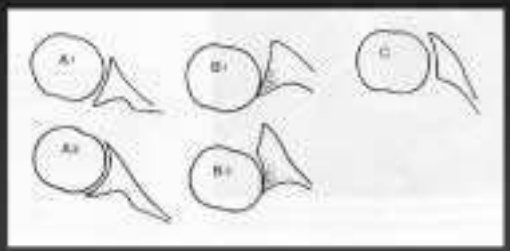
Glenoid Bone Loss: Classification

- Contained
  - Rim and wall must be intact
  - Glenoid fossa bone may be intact
  - Cancellous bone graft (non-structural)
- Uncontained
  - Rim and or wall deficient
  - Structural bone graft required

Methods and Materials

- This view through the rotator cuff interval demonstrates the position of a 0° version neck or anatomic neck cut

Glenoid Bone Loss in OA: Walch

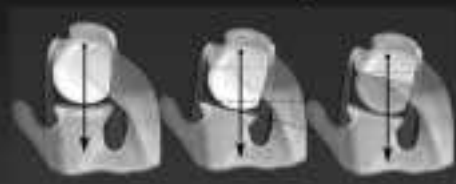


Methods and Materials

- The humeral version was changed by changing the modular neck sections through the rotator cuff interval

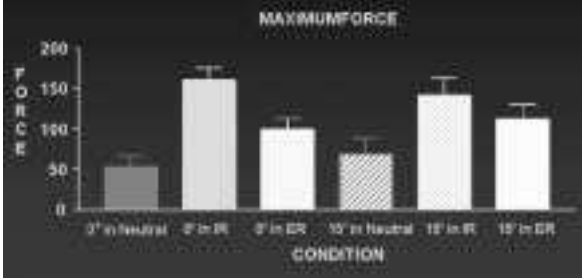
Specimen Testing

Joint Reaction Force Moves Posteriorly



- The rotator cuff centers the head within the glenoid
- The insertion and origins of the the cuff do not change with humeral version
- The head centers in the glenoid but is more posterior

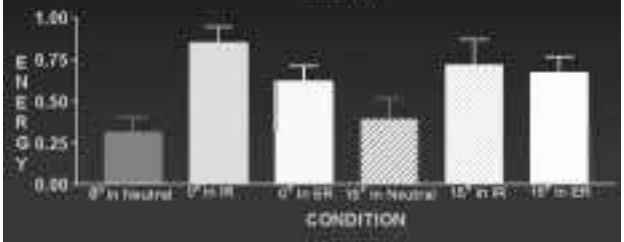
Results



Conclusions

- Anteverting the humeral component to compensate for a retroverted glenoid does not improve the posterior stability.
- Restoring a neutral glenoid surface is preferred with reaming, bone graft or augmented glenoid component.

Results

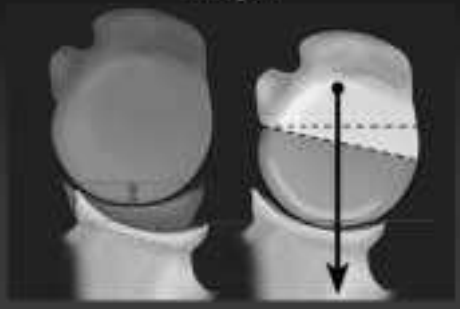


Hemiarthroplasty for Osteoarthritis

- Cofield, Frankle, Zuckerman
  - 35 cases, average 9.7 year follow-up
  - 51% had unsatisfactory rating at follow-up due to pain
  - 26% had conversion to TSA with excellent pain relief in all cases
  - Early good results with hemi for OA deteriorate over time

Seminars in Arthroplasty 1995

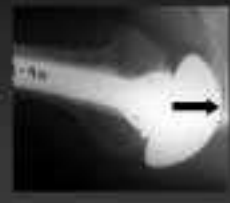
Decrease in Posterior Wall Height



Hemi. and Glenoid Erosion

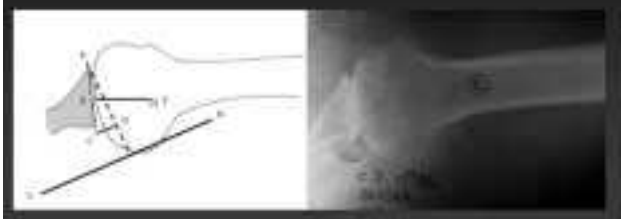
Levine, Dunaovic, Glisson, Pollack, Flatow, Biglani

- 31 patients with osteoarthritis having hemi.
- Eccentric glenoid wear
  - 37% failure rate
- Concentric glenoid wear
  - 14% failure rate
- Recommended: TSA
  - Data??



JSES 6:449-54, 1997

Posterior Glenoid Bone Loss: It's Effect on Outcome and the Use of a Glenoid Component



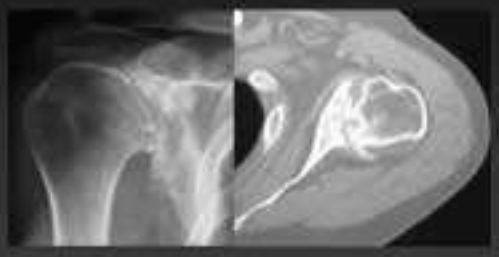
Avoid Cement Wedges

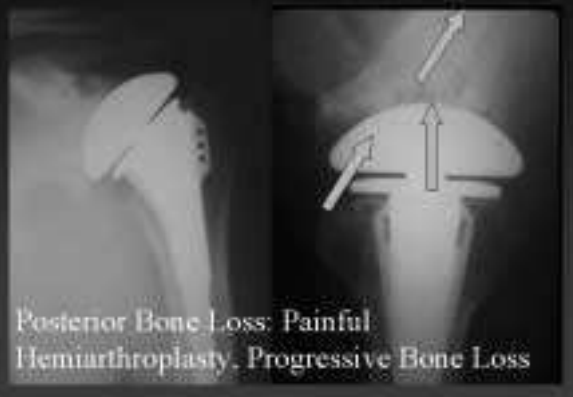
- Cement fragmentation
- Prosthetic loosening

Glenoid Erosion

- 27 Patients with moderate or severe glenoid erosion had better function with TSA than with hemiarthroplasty
  - Active forward flexion 140 vs. 117 degrees (p= 0.07)
  - Active external rotation 47 vs. 27 degrees (p = 0.001)
- Poor prognostic variable
- Recommend TSA

Glenoid Bone Graft; Structural Graft



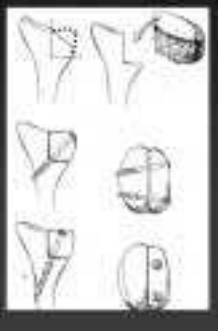


Posterior Bone Loss: Painful Hemiarthroplasty, Progressive Bone Loss

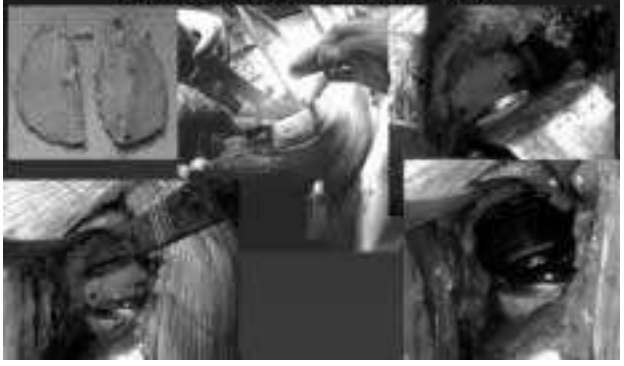
Posterior Subluxation: Clinical Findings

Severe Glenoid Erosion

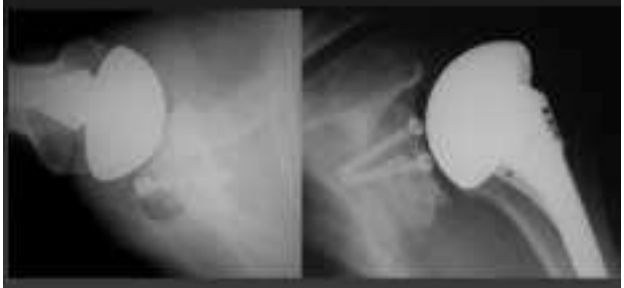
- Greater than 1 cm.
- Bone graft
  - Humeral head
  - Iliac crest graft
- Screw fixation



Bone Graft: Humeral Head



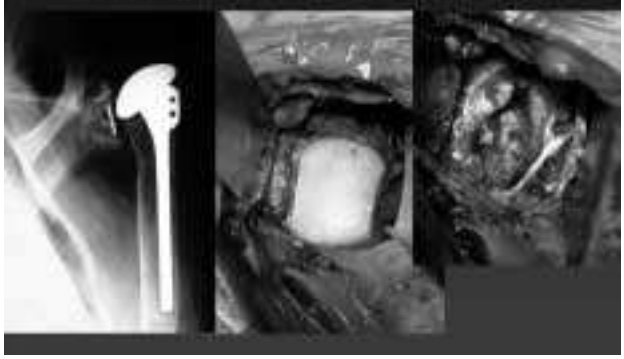
Post-op X-rays



Contained Glenoid Bone Loss
Rim, Vault and Subchondral Bone Intact

Clinical Result Bilat TSA

Massive- Contained Bone Loss



Results: Glenoid Bone Loss: Bone Grafts

- Neer and Morrison: JBJS 70 A, 1154
  - 17 patients, 16 Excellent, 1 Satisfactory, 4.4 year f/u
  - Two broken screws and one had worn through to contact the humeral head
  - No component loosening or graft migration

Uncontained Massive Bone Loss
Rim and or Wall Not Intact

Management Options: Contained Glenoid Bone Loss: Revision TSA

- Cancellous bone graft
- Interposition soft tissue arthroplasty:
  - Capsule (Burkhead)
  - IT band (Burkhead)
  - Achilles tendon,
  - Lateral meniscus (Yamaguchi)
  - Restore patch

Uncontained Massive Bone Loss
Rim and or Wall Not Intact


Uncontained Massive Bone Loss
Rim and or Wall Not Intact


Summary: Glenoid Bone Loss
• Contained defects
• Cancellous chips
• Hemi +/- biologic resurfacing
• Uncontained defects
• Ream high side with glenoid component
• Structural bone graft +/- glenoid component
• Augmented glenoid


Uncontained Massive Bone Loss
Rim and or Wall Not Intact


Thank You


• 8 month follow-up
• No Pain

TREATMENT OF SOFT TISSUE INSUFFICIENCY IN SHOULDER ARTHROPLASTY

Evan L. Flatow, MD

A. TECHNIQUES

I Implant options
- Modularity
- Various curvatures, thicknesses
- Variable offset
- Variable inclination
- Anatomical heads (3 dimensions)
- Precision instruments

II Capsule options
- Plication sutures
- Releases
- Autografts (fascia lata)
- Allografts (Achilles)
- Xenografts (porcine submucosa, bovine dermis)

III Muscle options
- Rotator cuff repair
- Subscapularis repair
- Latissmus/teres major transfer for infraspinatus
- Pec transfer for subscap

B. PROBLEMS

I Posterior subluxation
- Common in GH OA (worse with glenoid retroversion)
- Often severe in capsulorraphy arthritis
- Worst in old unreduced posterior dislocations
- Treatment: anterior release
  - correct glenoid retroversion
  - rarely: posterior capsular plication, anchors
  - adjust rehab -gunslinger brace, elevation in ER

II Anterior subluxation
- Unreduced anterior dislocations
- Subscapularis loss
- Glenoid fractures
- Treatment: restore bone/version
  - capsule reconstruction /graft
  - subscap repair or reconstruction

III Cuff deficiency
- Special issues
  1. Cuff deficient: undersize head (and RCR) vs.oversize vs. "just right"
  2. ?Role for bipolars
  3. ?Reverse prosthesis for cuff loss arthritis
- Indications: PAIN
- Technique (Cuff Loss)
  1. Interscalene block regional anaesthesia
  2. Skin incision
  3. Delto-pectoral interval
  4. Preserve deltoid origin and insertion
  5. Preserve coracoid
  6. Avoid axillary/musculocutaneous nerves
  7. Cement
     - -osteoporotic
     - -wide canals
     - -abnormal bone
  8. "New Fulcrum"
     - -preserve coracoacromial arch (esp. CA lig)
     - -replace head "in situ" (new superiorly translated articulation)
     - -reconstruct anterior/posterior cuff as possible (control rotation)
  9. Omit glenoid
  10. Rehabilitation
      - -early passive motion
      - -strengthening later

Results: Arthritis with Cuff Deficiency

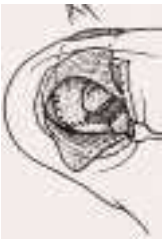
Current experience (2)
- -30 cases: 19 HHR, 11 TSR
- -pain improved in all but one
- -only 40% with active elevation > 90o
- -80% with improved ADL's
- -no significant difference in pain relief TSR vs. HHR
- -advantages of omitting glenoid
  1. less lateralization of humerus (easier cuff repair)
  2. decreased blood loss
  3. decreased OR time
  4. avoid "rocking horse glenoid" (1)
  5. avoid disturbing longstanding altered mechanics ("new fulcrum")

Newer options

1. Reverse prosthesis

2. Tendon transfers

-(lat., t. major, pec under straps)



C. PREVENTING COMPLICATIONS

(A) Correct Diagnosis
1. define type of arthritis

2. evaluate cuff (?MRI)
3. assess glenoid vault
4. r/o infection
5. r/o nerve injuries

(B) Proper preparation
1. have variety of components
2. Fx equipment
3. image prn
4. bone grafts available (rare)

(C) Intraoperative technique
1. antibiotics
2. clean room
3. scalene anaesthesia preferred (no general)
4. avoid undue traction
5. be gentle with soft tissues
6. adequate releases
7. careful reconstruction (esp. subscap)
8. check XR

(D) Appropriate rehabilitation
1. limit ER if subscap tight
2. supervise therapy

(E) Careful follow-up
1. follow wound
2. assess nerves
3. check XR

4. slow return to heavy activities

D. TREATING COMPLICATIONS AND REVISION SURGERY

(A) Evaluation
1. History -is problem pain or functional loss?
2. Prior op note
3. Any history drainage, infection etc???
4. Physical Exam
-ROM, active lag, nerves
5. X-rays
-lucent lines/migration, position

(B) Infection
1. Debridement alone: early Rx, sensitive bug
2. HWR/repeated clean-outs
3. Ab-impreg. Cement spacer
4. Reimplant vs. resection arthroplasty
-depends on patient preference

(C) Instability
1. Correct version
2. Repair cuff
3. Achilles allograft (capsule)
4. Adjusted rehab/brace
5. Fusion difficult and usu. not indicated

(D) Loosening
1. Revise stem
2. Revise glenoid vs. remove only
3. Bone graft options: allograft, iliac, local (e.g. coracoid)

(E) Cuff deficiency/tuberosity pull-off
1. Mobilize and repair if possible (posterior incision, deltoid off, etc. as options)
2. Latissimus/teres major transfer an option

(F) Fractures
1. Non-op: brace, spica, sling, etc.
2. Primary long-stem revision (esp. if already loose or headed for revision)
3. ORIF around stem (unicort. plate, wire, etc.)

(G) Stiffness
1. Arthroscopic/open release
2. Aggressive rehab (?scalene catheter)

(H) MOST CASES COMPLEX: MULTIPLE FACTORS (be prepared)
1. Revision instruments, cement tools, long stems
2. ?Allograft bone available
3. High speed drills
4. Orig system (in case must leave stem)
5. Nerve stimulator/bipolar cautery

THE ROLE OF THE INVERSE DELTA III PROSTHESIS IN COMPLEX PROSTHETIC REVISION

Christian Gerber, MD

THE INVERSE DELTA III PROSTHESIS

Revision shoulder arthroplasty is successful if components have to be changed in the presence of good bone stock and functional rotator cuff [1-3]. If the rotator cuff is irreparably torn, the clinical and structural situation is comparable to an irreparable rotator cuff tear with severe shoulder dysfunction. Osteoarthritis associated with massive rotator cuff tears can be treated with hemiarthroplasty[4] and soft tissue balancing or with an inverse prosthesis as described above[5]. Current experience suggests that the functional results of an inverse design as that of the delta prosthesis are substantially superior to those of hemiarthroplasty[6] and favorable short to midterm results in osteoarthritis associated with large cuff tears[5,7-11] or even in rheumatoid arthritis[12] have led to believe that prosthetic revisions at least in the presence of severe dysfunction of the cuff may be a good indication for the inverse prosthesis and the very first reports are encouraging[13].

REVISION ARTHROPLASTY USING THE DELTA III PROSTHESIS

The cementfree fixation of the so called métaglène or baseplate of the glenoid prosthetic component requires a solid bone stock of the glenoid (neck). Revision after hemiarthroplasty is almost always possible, even marked glenoid erosion allows for implantation of the métagène. Revision of a cemented glenoid component may not be possible without a marked risk of loosening of the métaglène which does not find solid anchorage in the deficient, non – vascularized bone.

Revision is always planned on a CT Scan of the shoulder to ascertain that a resonable anchorage of the glenoid prosthesis is possible.

The humeral component can be implanted as a non – cemented or as a cemented version. The author prefers the cemented version because of absence of rotational stability with the current design of the prosthesis and because of subsidence which has been observed and led to recurrent prosthetic instability. Removal of the humeral prosthesis and implantation of the delta prosthesis has no particularities as comparted to the implantation of an anatomical revision prosthesis except for the version, which should be between 0 and 10 degrees of retroversion of the humeral component.

RESULTS OF REVISION

We have performed 21 revision procedures. At follow – up of at least 2 years, one patient had died, two prostheses were removed because of recurrent infection, two very old patients were unable to attend a follow up examination, two further patients refused further follow- up examination.

Overall patient satisfaction was much higher than the objectoive results would lead to expect mainly because of the very poor preoperative state. Deteriaration with time has not yet been observed but remain clearly possible.

REFERENCES

1. Bigliani, L. U.; Connor, P. M.; Levine, W. N.; Ejnisman, B.; Arroyo, J. S.; Pollock, R. G.; and Flatow, E. L.: The Management of Failed Shoulder Arthoplasties. Closed Meeting of the ASES, October 19th, Amelia Island: 43, 1996.
2. Sperling, J. W., and Cofield, R. H.: Revision Total Shoulder Arthroplasty for the Treatment of Glenoid Arthrosis. J. Bone Joint Surg., 80-A(6): 860-867, 1998.
3. Petersen, S. A., and Hawkins, R. J.: Revision of failed total shoulder arthroplasty. Orthop Clin North Am, 29(3): 519-33., 1998.
4. Williams, G. R., Jr., and Rockwood, C. A., Jr.: Hemiarthroplasty in rotator cuff-deficient shoulders. J Shoulder Elbow Surg, 5(5): 362-7., 1996.
5. Sirveaux, F.; Favard, L.; Oudet, D.; Huguet, D.; and Lautmann, S.: Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive and non repairable cuff rupture. In 2000 Shoulder Prostheses. Two to ten year follow - up, pp. 247-252. Edited by Walch, G.; Boileau, P.; and Mole, D., 247-252, Paris, Sauramps Medical, 2001.
6. Favard, L.; Lautmann, S.; Sirveaux, F.; Oudet, D.; Y., K.; and Huguet, D.: Hemiarthroplasty versus reverse arthroplasty in the treatment of osteoarthritis with massive rotator cuff tear. In 2000 Shoulder Prostheses. Two to ten year follow - up, pp. 261 - 268. Edited by Walch, G.; Boileau, P.; and Mole, D., 261 - 268, Paris, Sauramps Medical, 2001.
7. Baulot, E.; Chabernaud, D.; and Grammont, P. M.: Résultats de la prothèse inversée de Grammont pour omarthroses associées à de grandes déstructions de la coiffe. A propos de 16 cas [Results of Grammont's inverted prosthesis in omarthritis associated with major cuff destruction. Apropos of 16 cases]. Acta Orthop Belg, 61 Suppl 1: 112-9, 1995.
8. Boulahia, A.; Edwards, T. B.; Walch, G.; and Baratta, R. V.: Early results of a reverse design prosthesis in the treatment of arthritis of the shoulder in elderly patients with a large rotator cuff tear. Orthopedics, 25(2): 129-33, 2002.
9. Grammont, P. M., and Baulot, E.: Delta shoulder prosthesis for rotator cuff rupture. Orthopedics., 16(1): 65-68, 1993.
10. Jacobs, R.; Debeer, P.; and De Smet, L.: Treatment of rotator cuff arthropathy with a reversed Delta shoulder prosthesis. Acta Orthop Belg, 67(4): 344-7, 2001.
11. Renaud, P.; Wahab, H.; Bontoux, L.; Dauty, M.; Richard, I.; and Bregeon, C.: Prothèse totale inversée de l'épaule et insuffisance de la coiffe des rotateurs: évaluation et approche de paramètres anatomiques prédictifs d'une bonne fonctionnalité à propos de 21 cas. [Total inverted shoulder prosthesis and rotator cuff insufficiency: evaluation and determination of anatomical parameters predictive of good functional outcome in 21 shoulders]. Ann Readapt Med Phys, 44(5): 273-80, 2001.
12. Rittmeister, M., and Kerschbaumer, F.: Grammont reverse total shoulder arthroplasty in patients with rheumatoid arthritis and nonreconstructible rotator cuff lesions. J Shoulder Elbow Surg, 10(1): 17-22, 2001.
13. De Wilde, L.; Mombert, M.; Van Petegem, P.; and Verdonk, R.: Revision of shoulder replacement with a reversed shoulder prosthesis (Delta III): report of five cases. Acta Orthop. Belg., 67(4): 348-53, 2001.

INSTABILITY OF SHOULDER ARTHROPLASTY

Jon J. P. Warner, MD

DEFINING THE PROBLEM: GH Instability is the most common complication after shoulder arthroplasty. It is closely correlated to glenoid component loosening and rotator cuff tears.

CONTROL OF STABILITY IN NORMAL SHOULDER:
- Static Elements (Ligament, Labrum, articular cartilage and joint congruity)
- Dynamic Elements (Coordinated scapulothoracic-glenohumeral control, rotator cuff muscles, long head biceps, adhesion-cohesion between joint surfaces, negative intra-articular pressure)

THE ARTHRITIC SHOULDER: PATHOANATOMY PREDISPOSING TO INSTABILITY:
- Eccentric glenoid erosion (usually posterior) with acquired retroversion.
- Soft-tissue injury from prior surgery
- Soft-tissue contractures

CONTROL OF STABILITY IN THE TSR OR HEMIARTHROPLASTY:
- Version of components
- Soft-tissue integrity (especially subscapularis tendon)
- Height of humeral component
- Correction of glenoid erosion

ANTERIOR INSTABILITY:
- Always consider subscapularis tendon repair disruption (poor tissue; poor repair; aggressive early rehabilitation)
- Consider excessive antiversion of humeral component
- Consider oversized humeral head (associated with subscapularis rupture)
- Consider undersized humeral head placed too low with loss of myofascial sleeve tension.
- Consider antiversion of glenoid component or glenoid surface (in hemi) which is usually due to prior injury or surgery.

POSTERIOR INSTABILITY:
- Consider uncorrected posterior glenoid erosion and retroversion.
- Consider excessive retroversion of humeral component

SUPERIOR INSTABILITY:
- Consider loss of rotator cuff (massive tear) with loss of coracoacromial arch usually due to prior surgery.

INFERIOR INSTABILITY:
- Consider low placement of humeral component and undersized humeral head (usually in case of fracture reconstruction)
- Consider week deltoid (i.e. axillary nerve palsy with loss of deltoid tone)

EVALUATION:
- Proper radiographs with true A-P and axillary with comparison views of contralateral side as needed.
- C.T. scan to demonstrate version of glenoid and determine need for bone grafting. Arthrogram shows subscapularis integrity.
- Aspiration arthrogram to rule out associated infection.

TREATMENT OPTIONS:
- Increasing humeral antiversion to compensate for glenoid retroversion that is uncorrected, DOES NOT WORK!!!
- Anatomic solution to defined problem is key.
- Correction of posterior glenoid erosion and severe retroversion with structural bone graft with/without glenoid component.
- Correction of humeral postion (height and version)
- Subscapularis reconstruction and/or pectoralis tendon transfer
- Occasionally static grafts such as Achilles allograft tendon.
- Delta Prosthesis (reverse ball-in-socket) for severe cuff insufficiency (Europe only currently).

REFERENCES:

1. Gerber A, Ghalambor, N, Warner JJP: Instability of Shoulder Arthroplasty. Balancing Mobility and Stability. Orthop. Clin N. Amer. 32(4):661-670, 2001.
2. Harryman, DT, Sildes JA, Harris SL, et al: The effect of articular conformity and the size of the humeral head on component laxity and motion after glenoumeral arthroplasty: A study in cadavera. J Bone Joint Surg. 77A:555-563, 1995.
3. Moekel BH, Altchek DW, Warren RF, et al: Instability of the shoulder after arthroplasty. J Bone Joint Surg. 75A:492-497, 1993.
4. Wirth MA, Rockwood CA Jr.: Complications of total shoulder replacement arthroplasty. J Bone Joint Surg. 78A:603-616, 1996.

GLENOID REVISION SURGERY

Robert H. Cofield, MD

Glenoid loosening is one of the three most common complications of total shoulder arthroplasty. In reviewing 16 series of total shoulder arthroplasty with 1046 shoulders, 17, or 1.6 percent, exhibited glenoid loosening. We performed long-term follow-up of our patients operated between 1975 and 1981. Survivorship was quite high overall; however, radiographic changes in these early patients were quite common, implying the potential for a substantial frequency of clinically important glenoid loosening. Glenoid loosening does overlap with the complications of rotator cuff tearing and instability. Most recently, in reviewing the shoulders performed between 1995 and 1999 at our institution, only three of 244 have required revision surgery and none for component problems, seemingly indicating that the frequency of glenoid loosening, at least clinically significant glenoid loosening, is currently reasonably uncommon.

It is important to recall that the diagnosis of glenoid loosening might not be straightforward in patients presenting with shoulder pain after arthroplasty. Radiographic imaging must be of the highest quality, and, if necessary, fluoroscopically positioned x-rays are quite useful. In loosening, the lucent line surrounding the glenoid component may be complete, but sometimes it is not. Usually the line is thicker than two millimeters through some portion of the interface. Even more commonly, there is a change in component position when comparing x-rays over time. So sequential x-rays are useful in this circumstance. One might wish to further assess the glenoid bone by narrow cut CT scanning, remembering that the amount of bone loss is always worse than it appears on plain films.

Currently, when evaluating a patient for pain and glenoid loosening seems to be the issue, one should always recall to evaluate for a low-grade infection, including a white blood cell count with differential, erythrocyte sedimentation rate, and C-reactive protein, supplementing this with aspiration and arthrography or paired Indium and bone scans as the level of suspicion dictates.

In addition to evaluating the glenoid, it is important to evaluate for other structural changes, including those associated with instability, rotator cuff tearing, or humeral component difficulties—most specifically, malposition. Also, it is important to understand whether the humeral component is modular or not. If it is modular and the component is in good position, this greatly simplifies surgery.

The technique for revision surgery is fairly standard. Usually it is possible to incorporate the old skin incision, incising a widened scar, and modifying the incision as necessary. Occasionally a lateral or transverse incision was utilized, and a new anterior incision needs to be created. There is layer by layer dissection of the scar, including the subcutaneous tissues, the subdeltoid and subacromial region, and the area beneath the conjoined tendon group. Usually, a long deltopectoral incision is used; sometimes an anteromedial approach is used, mainly to protect the anterior deltoid from difficult dissection on its undersurface or in the presence of a very frail deltoid or frail humeral shaft, neither of which will tolerate more than the mildest force during retraction.

If the external rotation with the arm at the side is greater than 30 to 40 degrees, one can generally incise the subscapularis through tendon and release the anterior shoulder capsule from the humerus. The inferior shoulder capsule is then usually released related to contractures and enhanced exposure. If there is less external rotation present than 30 degrees, consideration is given to incising the subscapularis from bone, but one must be fully aware that there is enough bone remaining on the anterior aspect of the proximal humerus to resuture the subscapularis—if this technique is used.

The humeral head is then subluxated forward, and the humeral component is assessed. Hopefully, it has correct height and version and is modular. The humeral head is then removed. A shoulder synovectomy is performed, and the loosened glenoid component is removed. By performing this synovectomy, one can then carefully define the tissue integrity. The remaining glenoid bone is then freshened using a curette and burr to clean the bone for acceptance of a bone graft or a new component. When doing these things, there are several notes of caution. First, be careful about levering on the posterior wall of the glenoid, for if that is weak or the glenoid is hollow, it may be crushed. It might be better to place the humeral retractor more inferiorly rather than straight posteriorly to prevent fracturing or crushing of the posterior wall. Second, the suprascapular vessels are in jeopardy just lateral to the spine of the glenoid notch when there has been some glenoid bone loss and central resorption. Of course, the suprascapular nerve is also in that region and must be protected. Third, the glenoid walls anteriorly and posteriorly may be quite thin. It is often useful to preserve the continuity between the anterior soft tissues and the anterior glenoid neck and the posterior soft tissues and the posterior glenoid neck to help reinforce the weakened bone.

One can then fully see and classify the bone deficiency. Sometimes there is only a minor amount of central cavitation; more often, there is significant central cavitation. There may be a segmental peripheral deficiency, but this is less common unless it is associated with large central cavitation.

A decision is then made whether or not one can place a glenoid component. This depends upon the amount of remaining bone, the age, activity, and pain sensitivity of the patient. One would, of course, tend to favor, in a marginal situation, hemiarthroplasty in the young or active patient with low pain sensitivity and tend to favor placement of a glenoid component in an older patient with less activity and more pain sensitivity. This is, however, predicated on the amount of remaining bone.

Certainly, if there is a large amount of central cavitation with our without a peripheral defect, one would usually use impaction bone grafting using corticocancellous autograft chips. This is shaped using a glenoid impactor, and with sequential placement of grafts and impacting, one can usually obtain a fairly firm surface against which to rest an appropriately sized humeral component.

If there is more glenoid bone remaining, it seems useful to reshape the surface, to fit the back of the new glenoid component, either with the appropriate reamer or burr. One can then fill any interstices with impacted bone graft and then cement glenoid component in place.

Occasionally, when there is moderate central cavitation, it seems unwise to cement a glenoid component filling essentially the whole glenoid cavity with cement and placing a keeled component in that bolus of cement. One might wish to impaction bone graft the defect and then re-prepare the glenoid and place a tissue ingrowth component that rests on native subchondral bone surface and engages the junction of the glenoid

neck with the body of the scapula using screws. One can place the component in this way without cement or with cement if the screw purchase is not absolutely firm.

Structural bone grafting is seldom necessary in this situation. Occasionally though, there is a segmental deficiency posteriorly or anteriorly. One can then take some bone from the remaining humeral neck (usually), thinning it somewhat, and then fix this to the remaining glenoid bone with two 3.5 millimeter cortical screws. Impaction bone grafting is then utilized to further secure this prior to placing the glenoid component.

Postoperatively, the rehabilitation is just slightly altered. The Phase One passive rehabilitation proceeds as usual, governed by soft tissue flexibility. Phase Two, gentle active assisted motion, stretching, and very light strengthening with isometrics, is then continued for a longer period of time, perhaps three months to allow more time for bone graft incorporation before vigorous stretching and strengthening are added.

In reviewing our patients who underwent glenoid revision surgery after total shoulder arthroplasty, 48 shoulders were identified that were followed approximately five years on average. A new glenoid component could be implanted in 30, and the glenoid component was removed and bone graft placed in the hollow glenoid in 18. There was significant pain relief with either technique. Patients were more consistently satisfied when a glenoid component could be placed. During the follow-up period, two of the 30 replaced glenoids needed to be re-revised for glenoid component loosening, and three of the 18 bone grafted glenoids needed to be revised after the bone graft healed with a new glenoid component because of pain.

Similarly, many of the things that hold true for revision of glenoid component failure hold true for revision arthroplasty for glenoid arthritis when a hemiarthroplasty alone has been performed. In understanding this problem better, we reviewed the results of 34 studies involving 581 shoulders that had been treated with a hemiarthroplasty. Thirty-three shoulders, or six percent, had required a reoperation. Of those, 21 had revisions for painful glenoid arthrosis.

Successful management of the patient who has had pain after replacement of a humeral head presents two major challenges. First, the cause of the pain must be determined using a systematic assessment of clinical, radiographic, and laboratory data. The differential diagnosis of pain after replacement of a humeral head includes low-grade infection, glenoid arthrosis, instability, impingement, tearing of the rotator cuff, nerve injury, fracture, and malposition or loosening of the humeral component. Radiographs must be of high quality. In addition to 40 degree posterior oblique radiographs with the shoulder in internal and external rotation, we obtain an axillary radiograph. We also regularly obtain an erythrocyte sedimentation rate, white blood cell count with differential, and C-reactive protein. Evaluation for infection proceeds further as outlined earlier in this presentation if it is more strongly suspected.

The exposure for placing a glenoid component is again as indicated earlier. It is important to assess preoperatively and intraoperatively the amount of bone remaining in the glenoid. If there is not enough bone to place a glenoid component (that can usually be determined preoperatively), surgery may not be possible. At the time of surgery, bone grafting might be necessary for a segmental or a small contained defect. The chief technical factor associated difficulties is the humeral component. Modular components are much easier to revise, of course. If the humeral component is malpositioned or is not modular, it may be necessary to remove the humeral component, and the difficulty of doing this depends primarily on the prosthetic design and whether or not methyl methacrylate bone cement has been used. With the prosthetic humeral head removed from a well-positioned and fixed humeral stem, placing a glenoid component proceeds as usual for a primary case, if there is not substantive bone loss.

We reviewed the outcome of our patients who underwent revision shoulder arthroplasty for the treatment of glenoid arthrosis. Eighteen shoulders were included in the study with an average follow-up of 5.5 years. The mean interval between hemiarthroplasty and total shoulder arthroplasty was 4.4 years. Thankfully, there were significant improvements in pain. Mean active abduction increased 30 degrees, and external rotation increased 26 degrees. If there was a relative failure of the operation, it was related to stiffness postoperatively that could not be fully relieved by intraoperative measures.

REFERENCES

1. Antuna, S., Sperling, J.W., Cofield, R.H.: Reimplantation of a glenoid component after component removal and allograft bone grafting: a report of three cases. J. Shoulder Elbow Surg. 11(6):637-41.
2. Antuna, S.A., Sperling, J.W., Cofield, R.H., Rowland, C.M.: Glenoid revision surgery after total shoulder arthroplasty. J. Shoulder Elbow Surg. 10(3):217-224, 2001.
3. Bonutti, P.M., Hawkins, R.J., Saddemi, S.: Arthroscopic assessment of glenoid component loosening after total shoulder arthroplasty. Arthroscopy 9(3):272-6, 1993.
4. Cofield, R.H., Daly, P.J.: Total shoulder arthroplasty with a tissue ingrowth glenoid component. J. Shoulder Elbow Surg. 1:77-85, 1992.
5. Franklin, J.L., Barret, W.P., Jackins, S.E., Matsen, F.A.: Glenoid loosening in total shoulder arthroplasty: association with rotator cuff deficiency. J. Arthroplasty 3:39-46, 1988.
6. Godeneche, A., Boileau, P., Favard, L., LeHuec, J.C., Levigne, C., Nove-Josserand, L., Walch, G., Edwards, T.B.: Prosthetic replacement in the treatment of osteoarthritis of the shoulder: early results of 268 cases. J. Shoulder Elbow Surg. 11(1):11-18, 2002.
7. Hill, J.M., Norris, T.R.: Long term resuls of bone grafting for glenoid deficiency in total shoulder arthroplasty. J. Shoulder Elbow Surg. 6:176, 1997.
8. Kelleher, I.M., Cofield, R.H., Becker, D.A., Beabout, J.W.: Fluoroscopically positioned radiographs of total shoulder arthroplasty. J Shoulder Elbow Surg 1(6):306-11, 1992.
9. Neer, C.S. II, Kirby, R.M.: Revision of humeral head and total shoulder arthroplasties. CORR 170:189-95, 1982.
10. Neer, C.S. II, Morrison, D.S.: Glenoid bone-grafting in total shoulder arthroplasty. J. Bone Joint Surg. 70A:1154-62, 1988.
11. Rodosky, M.W., Bigliani, L.U.: Surgical treatment of non-constrained glenoid component failure. Oper. Tech. Ortho. 4:226-36, 1994.
12. Shaffer, B.S., Giordano, C.P., Zuckerman, J.D.: Revision of a loose glenoid component facilitated by a modular humeral component. J. Arthroplasty 5:79-81, 1990.
13. Sperling, J.W., Cofield, R.H.: Revision total shoulder arthroplasty for the treatment of glenoid arthrosis. J. Bone Joint Surg AM. 81(4):592, 1999.
14. Steinnmann, S.P., Cofield, R.H.; Bone grafting for glenoid defieiency in total shoulder replacement. J. Shoulder Elbow Surg. 9(5):361-367, 2000.
15. Swieszkowski, W., Bednarz, P., Prendergast, P.J.: Contact stresses in the glenoid component in total shoulder arthroplasty. Proceedings of the Institution of Mechanical Engineers. Part H – J. Engineering Med. 217(1):49-57, 2003.
16. Torchia, M.E., Cofield, R.H., Settergren, C.R.: Total shoulder arthroplasty with the Neer prosthesis: long term results. J. Shoulder Elbow Surg. 4:S12, 1995.
17. Sperling, J.W., Cofield, R.H.: Revision total shoulder arthroplasty for the treatment of glenoid arthritis. J. Bone Joint Surg. 80-A:860-867, 1998.
18. Bell, S.N., Gschwend, N.: Clinical experience with total arthroplasty and hemiarthroplasty of the shoulder using the Neer prosthesis. Internat. Orthop. 10:217-222, 1986
19. Boyd, A.D. Jr., Thomas, W.H., Scott, R.D., Sledge, C.B., Thornhill, T.S.: Total shoulder arthroplasty versus hemiarthroplasty. Indications for glenoid resurfacing. J. Arthroplasty 5:329-336, 1990.
20. Jonsson, E., Brattstrom, M., Lidgren, L.: Evaluation of the rheumatoid shoulder function after hemiarthroplasty and arthrodesis. Scandinavian J. Rheumatol. 17:17-26, 1988.
21. Tonino, A.J., van de Werf, G.J.: Hemi arthroplasty of the shoulder. Acta. Orthop. Belgica 51:625-631, 1985.
22. Cofield, R.H., Frankle, M.A., Zuckerman, J.D.: Humeral head replacement for glenohumeral arthritis. Seminars in Arthroplasty 6:214-221, 1995.

◆ INNOVATIVE INTERVENTION FOR THE THORACIC AND LUMBAR SPINE (A)

Co-Moderators: Frank J. Eismont, MD, Miami, Florida and Harry N. Herkowitz, MD, Royal Oak, MI

This symposium will concentrate on current innovations for treating thoracic and lumbar spine problems. These therapeutic interventions will be presented in a format allowing the audience to evaluate the risks and benefits of each modality.

I. Lumbar Disc Replacements – Pros
Paul C. McAfee, MD, Towson, MD (a – Waldemar Line)

II. Lumbar Disc Replacements – Cons
Edward N. Hanley, MD, Charlotte, NC (n)

III. Kyphoplasty
Frank M. Phillips, MD, Chicago, IL (a, d, e – Kyphon, Inc)

IV. Spinal Fusion Enhancement
Scott D. Boden, MD, Decatur, GA (a – Medtronic, Centerpulse, Osteotech, DePuy, Wright, e – Metronic, Centerpulse)

V. Thoracoscopic Instrumentation
Peter O. Newton, MD, San Diego, CA (a, c – DePuy)

VI. Thoracic Pedicle Screws
Harry L. Shufflebarger, MD, Miami, FL (c – DePuy Acromed)

VII. IDET for Discogenic Low Back Pain – Pros
Gunnar B. J. Andersson, MD, Chicago, IL (e – Smith&Nephew)

VIII. IDET for Disogenic Low Back Pain – Cons
Gene Carragee, MD, Stanford, CA (a – Synthes-Spine, AO/ASIF)

A PROSPECTIVE RANDOMIZED FDA STUDY OF THE CHARITÉ DISC REPLACEMENT—A RADIOGRAPHIC – OUTCOME ANALYSIS OF 276 CONSECUTIVE PATIENTS

Paul McAfee, MD

A prospective randomized study was completed according to an FDA protocol with 2 year minimum follow up for one level disc pathology. One third of patients were randomized with anterior interbody BAK instrumentation and fusion (N= 99). Two thirds of patients were randomized with the Charité mobile bearing disk replacement (N = 205) and an additional group of 71 patients had received the Charité disc as "training cases" in a total of 15 United States investigational sites. All preoperative and follow up radiographs including flexion- extension x-rays were digitized in a central core laboratory and corrected for magnification factors (6,900 radiographs). The major findings included—

1) The Charité prosthesis was significantly more effective than the BAK in restoring the height of the collapsed disk space ($P < 0.001$)--

   The initial disk space height at the L5-S1 operative level started at 5.2 mm (mean) +/- 1.44 (Std Dev) and increased to 13.5 mm (mean) +/- 1.18 (Std Dev) for the Charité cases whereas the BAK patients at L5-S1 started at an initial disk space height of 5.9.mm +/- 1.74 and increased to an immediate post-operative disk space height = 11.9 mm +/- 2.07.

2) There was less subsidence with the Charite disk replacement than the BAK controls over the 24 months follow up ($p < 0.001$).

3) The surgical technical accuracy of Charité disk placement correlated with the clinical outcome measures at two years follow up. The 276 disc replacement patients were allocated into one of three groups based on radiographic technical paramenters--

   Group I –Ideal. This is defined by Charite disk insertion within 3 mm of ideal in both planes. Coronal plane = AP radiograph = midline or within 3 mm of midline. Mid-Sagittal plane= Lateral radiograph = 2mm posterior to middle of vertebral body or within 3mm of this axis. 83 % of the 276 Charité patients fell into this category.

   Group II—Suboptimal (11 %); and Group III – Poor (6 %).

   The Oswestry Disability index improved as the technical accuracy of prosthesis placement improved—Group I, 24.1; Group II, 30.3; and Group III, 36.3 ($p < .05$).

   The VAS at 2 years follow up also improved as the prosthesis placement became closer to the ideal parameters—Group I, 28.3; Group II, 35.4; and Group III, 48.4 ($p = 0.016$).

4) The flexion- extension range of motion and prosthesis function also improved with the surgical technical accuracy of radiographic placement—Group I, 7.12 +/- 4.06 degrees; Group II, 7.47 +/- 4.41 degrees; and Group III only 3.15 +/- 3.51 degrees ($p = 0.003$).

REFERENCES

1. Cinotti, G; David, T; and Postacchini, F (1996): Results of the Disc Prosthesis After a Minimum Follow Up Period of 2 Years. Spine 8: 995-1000.
2. Cunningham, B.W.; Lowery, G.L.; Gonzales, V.; and Orbegoso, C.M.: An Analysis of the Acroflex Lumbar Disk Prosthesis. A Non-Human Primate Model. Proceedings of the North American Spine Society, Friday November 3, 2001, Seattle, Washington, pages 74 + 75.
3. Griffith, SL; Shelokov, AP; Buttner-Janz, K; Lemaire, JP; and Zeegers, WS (1994): A Multicenter Retrospective Study of the Clinical Results of the Link SB Charité Intervertebral Prosthesis. The Initial European Experience. Spine 19:1842-1849.
4. Kuslich SD Ulstrom CL Griffith SL et al: (1998): The Bagby and Kuslich method of lumbar interbody fusion. History, techniques, and 2-year follow up results of a United States prospective, multicenter trial. Spine 23: 1267-1278.
5. Lemaire, JP; Shalli, W; Laveste, F; Templier, A; Mendes, F; Diap, A; Sauty, V; and Laloux, E (1997): Intervertebral Disc Prosthesis. Results and Prospects for the Year 2000. Clin Orthop Rel Res 337:64-76.
6. McAfee Paul C.: Symposium: A Critical Discrepancy – A Criteria of Successful Arthrodesis Following Interbody Spinal Fusions. Spine 26: 320-334, 2001.
7. McAfee, PC; Cunningham, BW; Devine, JD; Williams, Eric; and Yu-Yahiro, J: (2002) : Classification of Heterotopic Ossification (HO) in Artificial Disk Replacement. Proceedings of the 17th Annual Meeting of the North American Sine Society in Montreal Canada, The Spine Journal, Volume 2, page 94 S.
8. McAfee, PC; Cunningham, BW; Orbegoso,CM; Sefter,JC; Dmitriev, AE; and Fedder, IL (2003): Analysis of Porous Ingrowth in Intervertebral Disc Prostheses. A Non-Human Primate Model. Spine (in Press)
9. Zeegers, WS; Bohen, LMLJ; Laaper, M; and Vahaegen, MJA (1999): Artificial Disc Replacement with the Modular Type SB Charité III. 2 Year Results in 50 Prospectively Studied Patients. Eur Spine J 8: 210-217.
10. Yukawa, Y; Lenke, LG; Tenhula, J; Bridwell,KH: Riew, KD; and Blanke,K: (2002): A Comprehensive Study of Patients with Surgically Treated Lumbar Spinal Stenosis with Neurogenic Claudication. J.Bone Joint Surg, 84-A, 1954- 1959.

MINIMALLY INVASIVE TREATMENTS OF OSTEOPOROTIC VCFS

Frank M. Phillips, MD

Introduction

The National Osteoporosis Foundation estimates that over 100 million people worldwide, and approximately 44 million in the United States, are at risk for developing fragility fractures secondary to osteoporosis. Vertebral compression fractures (VCFs) occur in 20% of people over the age of 70 years and in 16% of postmenopausal women. In the United States there are an estimated 700 000 osteoporotic VCFs each year.[16] Unlike hip fractures, only one-third of VCFs present for clinical attention. This has led to a misconception that VCFs have fewer consequences than hip fractures. In fact data published over the past decade have shown that VCF whether acutely symptomatic or not, have devastating long-term effects in terms of diminished quality of life, impaired physical and social function, and increased mortality.[7,8,17] In addition, patients with significant spinal deformity secondary to osteoporotic VCFs have increased risk of back pain, disability and impaired health compared to matched patients without deformity. Kyphotic deformity in the osteoporotic spine may also create a biomechanical environment favoring additional fractures.[2,18]

VCF Treatment

Traditionally, VCFs have been treated non-surgically except in rare cases of fractures associated with neurologic compromise or advanced spinal instability. Open spinal surgery in the osteoporotic patient is fraught with complications related to the patient's advanced age and frequent co-morbidities and due to the difficulties in securing fixation in osteoporotic bone. Thus, the treatment of most patients with painful VCFs includes bed rest, analgesic medications, bracing, anti-osteoporotic drugs or some combination thereof. While these treatments appear to be reasonable, they are often ineffective and poorly tolerated by the elderly.

Over the past decade, vertebroplasty, involving the percutaneous injection of polymethylmethacrylate (PMMA) directly into a fractured vertebral body, has been used to stabilize osteoporotic VCFs. Substantial pain relief in a majority of patients treated with vertebroplasty has been reported.[3,11,13] Kyphoplasty is a minimally invasive orthopedic procedure designed to address the kyphotic deformity as well as the fracture pain. This operation involves the percutaneous insertion of an inflatable bone tamp into a fractured vertebral body under fluoroscopic guidance. Inflation of the bone tamp will elevate the end plates restoring the vertebral body back towards its original height, while creating a cavity to be filled with bone void filler.[15] Early results of kyphoplasty suggest significant pain relief as well as the ability to improve height of the collapsed vertebral body and to reduce spinal kyphosis.[1,5,6,12,14]

Surgical planning for Vertebroplasty / Kyphoplasty:

Before proceeding with vertebroplasty or kyphoplasty, the VCF must be confirmed as the source of the patient's back pain. This requires careful correlation of the patient's history and clinical examination with radiographic documentation of an acute or non-healed VCF. The physician should treat the symptomatic fractures(s) and should not indiscriminately treat multiple vertebral fractures seen on radiographic studies.

Pre-operative planning for vertebroplasty or kyphoplasty requires radiographic studies to identify the fracture, estimate the duration of the fracture, define the fracture anatomy and assess for posterior vertebral body wall deficiency. MRI is useful for detecting edema, which indicates an acute vertebral fracture, and for helping to rule out malignancy or infection.

Indications and Techniques

Vertebroplasty

Suggested indications include stabilization of painful osteoporotic vertebral fractures, painful vertebra due to metastases or multiple myeloma, Kummell's disease and painful vertebral hemangioma. Typically, vertebroplasty is accomplished through a trans - or extrapedicular approach to the vertebral body using an 11-13-gauge needle. After advancing the needle towards the center of the vertebral body, bone cement is injected into the vertebral body under live fluoroscopy. PMMA has been the bone cement most widely used for vertebroplasty. The procedure is typically performed on an outpatient basis.

Kyphoplasty

The indications for kyphoplasty are painful or progressive osteoporotic and osteolytic VCFs. I do not advocate performing kyphoplasty or vertebroplasty on more than three vertebral levels in one sitting because of the potential for deleterious cardiopulmonary effects related to cement and/or fat embolization to the lungs.

The patient is positioned prone and we have found simultaneous biplanar fluoroscopy to be advantageous. Following needle positioning into the fractured vertebral body via a trans- or extra-pedicular approach, a series of tools create a working channel into the vertebral body. Once inserted through the cannula into the vertebral body, the inflatable balloon tamps (IBT) are expanded until fracture reduction is achieved, the maximal balloon pressure or volume is reached or cortical wall contact occurs. The balloons are then deflated and removed. Thick cement can then be fed through the cannula to fill the void created by the balloon tamp. The cement volume should approximate the volume of the intra-vertebral cavity.

Clinical Results and Complications

Vertebroplasty

Reports on the outcome for vertebroplasty have suggested that most patients experience partial or complete pain relief within 72 hours of the procedure.[3,4,10,11,13] Overall, 60-100% of patients reported in the literature noted decreased pain after vertebroplasty. Zoarski et al. showed significant improvement in all four modules of the MODEM Scale (treatment score; pain and disability; physical function; mental function) shortly after vertebroplasty.[19] Similarly, improvement in the Nottingham Health Profile scores have been observed.[13] Grados et al. reported longer-term follow-up of 40 patients treated with vertebroplasty.[9] In 25 patients who were available for follow-up at a mean of 48 months, pain decreased from a mean of 80 mm before vertebroplasty to 37 mm after 1 month. These results remained stable over time, with a pain score of 34 mm at final follow-up (mean 48 months). Published reports have noted a low complication rate for vertebroplasty, with most complications resulting from extra-vertebral cement leakage causing spinal cord or nerve root compression or pulmonary embolism.[3,4,10,11,13]

The limitations of the vertebroplasty technique relate to the inability of the procedure to correct spinal deformity and the risk of extra-vertebral cement extravasation during injection. Extra-vertebral cement extravasation commonly occurs during vertebroplasty, with leak rates of up to 65% reported.[4] A higher rate of extravasation has been noted in patients with metastases or hemangiomas compared to patients with osteoporosis. The proponents of vertebroplasty have reported infrequent clinical sequelae of extra-vertebral cement leakage.

Kyphoplasty

Given that kyphoplasty is a relatively new procedure first reported in 2000, the literature on this procedure is less extensive than that for vertebroplasty. Garfin et al. reported on the initial multicenter experience with kyphoplasty to treat 2194 vertebral fractures in 1439 patients between 1998 and 2000. Ninety percent of patients reported significant pain relief within 2 weeks of the procedure.[5] There were 4 neurologic complications. The serious adverse event rate was 0.2% per fracture. In a prospectively followed cohort of patients, Lieberman et al. observed highly significant improvement in physical function, role physical, vitality, mental health and social function scores of the SF-36 questionnaire after kyphoplasty.[12] They reported a 8% rate of cement leaks all of which were clinically insignificant. No major systemic complications or neurological injuries occurred. Phillips et al. reported on 29 patients treated with kyphoplasty with a decrease in mean VAS pain scores from 8.6 preoperatively to 2.6 one-week postoperatively to 0.6 one-year postoperatively (cement leak: 6/61 fractures). In those patients with reducible fractures, local kyphosis improved by a mean of 14°.[14] The ability to reduce kyphosis may be a significant benefit of kyphoplasty.

Polymethylmethacrylate is not approved by the FDA for use in vertebroplasty or kyphopasty.

REFERENCES

1. Belkoff SM, Mathis JM, Fenton DC, et al. An ex vivo biomechanical evaluation of an inflatable bone tamp used in the treatment of compression fracture. Spine 2001;26:151-6.
2. Belmont PJ, Jr., Polly DW, Jr., Cunningham BW, et al. The effects of hook pattern and kyphotic angulation on mechanical strength and apical rod strain in a long-segment posterior construct using a synthetic model. Spine 2001;26:627-35.
3. Chiras J, Depriester C, Weill A, et al. [Percutaneous vertebral surgery. Technics and indications]. J Neuroradiol 1997;24:45-59.
4. Cortet B, Cotten A, Boutry N, et al. Percutaneous vertebroplasty in the treatment of osteoporotic VCFs: an open prospective study. J Rheumatol 1999;26:2222-8.
5. Garfin S, Lin G, Lieberman I, et al. Retrospective analysis of the outcomes of balloon kyphoplasty to treat vertebral body compression fracture (VCF) refractory to medical management. Eur Spine J 2001;10 (suppl 1):S7.
6. Garfin SR, Yuan HA, Reiley MA. New technologies in spine: kyphoplasty and vertebroplasty for the treatment of painful osteoporotic compression fractures. Spine 2001;26:1511-5.
7. Gold DT. The clinical impact of vertebral fractures: quality of life in women with osteoporosis. Bone 1996;18:185S-9S.
8. Gold DT, Lyles KW. Fractures: Effects on Quality of Lifeed. San Diego, Calif; London: Academic, 1999.
9. Grados F, Depriester C, Cayrolle G, et al. Long-term observations of vertebral osteoporotic fractures treated by percutaneous vertebroplasty. Rheumatology (Oxford) 2000;39:1410–4.
10. Jensen ME, Evans AJ, Mathis JM, et al. Percutaneous polymethylmethacrylate vertebroplasty in the treatment of osteoporotic vertebral body compression fractures: technical aspects. AJNR Am J Neuroradiol 1997;18:1897-904.
11. Lapras C, Mottolese C, Deruty R, et al. [Percutaneous injection of methylmetacrylate in osteoporosis and severe vertebral osteolysis (Galibert's technic)]. Ann Chir 1989;43:371-6.
12. Lieberman IH, Dudeney S, Reinhardt MK, et al. Initial outcome and efficacy of "kyphoplasty" in the treatment of painful osteoporotic VCFs. Spine 2001; 26:1631-8.
13. Mathis JM, Petri M, Naff N. Percutaneous vertebroplasty treatment of steroid-induced osteoporotic compression fractures. Arthritis Rheum 1998;41:171-5.
14. Phillips FM, McNally T, Wetzel FT, et al. Early clinical and radiographic results of kyphoplasty for the treatment of osteopenic VCFs. Eur Spine J 2001;10:S7.
15. Phillips FM, McNally TA, Lieberman IH, et al. Does kyphoplasty reduce potential for extra-vertebral and intra-vascular polymethyl-methacrylate leakage when compared to vertebroplasty? Eur Spine J 2001;10:S7.
16. Riggs BL, Melton LJ, 3rd. The worldwide problem of osteoporosis: insights afforded by epidemiology. Bone 1995;17:505S-11S.
17. Silverman SL. The clinical consequences of VCF. Bone 1992;13 Suppl 2:S27-31.
18. White AA, 3rd, Panjabi MM, Thomas CL. The clinical biomechanics of kyphotic deformities. Clin Orthop 1977:8-17.
19. Zoarski GH, Snow P, Olan WJ, et al. Percutaneous vertebroplasty for osteoporotic compression fractures: Quantitative prospective evaluation of long-term outcomes. J Vasc Interv Radiol 2002;13:139–48.

SPINAL FUSION ENHANCEMENT 2004

Scott D. Boden, MD

I. INTRODUCTION

A. The Clinical Problem

1. Autogenous bone is the "gold standard"
2. Why is anything else needed?
   a. multi-level fusion
   b. previous graft harvests (none left)
3. Donor site morbidity
   a. up to 25 - 30%
   b. hematoma, pain, OR time
4. Host metabolic hindrances
   a. previous failed fusion
   b. smoker
   c. diabetes
   d. osteoporosis
5. The "GOLD STANDARD" ain't perfect!
   a. lumbar nonunion rate 5 - 35%
   b. even see nonunions with instrumentation, EStim
6. Annual bone grafting procedures
   a. 500,000 per year in U.S.
   b. nearly 50% are spine fusions

B. Graft Requirements

1. Osteoinduction - chemical, biologic, mechanical, physical induction of bone cell differentiation
2. Osteoconduction - favorable scaffold and environment for bone formation
3. Osteogenic - direct transmittal of stem cells capable of making bone
4. Biocompatible - not excessively immunogenic
5. Structure ability to bear load load

C. Bone Graft Material Characteristics

Graft Material	Osteoinductive	Osteoconductive	Osteogenic
Autogenous Bone	X	X	X
Allograft Bone	X	X	
Bone Marrow	?		X
Bone Matrix (DBM)	X	X	
Collagen		X	
Ceramic		X	
Growth Factors	X		

D. Osteoconductive Substitutes

1. Results vary based on site and situation
   a. most are successful in metaphyseal defect as a substitute
   b. data less impressive as substutes for posterolateral spine fusion. May work (slowly) anteriorly if stable fixation and load protection
2. Role for spine
   a. Graft extender (not substitute) – likely must be used with autogenous bone or marrow.
   b. Possibly carriers for growth factors or genetically engineered cells
3. Scoliosis Fusions
   a. Different biology than intertransverse process fusion
   b. Not as tough to heal as lumbar spine
   c. Often adolescents (better healing)
   d. Greater surface area decorticated (lamina)
   e. Less mobile thoracic spine
   f. Always rigid segmental internal fixation (more tolerant environment for osteoconductive substitutes)
4. Allograft for Neuromuscular Scoliosis

Year Author	N	Type	Nonunion rate
1994 Bridwell	40	FF	7.5%
1986 McCarthy	32	FF	0%
1990 Montgomery	30	FD	6% auto, 0% allo
1997 Yazica	40	FD	5%

5. Allograft for Adolescent Idiopathic Scoliosis

Year Author	N	Type	Nonunion rate
1988 Dodd	40	FF	0% both groups
1985 Aurori	208	FF	4.4% auto, 5.3% allo
1991 Fabry	192	FF	1% auto, 1% allo
1997 Blanco	25	FD+	0%
1999 Grogan	87	FD	1%
1989 Herron	?	ETO	76%

6. Ceramic for Adolescent Idiopathic Scoliosis

Year Author	N	Type	Nonunion rate
1989 Passuti	12	HA/TCP+	(NMS)-no diff with auto
1990 Heise	14	HA+	same as auto
1997 LeHuec	24	TCP+	0%
1998 Ransford	341	HA/TCP+	18 mos – same as auto
2000 Delécrin	58	HA/TCP+	24-48 mos – same as auto

+ = ceramic used with local or auto bone

7. Scoliosis Summary
   a. Allograft (FF or FD) is OK
   b. Allograft (ETO) is NOT OK
   c. Ceramic (with local bone or autograft) OK for AIS
   d. Results with adult deformity will likely not be as good as those for adolescents

E. Weakly Osteoinductive Substitutes (Present)

1. Demineralized bone matrix
   a. good animal data (Excellent results in rabbit spine fusion- (see Morone et al, Martin et al.)
   b. Grafton Matrix DBM has shown "enhancement" of autograft healing in non-human primate postero-lateral spine fusion model
   c. Tremendous variability in activity between different products – Beware!
   d. little human data
   e. relatively inexpensive (compared to BMPs)
2. DBM Forms
   a. Gel, Putty, Flexible sheet, Matrix (new formulation of fluffy flex)
   b. osteoconductivity may vary based on form
   c. osteoinductivity may vary based on method, sterilization, etc.
   d. Grafton Matrix has shown osteoinduction in rhesus monkey spine model
   e. all brands do not give same results!!! Beware!

F. Osteoinductive Bone Growth Factors

1. Extracted (human, bovine)
   a. mixture of factors
   b. consistency may vary
2. Recombinant (rhBMP-2, rhOP-1, rhGDF-5)
   a. unlimited quantities
   b. only a single factor

G. Extraspinal Applications

1. Long bone defect models (Yasko, Cole, Lee, Gerhart, Kirker-Head)
2. Mandible defect model (Toriumi)
3. Avascular necrosis model – studies in progress

H. Spine Applications
1. Lower animal models
   a. rabbit/dog
   b. sheep/goat
2. Higher animal model
   a. non-human primate (Wiltse approach) - screening
   b. primate (Laminectomy + midline approach) - safety issues

II. SPINE APPLICATIONS

A. Lower Animal Models
1. Dog posterior lumbar fusion (Muschler et al., 1994)
   No significant difference in healing success or strength BMP-2 vs. ABG
2. Dog posterolateral lumbar fusion (Sandhu et al, 1995)
   a. Laminar, facet, and transverse process fusion (N=14) X 3 mos.
   b. 2.3 mg rhBMP-2 + 2.2 cc OPLA per site
   c. 2.2 cc autogenous bone graft-iliac (ABG)
   d. Results: 100% BMP-2 sites fused
      0% ABG sites fused
3. Dog Posterolateral Lumbar Fusion (Sandhu et al, 1995)
   a. Lamina, facet, and TP (N=29) X 3 mos.
   b. All BMP-2 doses stiffer than ABG, not much difference in stiffness of high vs lower BMP-2 doses
4. Dog Posterolateral Lumbar Fusion (David et al., 1995)
   a. Wiltse approach, TP only (N=18 beagles) X 12 weeks
   b.

Results	Fusions
ABG	0/3
Collagen Carrier (COL) Alone	0/3
BMP-2 (54 ug) + COL	3/3
BMP-2 (215 ug) + COL	3/3
BMP-2 (860 ug) + COL	3/3
BMP-2 (215 ug) + OPLA	3/3

5. Dog Posterolateral Lumbar Fusion (Chabot et al, 1994)
   a. Intertransverse process fusion, 6 dogs, 3 levels each X 6 weeks
   b. ABG ± rhBMP-2
      ABG ± rhBMP-2 + COL
      ABG ± rhBMP-2 + OPLA
      ABG ± rhBMP-2 + PLGA
   c. Results = all segments fused, no significant difference in carriers
6. Dog Posterolateral Lumbar Fusion (Sandhu et al.)
   a. Lamina, facet, TP (N=20) X 3 months
   b. 3 doses rhBMP-2 (58 ug, 230 ug, 920 ug)
      _ animals did not undergo decortication
   c. Results: 11/11 decorticated fused
      8/9 undecorticated fused
      (1 nonunion at 58 ug dose)
7. Rabbit Transverse Process Lumbar Fusion (Schimandle et al, 1995)
   a. Transverse processes, Wiltse approach L5-6
   b. N= 56 rabbits X 4-5 weeks
      Dose = 0.7 or 2.7 mg BMP-2
   c. Results: ABG 42%
      BMP-2 + COL 100%
      COL only 0%
      BMP-2 also successful with autograft ± COL
      fusions with BMP-2 were stronger + stiffer
8. Sheep Lumbar Fusion Model (Cunnigham et al)
   Work in progress with OP-1
9. Goat Cervical Interbody Model (Zdeblick et al, 1998)
   a. 21 alpine goats, cervical discectomy 3 levels
   b. Group I: BAK cage + local bone reamings
      3/21 Lucency 48% fused
      Group II: BAK (Ha-coated) + local bone reamings
      4/21 62% fused
      Group III: BAK + rhBMP-2 + COL
      0/21 95% fused
      better bone growth with BMP-2 than local bone
10. Goat cervical interbody model (Takahashi et al, 1999)
    a. 41 mature goats
    b. 3-level ACDF with pourous HA grafts and anterior plates
    c. 0, 5, or 50 ug rhBMP-2
    d. 100% fusion with 50 ug BMP-2, only 50% with 0 or 5 ug BMP-2
11. Rabbit posterolateral intertransverse process lumbar fusion OP-1 (Patel, Grauer et al, 2002)
    a. Used standard (human dose) 3.5 mg OP-1
    b. Achieved fusion in all rabbits

B. Higher Animal Models
1. Nonhuman Primate Lumbar Fusion (Boden et al)
   a. 12 adult rhesus, Wiltse approach L4-5 intertransverse process fusion X 18 weeks
   b.

Results	Fusions
Sham	0/2
ABG	1/2
rhBMP-2 (4 mg) + OPLA	2/2
rhBMP-2 (8 mg) + COL	1/2

2. Nonhuman Primate Laminectomy + Fusion Model (Boden et al)
   a. 12 adult rhesus, laminectomy L4-5
      Bilateral intertransverse process fusion X 24 weeks
   b. 6 mg - 32 mg dose range
   c. 18 - 32 mg dose 3/4 fused (collagen carrier)
   d. 9 - 12 mg dose 100% fusion with HA/TCP carrier
   e. collagen carrier too compressible
3. Nonhuman Primate Anterior Lumbar Interbody Cage Fusion Model (Boden et al.,1999)
   0 mg/ml + COL 0/2 Fused
   .75 mg/ml + COL 2/2 Fused
   1.75 mg/ml + COL 3/3 Fused
4. Nonhuman Primate Posterolateral Lumbar Fusion Model (Boden et al)
   a. rhBMP-2 at 6, 9, or 12 mg per side
   b. Carrier was 60:40 HA:TCP blocks
   c. 100% fusions at all 3 doses, 9mg dose seemed best quality bone

C. Human Clinical Trials
1. RhBMP-2/Collagen in ALIF Tapered Cage (Boden et al., 2000)
   a. 11 patients (BMP-2) , 3 control (autograft)
   b. All BMP-2 patients healed by 6 mos, f/u at 2 years unchanged.
   c. Only 2/3 controls healed by 1 year
2. rhBMP-2/collagen in ALIF Tapered Cage – Pivotal Trials
   a. Open and laparoscopic arms
   b. Over 350 patients
   c. Fusion success rate > 99.0% with BMP-2 based on CT scans and blinded interpretation
   d. Basis for FDA approval July 2, 2002
3. rhBMP-2/biphasic ceramic phosphate carrier in Posterolateral Lumbar Spine (Boden et. al 2002 Volvo Award ISSLS)
   a. 25 patients in randomized prospective pilot trial
   b. Autograft/pedicle screws, BMP-2/pedicle screws, or BMP-2 alone (no screws or auto)
   c. 20/20 patients with Grade I or less spondy fused with BMP-2 based on CT scans

d. Only 2/5 autograft were fused by CT scan (mean 17 month f/u)

4. NeOsteo Growth Factor Extract for Posterolateral Spine Fusion (Boden,Grob 2002)
   a. 26 patients with Grade I or less spondylolisthesis requiring lumbar posterolateral fusion
   b. BMP extract/mixture used
   c. Dose response was same as that seen in rhesus monkeys, with 25 mg per side 100% successful
   d. Carrier remains an important issue
5. OP-1 for Cervical Spine Fusion in Rheumatoid Arthritis (Jeppsson et al, 1999)
   a. C1-2 fusions attempted in 4 patients with RA
   b. OP-1 with type I collagen carrier
   c. Bridging bone formed in only 1 of 4 patients
   d. Also performed rat study in abdominal muscle pouch which showed that prednisolone did not inhibit the OP-1 ectopic bone formation.
5. OP-1 for Lumbar Posterolateral Spine Fusion (US trials, presented at NASS 2001,2002)
   a. Used with autograft or alone.
   b. CT scan assessment of fusion status not yet reported
   c. Fusion success apprx 55-70% based on plain radiographs
   d. Clinical outcomes generally as good or better than with autograft

D. Unresolved Issues
1. Ideal Carrier
   a. Collagen sponge
   b. Ceramic
   c. Ceramic + collagen
   d. Demineralized bone matrix
2. Optimal Dose
   a. Interanimal variability
   b. Step-up to human
   c. ? Higher dose for smokers, steroids, diabetes?
3. Instrumentation
   a. Will it be necessary
   b. When?

III. NEXT GENERATION BONE GRAFT SUBSTITUTES

A. Gene Therapy
1. Molecular control of bone formation (Gene Selection)
2. Secreted osteblast differentiation factors (BMPs)
3. Intracellular transcription factors (LMP-1)

B. Vectors
1. Adenovirus, HSV, AAV, lentivirus
2. Plasmid DNA (Gene-activated matrix – Bonadio, Goldstein vs. electroporation)
3. Liposomes

C. Local Gene Delivery Techniques
1. In vivo - direct injection into muscle (e.g., VEGF)
2. In vivo - direct injection of genetically transformed cells
3. Ex vivo-transfection of autologous or universal cells in culture, then implanted locally

D. Feasibility
1. Lieberman (UCLA) - Adeno-BMP-2 marrow cells made ectopic bone in nude rats
2. Huard (Pitt) – Adeno-BMP-2 in muscle progenitor cells made bone in athymic rats
3. Gazit (Israel) – Adeno-BMP-2 in stably transfected cell line made bone in mice
4. Boden (Emory) - pCMV - LMP-1 marrow cells fused 9/9 spine in athymic rats
   - Adeno - LMP-1 in bone marrow cells induced ectopic bone in athymic rats
   - Adeno-LMP-1 in peripheral blood buffy coat cells induced spine fusion in 10/10 immune competant rabbits (Viggeswarapu et al. JBJS 2001)

E. Rationale for Local Gene Therapy for Bone Formation
1. Only need short time of gene expression to intiate osteoblast cascade
2. Able to target by direct injection or implantation of cells at surgical site.
3. If secreted osteoinductive factor is made, efficiency is not a problem.

REFERENCES

1. Boden SD, Schimandle JH, Hutton WC. Lumbar intertransverse-process spinal arthrodesis with use of a bovine bone-derived osteoinductive protein. A preliminary report. J Bone Joint Surg Am 77(9):1404-1417, 1995.
2. Boden SD, Schimandle JH, Hutton WC. An experimental lumbar intertransverse process spinal fusion model. Radiographic, histologic, and biomechanical healing characteristics. Spine 20(4):412-420, 1995.
3. Boden SD, Schimandle JH, Hutton WC. An experimental lumbar intertransverse process spinal fusion model. Radiographic, histologic, and biomechanical healing characteristics. Spine 20(4):412-420, 1995.
4. Boden SD, Titus L, Hair G, Liu Y, Viggeswarapu M, Nanes MS, Baranowski C. The 1998 Volvo Award in Basic Sciences. Lumbar spine fusion by local gene therapy with a cDNA encoding a novel osteoinductive protein (LMP-1). Spine 23(23):2486-2492, 1998.
5. Boden SD, Liu Y, Hair GA, Helms JA, Hu D, Racine M, Nanes MS, Titus L. LMP-1, a LIM-domain protein, mediates BMP-6 effects on bone formation. Endocrinology 139(12):5125-5134, 1998.
6. Boden SD, Martin GJ, Jr., Morone MA, Ugbo JL, Moskovitz PA. Posterolateral lumbar intertransverse process spine arthrodesis with recombinant human bone morphogenetic protein 2/hydroxyapatite- tricalcium phosphate after laminectomy in the nonhuman primate. Spine 24(12):1179-1185, 1999.
7. Boden SD. Biology of lumbar spine fusion and use of bone graft substitutes: present, future, and next generation [In Process Citation]. Tissue Eng 6(4):383-399, 2000.
8. Boden SD, Zdeblick TA, Sandhu HS, Heim SE. The use of rhBMP-2 in interbody fusion cages. Definitive evidence of osteoinduction in humans: a preliminary report. Spine 25(3):376-381, 2000.
9. Bostrom MPG, Lane JM, Berberian WS, et al: Immunolocalization and expression of bone morphogenetic proteins-2 and -4 in fracture healing. Journal of Orthopedic Research 1995; 13:357-367.
10. Cole BI, Yasko A, Lane IM, et al: Comparison of recombinant human bone morpho-genetic protein combined with biodegradable polylacticglycolic acid copolymer versus cancellous bone to heal segmental bone defects. Abstract. Journal of Bone and Mineral Research 1993; 8:S244.
11. David SM, Murakami T , Tabor OB, et al: Lumbar spinal fusion using recombinant human bone morphogenetic protein (rhBMP-2): A randomized, blinded and controlled study. Abstract. Presented at the 22nd Annual Meeting of the International Society for Study of the Lumbar Spine, Helsinki, Finland, June 18-22, 1995.
12. Fischgrund JS, James SB, Chabot MC, Hankin R, Herkowitz HN, Wozney JM, Shirkhoda A. Augmentation of autograft using rhBMP-2 and different carrier media in the canine spinal fusion model. J Spinal Disord 10(6):467-472, 1997.
13. Gerhart TN, Kirker-Head CA, Kriz MJ, et al: Healing segmental femoral defects in sheep using recombinant human bone morphogenetic protein. Clinical Orthopedics and Related Research 1993; 293:317-326.
14. Jeppsson C, Saveland H, Rydholm U, Aspenberg P. OP-1 for cervical spine fusion: bridging bone in only 1 of 4 rheumatoid patients but prednisolone did not inhibit bone induction in rats. Acta Orthop Scand 70(6):559-563, 1999.
15. Johnson EE, Urist MR, and Finerman GAM: Resistant Nonunions and partial or complete segmental defects of long bones: Treatment with implants of a composite of human bone morphogenetic protein (BMP) and autolyzed, antigen-extracted, allogeneic (AAA) bone. Clinical Orthopedics and Related Research 1992; 277:229-237.

16. Kirker-Head CA, Gerhart TN, Schelling SH, Hennig GE, Wang E, Holtrop ME: Long-term healing of bone using recombinant human bone morphogenetic protein-2. Clinical Orthopedics and Related Research 1995; 318:222-230.

17. Lee SC, Shea M, Battle MA, et al: Healing of large segmental defects in rat femurs is aided by rhBMP-2 in PLGA matrix. Journal of Biomedical Materials Research 1994; 28:1149-1156.

18. Martin GJ, Jr., Boden SD, Titus L, Scarborough NL. New formulations of demineralized bone matrix as a more effective graft alternative in experimental posterolateral lumbar spine arthrodesis. Spine 24: 637-45, 1999.

19. Morone, M.A., Boden, S.D.: Experimental Posterolateral Spinal Fusion with a Demineralized Bone Matrix Gel (Grafton). Spine 1998; 23:159-167.

20. Martin GJ, Jr., Boden SD, Titus L, Scarborough NL. New formulations of demineralized bone matrix as a more effective graft alternative in experimental posterolateral lumbar spine arthrodesis. Spine 24: 637-45, 1999.

21. Martin GJ, Jr., Boden SD, Titus L, Scarborough NL. New formulations of demineralized bone matrix as a more effective graft alternative in experimental posterolateral lumbar spine arthrodesis. Spine 24: 637-45, 1999.

22. Morone MA, Boden SD, Martin GJ, Hair G, Racine M, Titus L, Hutton WC: Gene Expression during Autograft Lumbar Spine Fusion and the Effect of Bone Morpho-genetic Protein-2. Clin Orthop 1998.; 351:252-265.

23. Murakami H., Boden SD, Hutton WC. Anterior lumbar interbody fusion using a Barbell-Shaped Cage. J Spinal Disord . 2002. [In Press.]

24. Muschler GF, Hyodo A, Manning T, Kambic H, Easley K: Evaluation of human bone morphogenetic protein -2 in a canine spinal fusion model. Clinical Orthopedics and Related Research 1994; 308:229-240.

25. Ozuna R, Sandhu HS, Kanim LEA, et al: Carriers for bone morphogenetic protein for posterolateral spinal fusion. Presented at the 10th Annual Meeting of the North American Spine Society, Washington, D.C., 1995.

26. Sandhu HS, Kanim LE, Kabo JM, et al: Evaluation of rhBMP-2 with an OPLA carrier in a canine posterolateral (transverse process spinal fusion model). Spine 1995.; 20(24):2669-2682.

27. Sandhu HS, Kanim LE, Kabo JM, Toth JM, Zeegen EN, Liu D, Delamarter RB, Dawson EG. Effective doses of recombinant human bone morphogenetic protein-2 in experimental spinal fusion. Spine 21: 2115-22, 1996.

28. Sandhu HS, Kanim LEA, Toth JM, et al: Experimental spinal fusion with recombinant human bone morphogenetic protein-2 without decortication of osseous elements. Spine 1997; 22(11):1171-1180 [published erratum in Spine 1997, 22(20):2463].

29. Schimandle JH, Boden SD: Spine Update: The use of animal models to study spinal fusion. Spine 1994; 19:2474-2477.

30. Schimandle JH, Boden SD, Hutton WC: Experimental spinal fusion with recombinant human bone morphogenetic protein-2. Spine 1995; 20:1326-1337.

31. Toriumi DM, Kotler HS, Luxenberg DP, Holtrop ME, Wang EA: Mandibular recon-struction with a recombinant bone-inducing factor: Functional, histologic, and biomechanical evaluation. Archives of Otolaryngology - Head and Neck Surgery 1991; 117:1101-1112.

32. Urist MR, Mikulski A, Lietze A: Solubilized and insolubilized bone morphogenetic protein. Proceedings of the National Academy of Science of the United States of America 1979 ; 76:1828-1832.

33. Urist MR, Nilsson O, Rasmussen J, et al: Bone regeneration under the influence of a bone morphogenetic protein (BMP) beta tricalcium phosphate (TCP) composite in skull trephine defects in dogs. Clinical Orthopedics and Related Research 1987; 214:295-304.

34. Viggeswarapu M, Boden SD, Liu Y, Hair GA, Louis-Ugbo J, Murakami H, Kim HS, Mayr MT, Hutton WC, Titus L. Adenoviral delivery of LIM mineralization protein-1 induces new-bone formation in vitro and in vivo. J Bone Joint Surg Am 83-A(3):364-376, 2001.

35. Wozney JM: Bone morphogenetic proteins and their gene expression. In: Cellular and Molecular Biology of Bone, Academic Press, Inc, New York 1993. pp 131-161.

36. Wozney JM, Rosen V, Celeste AJ, et al: Novel regulators of bone formation: Molecular clones and activities. Science 1988; 242:1528-1534.

37. Yasko AW, Lane JM, Fellinger EJ , Rosen V, Wozney JM, Wang EA: The healing of segmental bone defects, induced by recombinant human bone morphogenetic protein (rhBMP-2). Journal of Bone and Joint Surgery 1992; 74-A:659-670.

38. Zdeblick TA, Ghanayem AJ, Rapoff AJ, Swain C, Bassett T, Cooke ME, Markel M. Cervical interbody fusion cages. An animal model with and without bone morpho-genetic protein. Spine 23: 758-65, 1998.

Bone Grafting in Scoliosis Surgery

1. Aurori BF, Weierman RJ, Lowell HA, Nadel CI, Parsons JR. Pseudarthrosis after spinal fusion for scoliosis. A comparison of autogeneic and allogeneic bone grafts. Clin Orthop(199):153-158, 1985.

2. Blanco JS, Sears CJ. Allograft bone use during instrumentation and fusion in the treatment of adolescent idiopathic scoliosis. Spine 22(12):1338-1342, 1997.

3. Bridwell KH, O'Brien MF, Lenke LG, Baldus C, Blanke K. Posterior spinal fusion supplemented with only allograft bone in paralytic scoliosis. Does it work? Spine 19(23):2658-2666, 1994.

4. Delécrin J, Takahashi S, Gouin F, Passuti N. A synthetic porous ceramic as a bone graft substitute in the surgical management of scoliosis: a prospective, randomized study. Spine 25(5):563-569, 2000.

5. Dodd CA, Fergusson CM, Freedman L, Houghton GR, Thomas D. Allograft versus autograft bone in scoliosis surgery. J Bone Joint Surg Br 70(3):431-434, 1988.

6. Fabry G. Allograft versus autograft bone in idiopathic scoliosis surgery: a multivariate statistical analysis. J Pediatr Orthop 11(4):465-468, 1991.

7. Grogan DP, Kalen V, Ross TI, Guidera KJ, Pugh LI. Use of allograft bone for posterior spinal fusion in idiopathic scoliosis. Clin Orthop (369):273-278, 1999.

8. Heise U, Osborn JF, Duwe F. Hydroxyapatite ceramic as a bone substitute. Int Orthop 14(3):329-338, 1990.

9. Herron LD, Newman MH. The failure of ethylene oxide gas-sterilized freeze-dried bone graft for thoracic and lumbar spinal fusion. Spine 14(5):496-500, 1989.

10. Horn BD. Autograft versus allograft versus bone-graft substitute in scoliosis surgery. Sem Spine Surg 10(1):68-72, 1998.

11. Le Huec JC, Lesprit E, Delavigne C, Clement D, Chauveaux D, Le Rebeller A. Tricalcium phosphate ceramics and allografts as bone substitutes for spinal fusion in idiopathic scoliosis as bone substitutes for spinal fusion in idiopathic scoliosis: comparative clinical results at four years. Acta Orthop Belg 63(3):202-211, 1997.

12. McCarthy RE, Peek RD, Morrissy RT, Hough AJ, Jr. Allograft bone in spinal fusion for paralytic scoliosis. J Bone Joint Surg Am 68(3):370-375, 1986.

13. Montgomery DM, Aronson DD, Lee CL, LaMont RL. Posterior spinal fusion: allograft versus autograft bone. J Spinal Disord 3(4):370-375, 1990.

14. Passuti N, Daculsi G, Rogez JM, Martin S, Bainvel JV. Macroporous calcium phosphate ceramic performance in human spine fusion. Clin Orthop(248):169-176, 1989.

15. Ransford AO, Morley T, Edgar MA, Webb P, Passuti N, Chopin D, Morin C, Michel F, Garin C, Pries D. Synthetic porous ceramic compared with autograft in scoliosis surgery. A prospective, randomized study of 341 patients. J Bone Joint Surg Br 80(1):13-18, 1998.

16. Takahashi T, Tominaga T, Watabe N, Yokobori AT, Jr., Sasada H, Yoshimoto T. Use of porous hydroxyapatite graft containing recombinant human bone morphogenetic protein-2 for cervical fusion in a caprine model. J Neurosurg 90(4 Suppl):224-230, 1999.

17. Yazici M, Asher MA. Freeze-dried allograft for posterior spinal fusion in patients with neuromuscular spinal deformities. Spine 22(13):1467-1471, 1997.

INDICATIONS AND ADVANTAGES OF THORACOSCOPIC ANTERIOR INSTRUMENTATION

Peter O. Newton, MD

Endoscopic Treatment for Spine Deformity
- Thoracoscopic release / fusion
- Thoracoscopic instrumentation

Thoracoscopic anterior release / fusion
- Crankshaft prevention
- Scoliosis / kyphosis release
- Congenital hemiepiphysiodesis
- Fusion levels T2-L1 (T5-T12)

Thoracoscopic anterior instrumentation

Indications: Adolescent Idiopathic Scoliosis
- Single structural thoracic curve (Lenke 1A, B, C)
- Normal or decreased thoracic kyphosis
- Lowest instrumented level T12 (L1)
- Cobb angle <70∞ (80∞)
- Bend films <35∞
- Instrument and fuse entire Cobb angle, end vertebra to end vertebra

Technique
- Patient positioning, direct lateral
- Plan portals with image intensifier, lateral and cross-table AP views
- 5 Portals + limited open thoracotomy
  - 2-anterior axillary line, place these first
  - 1-distal posterior axillary line, next
  - 2-posterior axillary line, after discectomies complete
- Discectomy
  - Divide pleura & segmental vessels
  - Circumferential exposure, pack sponges
  - Disc excision with ronguers, curettes
  - Disc spaces at apex must be able to completely collapse
  - Pack with Surgicel
- Screw placement
  - Confirm last 2 posterior portal sites w/ K-wires
  - Start screw placement proximally, smallest vertebra first
  - Starting point, mid-lateral, anterior to rib head
  - Direction, directly lateral
  - Awl, tap, probe for length
  - 5.5 or 6.5 diameter screws, bicortical
  - 2 or 3 screws per skin incision, 15 mm ports
- Rod insertion
  - Measure for length, anticipate 1-1.5 cm shortening
  - Contour to desired scoliosis and kyphosis
  - Hex head rod holder, inserter
    - Pass rod through inferior skin incision
    - Engage proximal screw with Typhoon cap
    - Tighten inner set screw
    - Cantilever rod into screws sequentially, proximal to distal
    - Rod approximator/cap inserter helpful in the distal incision
- Bone grafting
  - Fill the disc space completely with morselized autograft
  - Deliver to the disc space with the graft plunger
  - Distal to T11, consider structural support to maintain sagittal alignment
- Segmental compression
  - Two part compressor, each half through the same incision
  - Use the anterior incisions, except for the most distal level
- Closure
  - Pleural repair, Endostitch, running closure
  - Chest tube
  - Routine skin closure
- Post op Care
  - TLSO when out of bed x 3 months
  - Activity restriction 9-12 months

Potential Complications
- Screw loosening proximally
  - Bicortical screw fixation required
  - Contour the rod, avoid over-correction proximally
  - Use a washer or two proximally
- Vertebral body fracture
  - Smaller upper thoracicvertebrae, greatest risk
  - Place screws posterior 1/2 of body
  - Avoid smaller patients, < 30 kg
- Nonunion – rod breakage
- Discectomy must be complete
- Bone graft, Autograft only, complete fill
- Brace

Future
- Continued development
  - Implants
  - Tools
  - Fusion
- Prospective comparison
  - Radiographic assessment
  - Pulmonary Function
  - Chest and shoulder muscle fusion
  - Cosmesis
  - Patient satisfaction

REFERENCES

1. Arlet V. Anterior thoracoscopic spine release in deformity surgery: a meta-analysis and review. Eur Spine J 2000;9:S17-23.
2. Huang TJ, Hsu RW, Liu HP, et al. Video-assisted thoracoscopic surgery to the upper thoracic spine. Surg Endosc 1999;13:123-6.
3. Mack MJ, Regan JJ, Bobechko WP, et al. Application of thoracoscopy for diseases of the spine. Ann Thorac Surg 1993;56:736-8.
4. McAfee PC, Regan JR, Zdeblick T, et al. The incidence of complications in endoscopic anterior thoracolumbar spinal reconstructive surgery. A prospective multicenter study comprising the first 100 consecutive cases. Spine 1995;20:1624-32.
5. Newton PO, Shea KG, Granlund KF. Defining the pediatric spinal thoracoscopy learning curve: sixty-five consecutive cases. Spine 2000;25:1028-35.
6. Picetti GD, 3rd, J.P. E, Bueff HU. Endoscopic instrumentation, correction, and fusion of idiopathic scoliosis. The Spine Journal 2001;1:190-7.

THORACIC PEDICLE SCREWS

Harry L Shufflebarger MD

I. Introduction
- a. Controversial topic among spinal surgeons.
- b. In trauma and tumor surgery, pedicle screws permit shorter and stronger constructs compared to other spinal anchors. (Pedicles here are not deformed.)
- c. Use in deformity remains debated and questioned.
  - i. Pedicles are small and deformed.
  - ii. Weigh structures at risk with pedicle wall penetration versus benefits of segmental pedicle fixation.

II. Advantages of thoracic pedicle screws in deformity, compared to other anchors.
- a. Greater spinal anchor stability.
- b. More rigid fixation, controlling all three columns of spine.
- c. Better three dimensional correction.
- d. Obstruction-free (by implants) fusion bed.
- e. Less canal intrusion than any other anchor.
- f. Saves fusion levels in all types of idiopathic deformity.
- g. Easier assembly of construct than with hooks or combinations.

III. Disadvantages of thoracic pedicle screws in deformity, compared to other anchors.
- a. Pedicle breech giving the potential for visceral injury, particularly the aorta on the left in thoracic curves.
- b. Some learning curve for the established spinal surgeon.
- c. Increased intra-operative time.
- d. Increased cost of the spinal construct.

IV. Acceptable position of thoracic pedicle screws.
- a. In-out-in technique relative to the costo-vertebral joint acceptable.
- b. < 3mm medial penetration. (intra-canal hooks have a 3-4mm footprint).
- c. < 5mm lateral penetration (relate to vascular structures on CT if needed).
- d. No anterior penetration.
- e. No neurological deficit.

V. Techniques of thoracic pedicle screw placement.
- a. Free hand
- b. K-wires, x-rays, adjustments
- c. AP or lateral fluoroscopy
- d. 2-D guidance, FluoroNav
- e. 3-D guidance, Brain Lab or Stealth

VI. Author's preferred technique of thoracic pedicle screw placement
- a. Use AP fluoroscopy, with angulation and rotation permitting visualization down the axis of the pedicle.
- b. The ideal entry point is then established, and the hole made with an awl.
- c. A 2.7 mm drill bit on a hand drill is then employed to navigate the pedicle. The weight of the drill carries the bit down the pedicle. Changes in felt resistance indicate impending penetration, permitting alteration of trajectory.
- d. Follow the course of the drill bit down the pedicle on fluoroscopy. The isthmus of the pedicle is 10mm from the posterior cortex, and the entrance to the body 20mm.
- e. When the drill bit has reached 30mm, electrical stimulation is done (see monitoring). The drill is removed, and the trajectory palpated with a depth gauge or ball tipped probe. Canellous bone should be on all sides.
- f. After all screws are placed, AP and lateral fluoroscopic evaluation of all screws is accomplished.
- g. This technique should insure intra-osseous position of all screws.

VII. Electrical monitoring of thoracic pedicle screws
- a. SSEP's are employed throughout the scoliosis surgery.
- b. Stimulous evoked EMG's are employed during pedicle screw placement.
- c. Surface electrodes over the abdominal muscles permit monitoring of any screws placed in thoracic 7 distally.
- d. Surface electrodes over the lateral intercostals muscles are valuable to detect medial breech of the proximal thoracic spine. These are not of value to detect lateral breech.

VIII. Author's experience with thoracic pedicle screws
- a. >300 adolescent or pediatric deformity patients.
- b. Mean 12 screws per patient
- c. 3 screws in 2 patients removed for dangerous lateral breech.
- d. No neurological or vascular deficit, no re-operations.
- e. Correction 80% (58% hooks alone).
- f. Fusion levels generally limited to Cobb measurement.

REFERENCES

1. Lenke, LG, Kim, Y, Rinella A. Threatment of spinal deformity utilizing thoracic pedicle screws. Seminars in spine surgery. 14:66, 2002.
2. O'Brien MF, Lenke LG, Mardjetko SM et al. Pedicle morhpology in thoracic idiopathic scoliosis. Is pedicle fixation an anatomically viable technique? Spine 25:2285, 2000.
3. O'Brien MF, David AB Smith, Kuklo TR. Biomechanics of thoracic fixation in deformity. Part II: Hooks versus screws. Seminars in spinal surgery. 14:16, 2002.
4. Suk SI, Lee CK, Kim WJ, et al. Segmental pedicle screw fixation in the treatment of thoracic idiopathic scoliosis. Spine 20:1399, 1995.
5. Suk, SI, Kim WJ, Lee SM, et al. Thoracic pedicle screw fixation in spinal deformities. Are they really safe? Spine 26:2049, 2001.
6. Vaccarro AR, Rizzolo SJ, Allardyce TJ et al. Placement of pedicle screws in the thoracic spine. Part 1. A morphometric anaylsis of the thoracic vertebra. J Bone Joint Surg 77A:1193, 1995.
7. Vaccarro AR, Rizzolo SJ, Balderston RA, et al. Placement of pedicle screws in the thoracic spine. Part II. An anatomic and radiographic assessment. J Bone Joint Surg 77A:1200, 1995.

IDET FOR DISCOGENIC LOW BACK PAIN - PRO

Gunnar B. J. Andersson, MD, PhD

I. Treatment

Treatment for discogenic low back pain is typically non-operative. In patients who fail non-operative treatment, who have no other known source of pain and who have concordant pain on discography, fusion has been the primary surgical choice. Intradiscal electrothermal therapy (IDET) provides a less invasive alternative.

II. Technique

Intradiscal electrothermal therapy permits controlled delivery of heat to the intervertebral disc via a thermal resistive coil. The technique is performed under local anesthesia with intravenous sedation. General anesthesia is contraindicated, as the patient should be awake for monitoring of signs of nerve root irritation. After placement of a 17-guage needle into the center of the disc, the intradiscal catheter is introduced through the needle and positioned with fluoroscopic guidance. The strong outer layers of the annulus deflect the electrode, guiding it in a circumferential course toward the affected side. The catheter temperature is then gradually raised following a standard protocol to 90° C and is maintained at 90° C for 5 minutes. This creates an annular temperature of 60-65° C. After heating, the catheter is withdrawn, and prophylactic antibiotics are injected intradiscally. The therapy is an outpatient procedure that takes approximately one hour.

After surgery, the patients are encouraged to walk and do light stretching. Bending, twisting, lifting, and prolonged sitting are restricted for 8-12 weeks. Low intensity stabilization exercises are begun during the second month. Athletic activities are delayed until two to three months after surgery.

III. Biological Effects

Several mechanisms have been proposed to explain the effects of IDET. Heating causes shrinking of collagen fibrils and stabilization through remodeling. Heat also destroys nociceptors. It has been shown that irreversible damage to nerve tissue occurs at termperatures above 42 degrees Celsius.

IV. Results

Results of the IDET procedure have been published from a large number of centers. Two studies are randomized controlled trials. One cohort study uses concurrent controls. More than ten other studies are case series. The primary outcome measure used in all studies is a change in the pain score as measured by a Visual Analog Scale. Studies also use outcomes scales such as the Oswestry Disability Scale and the Short Form 36. The case series typically produce favorable results in sixty to 80 percent of patients. The prospective cohort study with concurrent controls showed significantly better results in the treated group. One of the randomized controlled trials had significantly improved pain and function while the other had equal results in both groups. Patient selection may well explain differences between these studies.

V. Summary

IDET is a beneficial treatment for discogenic pain in carefully selected patients. It provides a less invasive and destructive alternative to spinal fusions and disc replacements. The exact mechanism of action is still under investigation.

REFERENCES

1. Bogduk N and M Karasek (2002). "Two-year follow-up of a controlled trial of intradiscal electrothermal annuloplasty for chronic low back pain resulting from internal disc disruption." The Spine Journal 2: 343-350.
2. Derby R, B Eek, Y Chen, et al. (2000). "Intradiscal electrothermal annuloplasty (IDET): a novel approach for treating chronic discogenic back pain." Neuromodulation 3(2): 82-88.
3. Kartasek M and N Bogduk (2000). "Twleve-month follow-up of a controlled trial of intradiscal thermal anuloplasty for back pain due to internal disc disruption." Spine 25(20): 2601-7.
4. Kleinstueck FS, CJ Diederich, WH Nau, et al. (2001). "Acute biomechanical and histological effects of intradiscal electrothermal therapy on human lumbar discs." Spine 26(20): 2198-207.
5. Pauza KJ, S Howell, P Dreyfuss, et al. (2003). "A randomized, placebo-controlled trial of intradiscal electrothermal therapy (IDET) for the treatment of discogenic low back pain." The Spine Journal: (in press).
6. Saal JA and JS Saal (2002). "Intradiscal electrothermal treatment for chronic discogenic low back pain: prospective outcome study with a minimum 2-year follow-up." Spine 27(9): 966-73; discussion 973-4.
7. Shah RV, GE Lutz, J Lee, et al. (2001). "Intradiskal electrothermal therapy: a preliminary histologic study." Arch Phys Med Rehabil 82(9): 1230-7.

THE USE OF IDET IN THE TREATMENT OF PRESUMED DISCOGENIC PAIN

Eugene Carragee, MD

Overview:
IDET and other intradiscal thermoablation techniques have been introduced as a proposed treatment of back pain. This technology is relatively new and to this point the validity of application and comparative effectiveness of treatment has yet to be established.

Discogenic Pain:
The theoretical basis of IDET technologies is based upon a theory of discogenic pain. This assumes that discogenic pain can be reliably diagnosed and the pathogenesis established. Histological and biochemical data on balance support this theory however, epidemiologic data and studies of discography challenge the reliability of diagnosis. Discography is used in most trial of IDET to establish the patient pool for treatment.

Preliminary Trials:
Observational, uncontrolled trials by the developers have shown dramatic efficacy. Others have been less impressive. Some have reported deterioration of as many as one-third patients receiving IDET treatment. Others have pointed to possible subgroups with better outcome predictors.

In Vitro Data on Neuroablation Potential and Mechanical Effects:
There is contradictory data on the effectiveness, in vitro, of the heating protocol in causing changes compatible with the theoretical mechanism of action.

Controlled Trials:
Two weakly controlled trials were reported early on using different methodologies and no randomization. These had contradictory apparent outcomes from the IDET intervention. (Karasek and Bogduk 2000: Carragee et al 2001)

Two controlled trials with randomization need to be described in detail. (Pauza et al [in press], Frasier et al [in press]:) The Australian study enrolled subjects with severe LBP similar to subjects considering fusion. The American study enrolled subjects with mild to moderation LBP impairments. Neither study reported dramatic improvements compared to untreated patients, in the overall samples. In the Australian study there was no difference in outcomes compared to the "placebo" control. In the American study there were some significant differences in outcomes favoring the IDET group, particularly in post hoc subgroup analysis.

Observation of IDET usage in Clinical Practice:
1. Relatively low threshold to usage.
2. Poor patient understanding of expected outcomes.
3. Diagnosis often seriously in question (? Discogenic pain v other dx's)
4. Used to establish the need for and appropriateness of fusion or disc arthroplasty.
5. Used to establish bona fides of legal claims by demonstrating the need for invasive treatment.

◆ MODERN TECHNIQUES IN THE SURGICAL MANAGEMENT OF CERVICAL SPINE DISORDERS (S)

Moderator: K. Daniel Riew, MD, St. Louis, MO (n)

Over the past several years, a number of new or improved cervical spine surgical techniques have emerged. These include techniques of decompression, visualization, fusion and instrumentation. Some of these are techniques that have been present for many years but which have been modified and modernized. Others, such as artificial disc replacements, are not currently available in the United States but are expected to be in general use within the next 5-10 years. In this symposium, experts who have extensive experience with the technique will be discussing their indications, tips, pearls and problems.

I. Microsurgical Decompression of the Cervical Spine
K. Daniel Riew, MD, St. Louis, MO (n)

II. Cervical Laminoplasties: Indications and Techniques
John J. M. Rhee, MD, Decatur, GA (*)

III. Management of Odontoid Fractures: Odontoid Screws: Indications, Techniques
Alan S. Hilibrand, MD, Philadelphia, PA (n)

IV. Artificial Cervical Disc Replacement
Rick C. Sasso, MD, Indianapolis, IN (c – Medtronic)

V. Posterior Cervical Management of Upper Cervical Fractures, Subluxations: C1-2 Fixation Techniques, Hangman's Fractures: Halo, Bedrest, ACDF or Pedicle Screws?
Alexander Vaccaro, MD, Philadelphia, PA (n)

VI. Anterior Cervical Plates: Types of Plates, Advantages, Reconstruction Techniques for Multilevel Disease: Corpectomy, Corpectomy-Discectomy
Jeffrey C. Wang, MD, Los Angeles, CA (n)

MICROSURGICAL DECOMPRESSION OF THE CERVICAL SPINE

K. Daniel Riew, MD

Indications
The ideal indication for a posterior laminoforaminotomy procedure over an anterior cervical discectomy and fusion is in a patient that has reproducible symptoms with a Spurling's maneuver that then improves with forward flexion of the neck. In this type of patient, the nerve is being pincered between the anterior uncinate and the posterior facet and resecting the posterior aspect of the neuroforamen will yield a highly successful outcome. On the other hand, if the patient still has symptoms with maximum flexion of the neck where the neuroforamen widens, it is less likely to respond to a posterior foraminotomy, and our preference is proceed anteriorly. A laminoforaminotomy is an excellent technique to resect lateral disc herniations that impinge upon the nerve root, either at its axilla or further laterally. Although one can treat disc herniations even up to the lateral 1/3 of the disc space, we usually prefer to go in anteriorly for these. We also prefer to use an anterior approach for patients who have constant and significant numbness in their fingers. Even with a complete removal of a disc herniation, these patients may take several weeks, or sometimes even months, to recover. If we perform a posterior laminoforaminotomy and discectomy and the patient does not improve, there is always the question whether the patient is not improving because of permanent injury to the root at the time of the disc herniation or an inadequate foraminotomy and discectomy. When we go in anteriorly, we take out all of the disc material and actually visualize the nerve root and follow it out past the uncinate. In this way we can be positive that there is no further disc fragment and no uncovertebral impingement upon the nerve root. We can then feel much more confident that the persistent numbness is due to the original injury rather than an inadequate decompression. In addition, stabilizing the nerve root with a fusion may provide a more favorable environment for the nerve to recover.

In patients who otherwise meet the indications for a posterior laminoforaminotomy, this is an excellent procedure that is minimally invasive and that allows rapid return to normal activities. We usually perform these as outpatient procedures and allow the patient to return to their normal duties as quickly as they can tolerate. We offer a soft cervical collar for comfort only and recommend that the patients remove this as quickly as possible and resume normal activities, including exercise and work.

Patient Positioning
It is absolutely essential to position the patient properly in order to reduce blood loss and improve visualization. We prefer placing the patient prone on an open Jackson frame (OSI – Orthopedic Systems, Inc., 30031 Ahern Ave., Union City, CA 94587-1234, tel 1-800-777-4674 or 510-429-1500; fax 510-429-8500). We prefer to place the patient in Gardner-Wells tong traction and then suspend the head with two different ropes. If only a foraminotomy is being performed, the neck is kept in a flexed position to open up the facet joints. If a fusion is going to be performed following the foraminotomy, we first keep the neck in a flexed position and then, prior to the fusion, we extend the neck by switching the weights from the lower rope to the higher rope. The head of the bed is placed in the top rung of the table while the foot of the table is placed in the bottom rung. The patient is then placed in a modified knee-chest position with the legs supported in a sling and the thorax and abdomen on bolsters that allow the abdomen to hang free. A strap is placed behind the buttocks to keep the patient in place. The entire table is then tilted in a reverse Trendelenburg position to distribute the blood into the abdomen and the legs. A body warming blanket is placed underneath the table on the ventral side of the patient where the warm air can rise and heat the patient's ventral side.

Technique for a Foraminotomy –
For a single level unilateral foraminotomy, a 3 to 4cm incision can be made just off of the midline. A subperiosteal dissection is made to expose the lamina and the medial portion of the facet. The facet capsule should be preserved. In order to perform an adequate foraminotomy for foraminal stenosis, typically approximately _ of the facet joint needs to be removed. Removal of more than 50% of the facet joint can result in instability postoperatively, especially if the foraminotomy is performed bilaterally.

In order to perform an adequate foraminotomy, one must first have an understanding of what the compressive etiology is and what the boundaries of the foramen are. The most common cause of foraminal stenosis is uncinate hypertrophy that results in foraminal compression from the ventral aspect. Other causes include an intraforaminal disc herniation and, more rarely, posterior facet hypertrophy due to arthrosis. The anterior medial border of the foramen is bounded by the uncovertebral joint. The posterior margin is the superior articular facet of the caudal vertebral segment. Cranially and caudally, the neuroforaminal borders are the pedicles. Compression of the nerve in a patient with spondylosis usually occurs between a hypertrophied uncovertebral joint and the superior articular facet in the anterior-posterior direction. It is rare for there to be such extensive loss of disc height such that the pedicles cause compression in a cranial-caudal direction. It is rare for there to be such extensive loss of disc height such that the pedicles cause compression in a cranial-caudal direction. Therefore, when one approaches a decompression of the foramen for uncinate hypertrophy posteriorly, one needs to decompress the neuroforamen in an anterior-posterior direction. This is most readily accomplished by resecting the medial portion of the superior articular facet. Although the uncovertebral joint can be burred down from a posterior aspect, this requires a fair degree of retraction of the nerve root and exposes the root to potential injury from the burr itself. As one proceeds more ventrally along the neuroforamen, there is also the risk of injuring the vertebral artery. For this reason, we prefer just to resect the superior articular facet alone. In order to expose the superior articular facet, however, one must first remove the overhanging inferior articular facet of the cranial segment. This can be minimized by flexing the neck such that more of the underlying superior articular facet is exposed without resecting the inferior articular facet.

When is a laminoforaminotomy adequate?
The principle of decompression posteriorly is to resect the dorsal border of the neuroforamen such that the nerve root can displace dorsally in the neuroforamen and away from the uncinate spur. We believe that a simple keyhole foraminotomy that resects the medial half of the facet can occasionally be inadequate in a patient with a large anterior spur. For this reason, we prefer to resect a small portion of the medial lamina of the supe-

rior and inferior segments so that the root can displace dorsally all the way from its origin in the spinal cord to the lateral margin of the neuroforamen. Following a simple keyhole foraminotomy, there can often be some kinking of the dorsal root against the lateral aspect of the lamina. When a small portion of the lamina is also resected, such kinking does not occur. A more common question that is asked is, "How far lateral should the decompression go." The decompression is complete when the dorsal roof of the lateral margin of the neuroforamen is decompressed. Therefore, when one can place a small probe lateral to the pedicles, then one has decompressed far laterally enough. In addition, there should be no dorsal overhang. One should be able to palpate the superior and lateral borders of the caudal pedicle and not feel any overhanging superior articular facet. This way the root can migrate dorsally without any impediment. Resection of any more facet beyond the lateral margin of the pedicle is not only unnecessary, but contraindicated, as it will lead to greater instability of the facet joint.

Foraminotomy for a disc herniation

The exposure is identical to that described above for cervical spondylosis and uncinate hypertrophy. This time, however, the nerve root must be manipulated in order to expose the herniated disc fragment that is ventral to the nerve root. The easiest way to perform this is to burr down part of the caudal pedicle. Only the cranial 2 to 3mm of the pedicle needs to be burred flush with the vertebral body. One can then retract the nerve root caudally without injuring the nerve root. In addition, it is easier to dorsally retract the nerve root and extricate the disc fragment. We use small micro instruments including a 1mm Kerrison punch, and micro probes. Two and 3mm right-angle ball-tipped probes are ideal to fish out the disc herniation and also to retract the nerve root. Prior to concluding the procedure, one should check both above and below the nerve root to make sure that all of the disc fragments have been adequately removed. The area is flushed with saline and we use a hemostatic agent such as FloSeal, (BaxterHealthcare Corp, Deerfield, IL) or Gelfoam (Pharmacia-Upjohn, Kalamazoo, MI). The wound is then closed in multiple layers. Depending on the amount of bleeding intraoperatively, a drain can be used. Usually this is not necessary however.

Anterior Decompression

Under microscopic visualization, the disc material is removed. The patient is placed into 20 to 30 lbs. of skeletal traction, and a small Cobb elevator is placed between the disc spaces and turned sideways to lever it open. If a corpectomy is performed, a Leksell rongeur is used to begin the decompression. It is then completed with a 5-mm carbide burr. A high-speed burr that does not "kick" when it comes into contact with bone is absolutely essential for the safe removal of bone around neural and vascular structures.

In patients with an intact posterior longitudinal ligament (PLL), a high-speed carbide burr under good visualization will safely remove all of the bony material without violating the PLL. The burr is held pencil-like in the dominant hand, and a suction tip is held in the opposite hand. The assistant provides constant irrigation using a syringe tipped with a 20-gauge intravenous catheter to prevent thermal injuries. With microscopic visualization and constant palpation with the suction tip to determine if all of the bony material has been removed, it becomes readily apparent when one has removed all of the bone and reached the PLL. If the posterior longitudinal ligament is absent or ossified, a diamond burr can be used under constant irrigation.

The width of the decompression is determined preoperatively, based on axial computed tomography or magnetic resonance images. The distance between the medial walls of the transverse foramina, where the vertebral artery lies, is measured. This usually measures between 22 and 35mm. An adequate decompression addresses all of the posterior osteophytes, enlarges stenotic foramina, and leaves at least the lateral 3mm of bone on each side to protect the vertebral artery. The usual width of the decompression is 15 to 29mm, and the most common range is between 18 and 20mm. During surgery, the uncovertebral joints are used as reference points to keep the decompression central and to prevent injury to the vertebral artery. A thorough decompression of the uncinate is necessary to perform a complete anterior foraminotomy. One must undercut the uncinate that is lying ventral to the nerve root. If one can palpate the lateral margin of the pedicle adequately, and there is no overhang, then an anterior foraminotomy is complete. The video demonstration will go over this in more detail.

CERVICAL LAMINOPLASTY: INDICATIONS AND TECHNIQUES

John M. Rhee, MD

I. Cervical Spondylotic Myelopathy (CSM)
- A. caused by spinal cord compression due to degenerative (spondylotic) process
- B. symptoms: loss of balance, clumsiness of gait or hands, numb/weak hands
- C. physical signs: spasticity
  1. +/- hyperreflexia
  2. long tract signs: Lhermitte's, Hoffman's, finger escape sign, inverted radial, scapulohumeral, clonus
- D . radiographic findings
  1. XR: diminished Pavlov ratio (<0.8), SAC<13 mm
  2. MRI
     a. cord signal change: poor prognosis
  3. CT myelogram
- E. Treatment: surgical, unless there is a contraindication to surgery
- F. Factors to consider in surgical decision making
  1. neurologic compression (where, by what, and how many levels are involved?)
  2. what is the alignment of the spine (lordotic, neutral, kyphotic?)
  3. is there instability?
  4. has there been prior surgery?
  5. what co-morbid conditions does the patient have?

II. Surgical alternatives in treating CSM
- A. Laminectomy
  1. Problem: post-laminectomy kyphosis, recurrent myelopathy, neck pain
- B. Anterior decompression and fusion
  1. Problem: pseudarthrosis (11-46%), graft displacement (7-50%), adjacent level degeneration (Hilibrand, JBJS 1999)
  2. Plating does NOT solve the problem associated with strut grafts. Anterior strut grafting is a biomechanically difficult proposition!
- C. Laminoplasty
  1. Head to head comparisons with anterior decompression and fusion
     a. Yonenobu (Spine, 1992): similar recovery, but laminoplasty with fewer complications
     b. Edwards (Spine, 2002): similar improvement, but laminoplasty with fewer complications, no difference in neck pain
  2. Laminoplasty vs. laminectomy
     a. Heller (Spine 2001): laminoplasty with trend toward better recovery, and again laminoplasty with fewer complications
  3. Laminoplasty vs. anterior decompression and fusion vs. laminectomy
     a. Herkowitz (Spine 1988): anterior and laminoplasty similar outcomes, but laminectomy inferior
  4. Benefits
     a. indirect decompression – easier especially in the setting of severe compression, and possibly also safer
     b. can quickly decompress multiple segments
     c. no fusion involved – preserves motion, avoids fusion-related surgical complications, less postoperative restrictions
     d. can "prophylactically" decompress levels at future risk for compression with one operation
     e. can always do selective anterior decompression later if necessary
     1. may be safer to do anterior procedure later, when canal is already partially decompressed
  5. Problems with laminoplasty
     a. reliance on indirect decompression
     b. neck pain (Hosono, Spine 1996)
     c. segmental root level palsy (Uematsu, Spine 1998)
     d. some loss of motion despite lack of fusion
     e. kyphosis

III. Indications for laminoplasty
- A. 3 or more motion segments involved in compression
- B. Non-kyphotic (although this is somewhat debatable)
  1. if considering laminoplasty in a kyphotic patient, need to determine that some degree of decompression can be achieved with a posterior operation because of segmental "drift back" of the cord or by release of circumferential compression
- C. Pt is at higher risk for nonunion (eg, diabetic, smoker, steroid use, severe osteopenia, etc) and thus poor fusion candidate
- D. High risk surgical patient, where goal is to get "in and out" quickly
- E. Pre-existing adjacent segment degeneration makes fusion undesirable
- F. Myelopathy > radiculopathy
- G. Neck pain is not primary complaint
- H. Factors favoring anterior surgery
  1. Significant axial pain
  2. Kyphosis
  3. Radiculopathy > myelopathy
  4. 1-2 points of compression, especially soft discs

IV. Techniques
- A Positioning
  1. Mayfield headrest
  2. Reverse trendelenberg position (limit bleeding)
  3. Neck alignment: neutral to slight flexion
     a. limits shingling of laminae, facilitating surgery
     b. assess preop extension and do not go beyond
- B. Monitoring, anesthesia
  1. fiberoptic awake intubation considered in severely myelopathic patients who do not tolerate extension
  2. SSEP/ MEP baselines, prior to positioning, after positioning, intraop
  3. watch out for hypotension, especially as pt positioned into rev trendelenberg
     a. keep MAP reasonably high
- B. Exposure
  1. C2-T1, to midpoint of lateral masses
  2. Widen the C2-3 interlaminar space
     a. burr the inferior lamina of C2 to facilitate opening
- C. Hinge
  1. Location: at junction of lateral mass and lamina C3-7
  2. Direction: perpendicular to the floor
  3. Depth: need only remove the dorsal cortex
     a. the superior end of the lamina will always be the limiting factor
        i. it is thicker
        ii. overhang of the lamina above "hides" it
- D. Open side
  1. Location: at junction of lateral mass and lamina C3-7
  2. Direction: perpendicular to floor through dorsal cortex
     a. then, perpendicular to lamina to avoid drilling into lateral mass

3. Depth: quickly through dorsal cortex and cancellous bone
   a. slowly thin out the anterior cortex to a thin shell
   b. epidural veins or lateral edge of dura become visible as anterior cortex is thinned
   c. flake off the anterior cortex with microcurette or micro kerrsion
      1. "no touch" technique preferable!
      2. if epidural veins bleed, can control with bipolar or gelfoam
   d. can determine when complete by testing mobility of each lamina

E. Opening the door
1. remove interspinous ligaments at C2-3 and C7-T1
2. Burr off inferior surface of C2 to facilitate opening of C3
3. Start at C7, work cranially with gradual, repeated deformation of laminae
   a. goal to produce a greenstick fracture
4. As door is opened, microkerrsion used to resect ligamentum flavum between adjacent laminae along the opening, as well as C7-T1 and C2-3
5. Lyse epidural adhesions gently with mircocurrette
6. bipolar or gelfoam veins
   a. occasionally, massive bleeding can occur, especially in large patients
   b. proper positioning critical to limit this
   c. sometimes, cannot be avoided
   d. as dura expands, epidural bleeding usually diminishes from counterpressure
7. If door does not open, usual culprit is the cephald aspect of the lamina on either the hinge or open side, or overhang of C2 on C3

F. Keeping the door open
1. Bone (spinous process, allograft rib)
2. suture/ mitek
3. plates
   a. most secure, can stabilize a floppy hinge
   b. caveat: avoid injury to facet joints with screws, esp at C7-T1
4. How big: usually ~10 mm (C3) to 15 mm (C7)

G. Spinous process removal
1. Optional
2. C7 can be prominent
3. Prefer to do this last, as it is easier to open the door with a longer lever arm

H. Postop
1. Hard or soft collar 4-6 weeks
2. Shoulder, neck rehab at 6wks

V. Pitfalls

A. Malpositioned hinge
B. Malpositioned trough
C. Closure of door
D. Segemental root palsy ~ 5% incidence
1. usually, but not always, C5
2. often develops several days postop - ? stretch phenomenon?
3. Cause: many theories, probably multifactorial
   a. stretch
   b. C5 is usually at apex of lordosis, making it stretch the most
   c. deltoid receives single innervation: thus injuries are most obvious
   d. segmental edema within the cord after decompression
4. prevention: unclear
   a. avoid excessive opening > 45-60o
   b. prophylactic foraminotomy
5. usually recovers substantially in 3-6 months

E. Increased axial pain
F. decreased ROM
1. usually about 30% _ C2-7 arc
   a. spontaneous facet fusion
   b. stiffening

VI. Summary

A. excellent alternative to anterior surgery
1. indirectly and quickly decompress multiple levels

B. clinical outcomes equal to anterior surgery, but:
1. no fusion related complications (graft, pseudarthrosis)
2. less postop restrictions
3. motion relatively spared

REFERENCES

1. Baba H, Uchida K, Maezawa Y, Furusawa N, Azuchi M, and Imura S. Lordotic alignment and posterior migration of the spinal cord following en bloc open-door laminoplasty for cervical myelopathy: a magnetic resonance imaging study. J Neurol. 1996;243:626-32.
2. DiAngelo DJ, Foley KT, Vossel KA, Rampersaud YR, and Jansen TH. Anterior cervical plating reverses load transfer through multilevel strut-grafts. Spine 2000;25:783-95.
3. Edwards CC, Heller JG, Murakami H (2002): Corpectomy versus laminoplasty for multilevel cervical myelopathy: an independent matched-cohort analysis. Spine 2002:27:1168-1175.
4. Emery SE, Bohlman HH, Bolesta MJ, and Jones PK. Anterior cervical decompression and arthrodesis for the treatment of cervical spondylotic myelopathy. Two to seventeen-year follow-up. J.Bone Joint Surg.Am. 1998;80:941-51.
5. Heller JG, Edwards CC, Murakami H, Rodts GE: Laminoplasty versus laminectomy and fusion for multilevel cervical myelopathy: an independent matched cohort analysis. Spine 20012:26:1330-1336.
6. Herkowitz HN: A comparison of anterior cervical fusion, cervical laminectomy, and cervical laminoplasty for the surgical management of multiple level spondylotic radiculopathy. Spine 1988:13: 774-780
7. Hilibrand AS, Carlson GD, Palumbo MA, Jones PK, Bohlman HH: Radiculopathy and myelopathy at segments adjacent to the site of a previous anterior cervical arthrodesis. JBJS 1999:81A: 519-528
8. Hirabayashi K, Watanabe K, Wakano K, Suzuki N, Satomi K, Ishii Y: Expansive open-door laminoplasty for cervical spinal stenotic myelopathy. Spine 1983:8: 693-699
9. Hirabayashi K, Bohlmann HH: Multilevel cervical spondylosis: Laminoplasty versus anterior decompression. Spine 1995:20:1732-4.
10. Hosono N, Yonenobu K, and Ono K. Neck and shoulder pain after laminoplasty: A noticeable complication. Spine 1996;21:1969-73.
11. Rhee JM: Cervical Decompression: Anterior and Posterior. In press, Spine Surgery: Essentials of Orthopaedics. Editors Bono CM, Garfin SR. Lippincott Williams and Wilkins.
12. Riew KD, Sethi NS, Devney J, Goette K, and Choi K. Complications of buttress plate stabilization of cervical corpectomy. Spine 1999;24:2404-10.
13. Satomi K, Nishu Y, Kohno T, and Hirabayashi K. Long-term follow-up studies of open-door expansive laminoplasty for cervical stenotic myelopathy. Spine 1994;19:507-10.
14. Uematsu Y, Tokuhashi Y, Matsuzaki H: Radiculopathy after laminoplasty of the cervical spine. Spine 1998:23:2057-2062.
15. Vaccaro AR, Falatyn SP, Scuderi GJ et al. Early failure of long segment anterior cervical plate fixation. J.Spinal Disord 1998;11:410-5.
16. Yonenobu K, Hosono N, Iwasaki M, Asano M, and Ono K. Laminoplasty versus subtotal corpectomy. A comparative study of results in multisegmental cervical spondylotic myelopathy. Spine 1992;17:1281-4.
17. Yonenobu K, Yamamoto T, Ono K: Laminoplasty for myelopathy: Indications, results, outcome, and complications. In: The cervical spine. Philadelphia: Lippincott-Raven, pp 849-864, 1998

MANAGEMENT OF ODONTOID FRACTURES: ODONTOID SCREWS – INDICATIONS AND TECHNIQUES

Alan S. Hilibrand, MD

I. OVERVIEW OF ODONTOID FRACTURES

A. Incidence
1. 8-18% of cervical fractures
2. 2 groups of patients affected
   a. Elderly: low energy, look for facial bruising
   b. Young patients: high energy, multiple injuries

B. Clinical Diagnosis: SHOULD HAVE A HIGH INDEX OF SUSPICION IF:
1. Facial and head injured patients
2. Patients with occipital and posterior neck pain after trauma
3. Limited cervical rotation
4. Patients with appropriate mechanism (see above)

C. Radiographic Diagnosis
1. Plain radiographs: AP, lateral, and open mouth odontoid views
2. CT scans with sagittal and coronal reconstruction
3. MRI scans –helpful if:
   a. Uncertain acuity of fracture
   b. Diagnose transverse disruption

D. Key Radiographic Features
1. Level of fracture
   a. Tip of odontoid, avulsion of alar ligament-Type I fracture
   b. At neck -- classic Type II fracture
   c. At base – involving body, Type III
2. Associated upper cervical injuries (C1 arch fractures)
3. Obliquity of fracture
   a. Anterior superior to posterior inferior
   b. Anterior inferior to posterior superior
4. Presence of well corticated fracture margins (likely not acute)
5. Prevertebral soft tissue swelling (suggests acute fracture)

II. TREATMENT OPTIONS

A. Non-operative Treatment
1. Closed reduction
   a. Bivector traction
   b. Necessary for displaced fractures
2. Halo vest
   a. Most appropriate form of non-operative treatment
   b. Associated with high non-union rate for Type II fractures
   c. High rate of complications in older patients (Seybold, Spine 1998)
3. Hard collar
   a. Elderly or disabled patients
   b. Associated with non-union, possible late instability

B. Indications for Operative Treatment
1. Posterior displacement
   a. > 6 mm ‡ non-union rate 60%
   b. < 6 mm ‡ non-union rate 10%
2. > 10% angulation
3. Loss of closed reduction
4. Age > 50 years
   a. Associated with higher non-union rate
   b. Lennarson, Spine 2000

C. Operative Treatment – Posterior Fusion
1. Typically C1-2 fusion (rarely occ-C2)
2. Surgical techniques (discussed in other lecture)
   a. Transarticular screws
   b. C1/C2 lateral mass screws (Harms)
   c. C1/2 wiring techniques

D. Indications for Anterior Fixation
1. Appropriate fracture obliquity
   a. Best if anterior superior to posterior inferior
   b. O.K if transverse
   c. Contraindicated if anterior inferior to posterior superior
2. Adequate bone density for cancellous screw fixation
3. Reducible, posteriorally displaced fracture
4. Acute fractures (< 3 months)
5. Associated C1 ring fractures

E. Advantages of Anterior Odontoid Fixation
1. No loss of motion at C1/2
2. Avoidance of bone grafting (Osteosynthesis)
3. "Minimally invasive" technique

F. Contraindications to Anterior Odontoid Fixation
1. Wrong fracture obliquity (see above)
2. Transverse ligament disruption (needs C1/2 fusion)
3. Anatomic restrictions
   a. Barrel chest deformity
   b. Thoracic kyphosis
   c. Spinal cord compression not allowing extension

III. TECHNIQUE FOR ANTERIOR ODONTOID FIXATION

A. Positioning
1. Biplanar fluoroscopy is essential
2. Must visualize odontoid and C1/2 lateral masses in both planes
3. Must reduce fracture
   a. May require intra-operative manipulation
   b. Must be reduced prior to fixation
4. Must confirm adequate angle of approach (K-wire with fluro)

B. Surgical Approach
1. Same as C5/6 ACDF
2. 1″ transverse incision
3. Identify C2/3 disc space
4. Bovie/fix on anterior corner of C2/3 disc space

C. Screw Placement
1. Check approach angle on lateral
2. Check medial/lateral direction on AP
3. Advance drill under both images
4. Consider K wire if very unstable

D. One vs. Two Screws
1. Small diameter (9 mm) for two 3.5 mm screws
2. No difference in fusion (Jenkins, J Nsg 1998)
3. No difference in strength (Graziano, Spine 1993)

E. Technical Tips
1. Threads must all be across fracture
2. May require purchase in cortex of odontoid tip
3. Beware of drilling over K-wires

F. Complications of Anterior Odontoid Fixation
1. Penetration of posterior cortex

2. Anterior C2 cortex failure
3. Threads at fracture line
4. K-wire into spinal cord

IV. SUMMARY

A. Ideal patient
1. Type II fracture with anterior superior to posterior inferior fracture line
2. Associated C1 ring fracture
3. Adequate bone density
4. Posteriorally displaced fractures

B. Clinical Perils
1. Follow basic orthopaedic concepts
   a. Cancellous bone screws
   b. Compression across fracture site
2. Biplanar C-arm essential
3. Positioning is the key

ARTIFICIAL CERVICAL DISC REPLACEMENT

Rick C. Sasso, MD

Surgical Technique:
The technique of implanting an artificial disc replacement is dependent upon the characteristics of the device. Specifically, this includes the type of articulation, the biomaterials of the bearing surfaces, the design of the implant, the method of fixation, and the kinematics of the apparatus. The Bryan disc is a one-piece, bi-articulating, metal on poly (titanium on polyurethane), unconstrained device with a fully variable instantaneous axis of rotation that is not dependent upon supplemental fixation. Initial stability is achieved by exact milling of the vertebral endplates and long-term stability is provided by bone growth into the plasma-sprayed titanium endplates.

A fundamental concern of every artificial disc replacement is the reliability of placing the device in perfect sagittal alignment. The Bryan disc utilizes a jig that is oriented precisely based on intraoperative fluoroscopy of the local sagittal anatomy. This allows exact milling of the vertebral endplates through the jig. The third step after preoperative x-ray evaluation and intraoperative milling of the endplates is simply placing the artificial disc into the milled interspace.

1. Pre-operative
A pre-operative CT scan is helpful in order to template the appropriate size of the Bryan disc. Intraoperatively, the patient should be positioned in a physiologic sagittal attitude, not hyper extended. A roll under the neck and a chin halter stabilize the head and neck. An AP x-ray assures perfect anterior-to-posterior position of the vertebrae so that drilling and milling are not performed obliquely. The spinous process should bisect the cervical pedicles. If the spinous process is not in the midline, the surgical table can be rotated slightly. A lateral x-ray is taken with a gravity plumb attached to the C-arm in order to measure the angle of the disc with respect to the vertical. This angle is used to set the intraoperative jig.

2. Intraoperative
A transverse incision is made in a skin crease at the appropriate disc level as verified by the pre-operative fluoroscopic images. Table mounted retractors provide stability and visualization for insertion of the milling jig. The jig is fixed to the vertebral bodies above and below the distracted disc at the appropriate sagittal angle (perfectly parallel to the disc space) as measured by the pre-operative x-ray. A final check of the correct size is made and the endplates are smoothed out with a drill. The endplates are then milled with the correct sized milling tool. The jig is removed with the distracter pins remaining. Decompression of the spinal canal and neural foramen is then performed.

3. Disc Implantation
The artificial disc is filled with saline and gently placed into the milled interspace. The distracter is removed and final x-rays are obtained.

Clinical results:
Human clinical trials of the Bryan cervical disc replacement began in Europe during the year 2000. A prospective, non-randomized single-level trial from six European countries has completed two-year follow-up. A more limited two-level European trial also accomplished final two-year data. The first cervical artificial disc replacement performed in the United States was a Bryan disc implanted in May, 2002 by Rick Sasso, MD. This initiated the ongoing prospective, randomized, multicenter USA study. Worldwide, over 4000 Bryan discs have been inserted. Only seven have been explanted: four due to infection and three because of incomplete neural decompression. There have been no implant failures.

European study
Ninety-seven patients were enrolled in a multicenter trial including 9 surgeons in 7 centers from 6 countries (Belgium, France, Sweden, Germany, Great Britain, and Italy). All patients suffered from a cervical radiculopathy or myelopathy due to a disc herniation or stenosis at one level from C3-4 to C6-7. They were at least 21 years of age and did not respond to non-operative treatment. Exclusion criteria included axial neck pain only, previous spine surgery, radiographic instability, active infection, and metabolic bone disease.

After the one-level Bryan artificial disc replacement, all patients were systematically evaluated by a physician-completed neurologic exam and a patient-completed pain and function outcome instrument. An independent radiologist performed radiographic assessment of motion and device stability. An excellent outcome is defined as improvement in most (80%) of the preoperative signs and symptoms, with little deterioration (not more than 10%). A good functional outcome is improvement in some (70%) of the preoperative signs and symptoms, with some deterioration (not more than 15%). A fair outcome is improvement in half (50%) of the preoperative signs and symptoms, with some deterioration (not more than 20%), and poor is improvement in few (less than 50%) of the preoperative signs and symptoms, or significant deterioration (more than 20%).

As of June 2003, 73 patients achieved 2-year follow-up status. 42 patients were rated as excellent at the one-year and at the two-year follow-up time points. 2 patients were scored as good at both the one-year and the two-year marks. 4 patients were fair at both the one and two-year intervals, and 6 patients were poor at both times. Few patients changed their functional outcome category from one to two years postoperatively with 8 patients improving somewhat and 11 deteriorating slightly. SF-36 functional outcome data demonstrated significant improvement from pre-operative to 3-month post-operative time points, which held stable out to 24 months postoperatively. The physical component summary of the SF-36 instrument averaged 36.0 preoperatively and 44.2 at 3-months after surgery and 45.5 at 24 months. The mental component summary was 41.2 preoperatively, which improved to 51.4 at 3 months postoperatively, and holding steady with an average of 51.0 at 24 months.

Radiographic analysis showed no evidence of subsidence. Motion equal to or greater than 2 degrees was present in 89% of patients at one year and 89% of patients at two years as of June 2003. Average range of motion at both time intervals was 8 degrees. There was one early case of temporary anterior migration of the device (3.0 mm). This was associated with a partially milled cavity.

Complications in this one-level study were: one temporary dysphonia, one evacuation of a postoperative hematoma, and three revision decompressions due to incomplete removal of neural compromise. (One disc fragment, one posterior osteo-

phyte, and one posterior decompression to treat residual myelopathic symptoms.)

In January 2001, a multicenter European trial began to study the results of the Bryan disc implanted at two adjacent levels. The inclusion/exclusion criteria were the same as in the one-level study and the follow-up assessments were also similar. Thirty-nine patients were enrolled from three centers in two countries (Belgium and France).

As of June 2003, 30 patients had reached the one-year endpoint. 14 patients were rated as excellent at both the 6-month and the one-year marks. One patient each had fair and poor outcomes at both time points. Significant improvement occurred from the 6-month to the one-year analysis such that a total of 21 of the 30 patients were rated as excellent at one-year follow-up. SF-36 functional outcome measures similarly improved postoperatively. The physical component summary averaged 37.3 preoperatively and 46.8 at 12 months follow-up. The mental component summary averaged 35.4 preoperatively and improved to 45.2 one-year after surgery.

Radiographic analysis showed no evidence of subsidence in this bi-level study. 84% of patients at one-year follow-up had motion greater than 2 degrees at both artificial disc levels. The average amount of motion occurring in each disc was 8 degrees. One case of temporary posterior migration of the device (less than 3 mm) was observed. This was also associated with a partially milled cavity.

Complications in this bi-level study were: one CSF leak while decompressing posteriorly in the disc space, one pharyngeal/esophageal injury, and surgical evacuation of two retropharyngeal and one epidural hematoma.

Overall, the European study demonstrated good to excellent outcomes in patients with cervical radiculopathy and myelopathy resulting in resolution of neurologic signs and symptoms while restoring range of motion. There was evidence of minimal postoperative migration in two devices, which highlights the importance of complete milling of the vertebral endplates. Also, incorrect intraoperative positioning with relative kyphosis may lead to misaligned shells and subsequent restricted range of motion. There were no device-related surgical interventions or implant failures. It is clear, however, that with a motion sparing implant, inadequate decompression of the symptomatic level may result in ongoing symptoms.

Paravertebral ossification was incidentally discovered on a few randomly selected postoperative CT scans. The ossification was seen anteriorly at the level of the longus colli muscle. This ossification did not result in an ankylosed disc space and was not associated with loss of motion. There did appear to be an association with the lack of use of postoperative non-steroidal anti-inflammatory medications. Based on this observation, John Heller, MD retrospectively evaluated CT scans from 83 patients in the European Bryan disc study. A scoring system was created and the CT scans were assessed for amount of paravertebral ossification and the length of time postoperatively as well as use of non-steroidal anti-inflammatory drugs. Neo-bone formation did not appear to progress with time. If bone was observed anterior to the implant, it tended to be present in the first 100 postoperative days. Significantly less bone was observed among patients treated with postoperative NSAIDs (p=0.00085) compared to the control group. Based on this data, the US study included NSAIDs in the postoperative protocol.

United States study

The US Bryan disc study is a prospective, randomized, multicenter FDA sponsored IDE evaluating one-level cervical radiculopathy or myelopathy due to a focal disc herniation or stenosis. The control arm is a standard anterior cervical discectomy and fusion with allograft bone and an anterior cervical plate. The randomization scheme is 1:1. Objective neurologic deficits must be present preoperatively. Functional outcome is assessed at all intervals with the Neck Disability Index (NDI) and SF-36. Postoperatively, all patients are placed on their NSAID of choice for 2 weeks. Enrollment will be completed this year.

The interim results of the US study match the functional outcome improvements seen in the European study. There have been no device failures and no devices have been explanted. There have been no hematomas or repeat operative procedures for further decompressions. There has been no radiographic evidence of paravertebral ossification.

While we are awaiting the final two-year results of the scientifically rigorous US study, the Bryan disc has been successfully implanted in over 4000 patients worldwide. This is by far the most extensive experience with any cervical artificial disc to date. Of these 4000 cases, only 7 devices have been explanted. All explanted devices have been very stable with exuberant bone growth into the plasma sprayed titanium shells. No devices were removed because of implant failure. This large series has demonstrated the importance of implanting artificial discs with perfect precision. The ability to reliably and reproducibly place the artificial disc in anatomic position is paramount to optimal outcome. Also, adequate neural decompression is extremely important when motion-sparing devices are utilized. With a fusion, the neural elements are protected even if perfect decompression is not obtained. If motion is to be preserved, complete and generous neural decompression cannot be overemphasized.

UPPER CERVICAL SPINE TRAUMA CONTEMPORARY MANAGEMENT

Alexander R. Vaccaro, MD

Upper cervical spine anatomy:
The basion, the apical, dental ligament, opisthion, the anterior atlanto-occipital membrane, the transverse atlantal ligament, the tectorial membrane, the posterior atlantal occipital membrane.

Cross sectional illustration of the upper cervical anatomy- the alar ligaments, the cruciform ligaments, ie: the superior longitudinal fibers, the transverse ligamentous fibers and inferior longitudinal fibers. As well as the accessory C1-C2 ligaments.

Vascular anatomy: the vertebral arteries, the anterior descending artery and the posterior ascending artery, as well as the apical arcade.

Diagnosis:
Complete history and physical is necessary with these injuries, including a complete spine series, AP and lateral. The best imaging study to evaluate the upper cervical spine is a CT scan occiput through C2, as well as an MRI, especially in patients with a neurologic deficient or transverse ligament injury.

Occipital condyle fractures are rare. Up until 1997, there is only 58 living and 38 post-mortem cases reported in the literature. It is very difficult to diagnosis. This was presented by Tuli in Neurosurgery, 1997.

Anderson and Montesano in Spine in 1998 classified occipital condyle fractures based on strain applied to the occipital cervical spine. Type I fractures are comminuted and undisplaced. Type II fractures are a linear fracture through the base of the cranial vault. Type III fractures are avulsions of the condyle, which reveals incompetence of the alar ligament. These fractures are unstable.

Tuli et al developed a classification system in 1997. Stable injuries were Type I, which are undisplaced. Type IIA are stable, appear displaced, but there is no ligamentous injury. The unstable injuries are Type IIB, with an instability of the occipital C1-C2 joint and ligamentous injury.

Instability criteria, Tuli determined instability as being greater than 8 degrees of axial rotation and greater than 1 mm of translation of the occiput on C1.

Treatment: Tuli recommends treatment to be individualized. Type I, no immobilization. Type IIA, hard collar. Type IIB, halo immobilization vs surgical stabilization.

Atlanto-occipital dislocation.
Survival is very unusual and the true incidents is unknown. They account for 0.67 to 1% of all cervical spine trauma.

Types: Traynelis, Journal of Neurosurgery, 1990, discussed three types. Type I results from pure longitudinal forces. Type II, anterior subluxation which is most common as a result of a hyperflexion distraction force. Type III is posterior displacement.

The diagnosis is determined radiographically by the powers ratio. This was published in Neurosurgery, 1979. The average is 0.77, anything greater than 1 is abnormal for anterior subluxation. The ratio is the distance from the basion to the anterior border of the posterior C1 lamina divided by the distance from the opisthion to posterior border of the anterior arch of C1.

Treatment is surgery. Usually a posterior occipital cervical fusion.

Complications. Complications of injuries as a result of Atlanto-occipital dislocation include a unilateral injury to the vertebral basal artery system. This may result in Wallenberg's syndrome, which can manifest as an ipsilateral cranial nerve 5, 9, 10, 11 dysfunction and Horner syndrome on the ipsilateral side, loss of contralateral pain and temperature, as well as cerebellar ataxia. This is discussed in by An in Spine in 1998.

Jefferson fractures
The result of an axial load to the cervical spine. Anterior arch fractures are caused by a flexion vector. Posterior arch fractures are caused by an extension vector. Infrequent neurologic deficits occur secondary to the large space available for the cord.

The classification system described by Levine in Clinical Orthopedics in 1989 discussed several types. Burst fractures occurred in 33%, posterior arch fractures occurred in 28%, comminuted lateral mass injuries occur 22% of the time and anterior arch fractures, transverse process fractures, as well as inferior tubercle have been described.

Radiographic diagnosis. Spence discussed various radiographic indices to determine if there is significant instabilities as a result of a C1 fractures. This was published in JBJS in 1970. An open mouth odontoid view demonstrates the amount of overhang of the C1 lateral mass. Less than 5.7 mm of overhang is normal. If it is greater than 6.9 this is usually abnormal. CT scan, as well as the MRI demonstrating TA disruption are often effective imaging studies.

Treatment. Lee in Spine, 1998 mentioned that the most common treatment is non-operative, which may be a collar or cervicothoracic orthosis. When severely comminuted a Halo may be in the patient's best interest. The question is, should we perform a traction reduction to improve overall symptoms of arthritis.

Atlanto-dens interval. Stability is determined by the integrity of the transverse atlantal ligament. If it is a midsubstance tear, these injuries tend to be extremely unstable and often need surgery in the majority of cases. If there is an avulsion fracture these can be treated non-operatively, at which time follow up MRI study should be obtained.

Treatment. An Spine, 1998, discussed treatment. If there is a midsubstance transverse atlantal ligament, he recommends a fusion from the occiput to C2 or a C1 - C2 Magerl fusion.

Complications. Connolley Spine, 2000 talked about complications of an atlas fracture, this may be a result of greater occipital nerve irritation or dysfunction to cranial nerve 6, 9, 10, 11 and 12.

Atlanto-occipital rotatory subluxation.
Mechanism. The mechanism of injury may be translation, rotation or both.

Rotatory instability. Rotatory instability is more common in children. It presents with suboccipital pain, as well as restricted cervical range of motion. Physical examination reveals obvious cervical rotation and tilt.

Atlanto-occipital rotatory fixation. Fielding in JBJS, 1976, talked about several types of rotatory fixation. It is based on displacement of the ADI. Type I is less than 3.0 mm, Type II is 3.0 to 5.0 mm, Type III is greater than 5.0 mm, and Type IV is posterior displacement of C1 and C2.

Treatment. Fielding has recommended initial traction. Halo and surgery is indicated in acute subluxation in the adult or evidence of chronic instability.

Surgery may include a C1 - C2 fusion. This could be done posteriorly with transarticular Magerl screw, anteriorly or laterally, which also allows for an open reduction. Screws can be used to fixate the joint.

Axis fractures. Axis fractures may involve injuries to the odontoid peg, isthmus, C2 lateral mass and body fractures.

Odontoid fracture classification. The classic classification is by Anderson and Da Lonzo, 1974. Tyle I is an avulsion fracture. Type II is a fracture at the base of the odontoid. Type III is a fracture through the body itself.

Type II fractures have unpredictable healing. They have reported nonunion rates between 0-64%. The reported risks of nonunion are if the fracture is translated greater than 6.0 mm, failed reduction, age greater than 50 or if angulation is greater than 10 degrees.

Treatment. Treatment may be traction, collar, Halo or surgery.

Surgery may be anterior (odontoid screws) or posterior (Brooks fusion or C1, C2 transarticular screws.

Posterior spinal fusion. The Brooks fusion is the gold standard with a 90 to 100% fusion rate. The disadvantages included a decreased range of motion, as well as bone graft donor site morbidity. Transarticular screws provide optimal rigidity.

Odontoid screws may be a single screw or two screws. Biomechanically there has been no significant difference between one or two screws. This was published by Jenkins in Journal of Neurosurgery, 1998.

Jenkins also revealed fusion rate of 81-96% with the use of odontoid screws. A patient would need to have a 9.0 mm outer diameter for two 3.5 mm screws to be placed safely. He found, however, that 66% of the population has an outer odontoid diameter of less than 9.0 mm. He again found there was no difference between one and two screws.

The contraindications to odontoid screw fixation include a ruptured transverse atlantal ligament an irreducible fracture, Comminution of the atlantal axial joint, thoracic kyphosis, barrel-chest, obesity or nonunion.

Type II odontoid fracture, Lennarson Spine, 2000, found that the only significant risk factor for nonunion was age greater than 50. These patients are 21 times more likely to develop a nonunion with Halo treatment.

Hangman's fracture classification. Effendi JBJS, 1981. Described a Type I Hangman's fracture, where there is a fracture bilaterally through the pars with less than 3.0 mm of translation and no angulation.

Hangman's fracture. Type II fracture is greater than 3.0 mm of translation with severe angulation. There may be an anterior compression fracture of the C3 vertebral body.

Type IIA fractures. There is no fracture displacement. There is obvious angulation. This fracture is extremely unstable and traction may cause a pithing of the patient's spinal cord. The anterior longitudinal ligament is intact, however, the PLL and C2, C3 posterior annulus are disrupted.

Type III fracture. Type III fractures reveal significant displacement or angulation in a setting of either unilateral or bilateral facet dislocation of C2 on C3.

The treatment for Type I fractures: a collar or Halo is adequate. Type II fractures are treated with traction and a Halo. Type IIA gets no traction, but should have an extension/compression reduction and halo. Type III is treated with an open reduction and internal fixation with a Halo or a collar

C2 lateral mass fracture. C2 lateral mass fractures occur as a result of axial compression and lateral bending, the diagnosis is usually through an open mouth view, as well as a CT scan.

Jarrett in Skeletal Trauma, 1992, discussed the treatment as being based on the degree of articular involvement. If there is a slight incongruity, a collar may be used. If there is more expensive displacement, traction for realignment and then Halo.

C2 body fractures. These are classified as either avulsion fractures, transverse fractures, burst fractures or sagittal fractures. This is discussed by Fujimura in the Journal of Orthopedic Trauma, 1996.

Treatment. These are inherently stable and nonoperative treatment is always the initial mode of management. Sagittal fractures tend to be unstable and some of them may require surgical intervention.

Precise knowledge of the anatomy and radiographic indices are imperative to treat these successfully. One should have a high index of suspicion for noncontiguous fractures and keep in mind that midsubstance transverse atlantal ligaments are extremely unstable.

Summary: There is a trend now for more aggressive treatment strategies in the elderly.

ANTERIOR CERVICAL PLATES, RECONSTRUCTION TECHNIQUES FOR MULTILEVEL CORPECTOMY AND DISCECTOMY

Jeffrey C. Wang, MD

Anterior Cervical Plates
- Rationale for the use of cervical plates
- Increased stability
- Less need for postoperative immobilization
- Increased fusion rates
- Low complication rates

Advantages for the use of cervical plates
- Kyphosis/alignment
- Pseudarthrosis rates

Disadvantages
- Increased stability with long fusions?
- Rigid
- Stress shield the graft
- Lower fusion rates?
- Overcoming the problems with multi-level fusions?

Types of plates available
- Rigid plates
  - Fixed angle screws
  - Advantages with stability with trauma
  - Disadvantages with bone/graft resorption
  - Hold graft in distraction
- Variable screws
  - Allow for placement of screws at an angle
  - Allow for settling around the screw
  - Partial dynamization
  - Dynamic component bending around screw/plate interface
- Dynamic plates
  - Slotted holes
  - True load sharing with the graft
  - Force in line with the plate/axial loads
  - Control amount of settling
  - More stability or less stability?
  - Impingement on adjacent segments
- Fixed dynamic plates
  - Dynamic plates
  - True graft compression
  - Ends of plate rigidly fixed, allowing for compression along midportion of plate

Results of use of cervical plates
- Anterior cervical discectomy and fusion
  - Single-level fusion
  - Questionable benefit
  - Excellent healing rates
  - Autogenous bone or allograft bone graft introduces another variable
- Multi-level discectomy
  - Increased pseudarthrosis rates
  - Benefit to use of plates
  - Allograft bone graft
  - Compared to corpectomy
- Single-level corpectomy
  - Excellent fusion rates
  - Two graft surfaces needed to heal
  - Plate with excellent stability
- Multi-level corpectomy
  - Three-level corpectomy less stable with plate fixation
  - Increased complication rates with longer fusions
  - Increased stability to a point, then with lower fusion rates

Alternative strategies
- Combination of discectomies/corpectomies
  - Fewer graft surfaces
  - Benefits of corpectomy combined with segmental stability of discectomies
  - Better anchor points for the plate to bone with more points of fixation
  - Incomplete decompression with discectomy
- Corpectomies
  - Subtotal corpectomy with preservation of posterior cortex
  - Three surfaces to ingrow to graft with better healing
  - Less danger to spinal cord
  - Perhaps more stability

Other considerations
- Graft material
  - Biological potential for fusion can increase stability as race to fusion progresses
  - Allograft
  - Cortical allograft
  - Cancellous allograft
    - Difference in incorporation?
- Decompression
  - Need to decompress regardless of fusion techniques
  - Accomplish goals of surgery
- Biological adjuncts
  - Autograft taken from local bone
  - Demineralized bone matrix
  - Bone marrow aspirate
  - Platlet gel materials

CELL-BASED THERAPIES FOR BONE AND CARTILAGE REPAIR – CURRENT STRATEGIES FOR CLINICAL PRACTICE (0)

Moderator: George F. Muschler, MD, Cleveland, OH (a, c, e – NIH-NIAMS, Stryker Biotech, DePuy Spine, Stryker Howmedica Osteonics, Musculoskeletal Transplant Foundation)

Current clinical practice has begun to evaluate and incorporate a variety of clinical strategies that involve the harvest and transplantation of viable cells for regeneration of bone and cartilage tissues. This Symposium will evaluate and review the fundamentals of cell-based tissue engineering of bone and cartilage tissue engineering, the rationale for these methods, pitfalls in implementation, and the current status of outcome studies, in an effort to provide participants with the information needed to make objective judgment regarding the role for these procedures in their current clinical practice.

I. The Clinical Needs and Challenges for Cell-Based Bone and Cartilage Repair and Regeneration
Randy N. Rosier, MD, Rochester, NY (*)

II. The Biological Principles of Stem Cell and Progenitor Cell Therapies
George F. Muschler, MD, Cleveland, OH (a, c, e – DePuy Spine, a – NIH-NIAMS, Musculoskeletal Transplant Foundation, Stryker Biotech, Stryker Howmedica Osteonics)

III. The Engineering Principles of Tissue Engineering
Farshid Guilak, PhD, Durham, NC (a, e – Artecel Sciences, Inc.)

IV. Clinical Strategies and Outcomes using Cell Based Cartilage Repair and Regeneration
Sean P. Scully, MD, Rochester, MN (n)

V. Clinical Strategies and Outcomes using Cell Based Bone Repair and Regeneration
J. Tracy Watson, MD, St. Louis, MO (a – Johnson & Johnson)

CELL-BASED THERAPIES IN FOR BONE AND CARTILAGE REPAIR - CURRENT STRATEGIES FOR CLINICAL PRACTICE"

George F. Muschler, MD

Stem Cell Biology Concepts and Stem Cell Kinetics in Clinical Cell-Based Orthopaedic Therapies

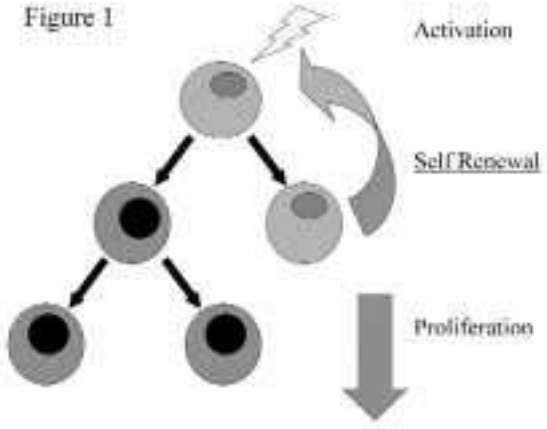
I. Cell Therapy Paradigm of Tissue Engineering
a. All new tissues are made by cells derived from stem cells and progenitor cells
b. All healthy remodeling tissues contain stem cells and progenitor cells
c. No tissue engineering treatment (matrix or growth factor) can be effective without modulating the stem cell and progenitor cell populations

II. The Paradigm of Stem Cells and Progenitor Cells

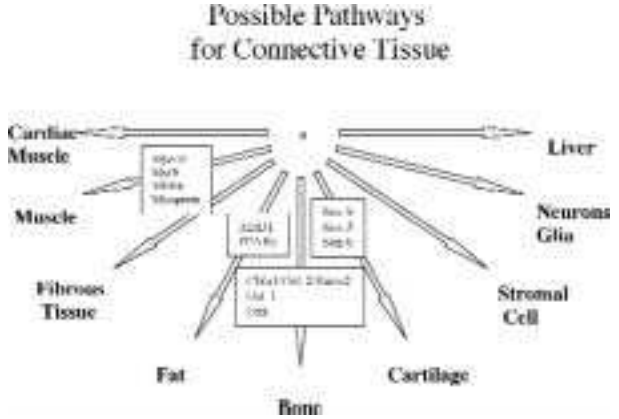
The Stem Cell Life Cycle

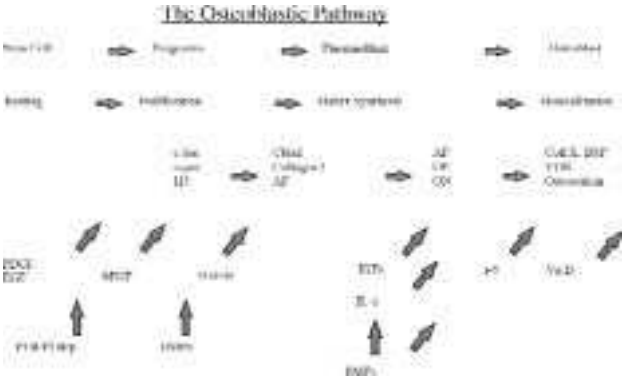
Activation
Self Renewal
Proliferation
Migration
Differentiation
Apoptosis/Death

Self Renewal

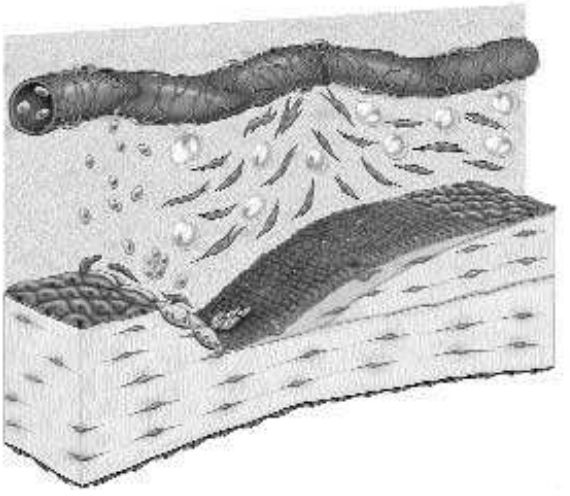


Multipotentiality and Lineage Restriction/Committment

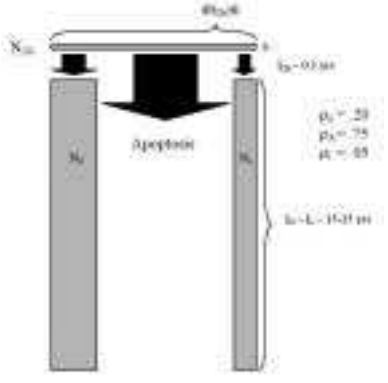




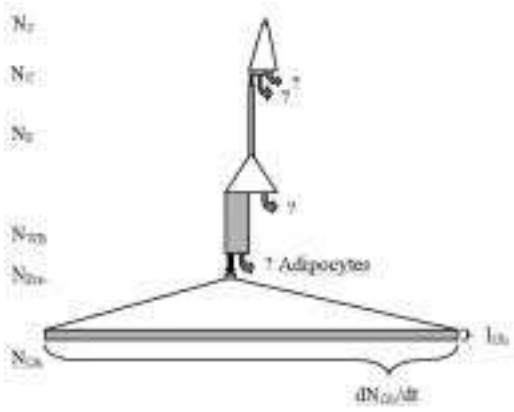
Stem Cell and Progenitor Cell Compartments



IV. Kinetics downstream from the Osteoblast



V. Kinetics Upstream from the Osteoblast



VI. Practical Issues in Cell-Based Tissue Engineering

A. Cell Based Tissue Engineering Strategies
- a. Cell Targeting
  - i. conductive materials
  - ii. promotive stimuli
  - iii. inductive stimuli
    1. local delivery
    2. local expression
    3. systemic delivery
- b. Cell Homing / Cell Recruiting
- c. Cell Transplantation
  - i. Harvest
  - ii. Manipulation
    1. Concentration
    2. Selection
    3. Ex vivo treatment (e.g. soluble factors)
- d. Cell Modification
  - i. Ex vivo expansion
  - ii. Ex vivo modification of Maturation state
  - iii. Engineering Gene expression
    1. transformation
    2. transfection

B. Sources of Stem Cells and Progenitors
- Osteogenic Cells
  - Marrow
  - Peritrabecular cells
  - Perivascular cells
  - Periosteum
  - Muscle
  - Fat
- Chondrogenic cells
  - Marrow
  - Periosteum
  - Perichondrium
  - Physis

C. Mass Transport as a Metabolic Barrier to Cell Transplantation

Necrosis of Cells within a transplanted cellular graft is dependent upon five key variables:
- Cell Number in the graft site
- Metabolic Demand of the transplanted cells
  - Transplanted cells
  - Inflammatory Cells
- Oxygen Concentration at the surface of the graft
- Diffusion and Convection within the graft site
- Cellular response to hypoxia

REFERENCES

Fleming - Cell Biology of Bone Tissue Engineering

1. Muschler GF, Boehm C, Easley K: Aspiration to obtain osteoblast progenitor cells from human bone marrow: the influence of aspiration volume. J Bone Joint Surg Am 79:1699-1709, 1997.
2. Bauer TW, Muschler GF: Bone graft materials. An overview of the basic science. Clin Orthop 371:10-27, 2000.
3. Fleming JE, Jr., Cornell CN, Muschler GF: Bone cells and matrices in orthopedic tissue engineering. Orthop Clin North Am 31:357-374, 2000.
4. Lieberman JR: Orthopaedic gene therapy. Fracture healing and other nongenetic problems of bone. Clin Orthop 379 Suppl:S156-158, 2000.
5. Muschler GF, Midura RJ: Connective Tissue Progenitors : Practical Concepts for Clinical Applications. Clin Ortho 395:66-80, 2002.
6. Cheng H, Jiang W, Phillips FM, et al: Osteogenic activity of the fourteen types of human bone morphogenetic proteins (BMPs). J Bone Joint Surg Am 85-A:1544-1552, 2003.
7. Muschler GF, Midura RJ, Nakamoto C: Practical Modeling Concepts for Connective Tissue Stem Cell and Progenitor Compartment Kinetics. J Biomed Biotechnol 2003:170-193, 2003.
8. Muschler GF, Nitto H, Matsukura Y, et al: Spine Fusion Using Cell Matrix Composites Enriched in Bone Marrow-Derived Cells. Clin Orthop 407:102-118, 2003.
9. Muschler G, Nakamoto C, Griffith L: The Engineering Principles of Clinical Cell-Based Tissue Engineering. J Bone Joint Surg Am, 2003 in press.

CLINICAL CELL BASED CARTILAGE REPAIR TECHNIQUES

Sean P Scully, MD, PhD

I. Historical Views on Cartilage Repair
Hunter, 1743 "Damage to cartilage does not heal"
Intrinsic repair: A process confined to surrounding cartilage tissue. An intrinsic repair process has not been demonstrated in damaged cartilage to date
Extrinsic repair: A process which involves the introduction of heterotopic tissue. There have been many attempts to provide a functional joint surface with biologic tissues such as fascia, periosteum, mesenchymal marrow elements, and inorganic materials
Chondrocyte Grafting: Intrinsic or extrinsic

II. Chondrocyte Function
ECM synthesis: Maintain proteoglycan and non-collagenous proteins in the extracellular matrix

III. Cartilage Structure
Benninghof cascades
Tangential/ radial zones

IV. Cartilage biomechanical properties
Cartilage mechanical properties are a results of the complex structure of the tissue

V. What type of Cartilage Repair are we trying to attain? (R Poole, JBJS, 2003)
Restoration of mechanical properties, integration, and arresting pathologic process

VI. Evaluation of Results
Clinical Symptoms
Arthroscopy
Biochemical Determination
Biomechanical Determination
Monitored non invasively by MRI recently
Monitor composition
Evaluate integration

VII. Cell-Based Therapy Strategies
Cell Targeting – Utilization of local cells
Cell Transplantation – Delivery of chondrogenic cells into the wound site.

VIII. Cell Targeting as a Strategy
Local delivery of cytoknes as a means of stimulating primary repair by local cells

IX. Cell Transplantation Strategies
Mosaicplasty
? doomed from the outset since removal destroys as much healthy tissue as the diseased being treated
Osteoarticualr allografts (Czitrom, JBJS, 1990)
- ?immunologic implications
- 65-85% clinical success rates (Mahomed et al ,Orthop, 1992)
- Scarcity of donor material
- Urgency of surgical procedures

Autogenous Chondrocyte Implantation
Brittenberg et al: process involves the harvest and in vitro proliferation of articular chondrocytes and transplantation under a periosteal patch graft.
- Implanted cells persist for at least 14 weeks in animal models (Accico, JOR, 2003)
- Implanted chondrocytes contribute to structural repair:
- A switch from type II to type I collagen production
- A change in glycosaminoglycan chain length
- ? other non collagenous protein changes
- This phenotypic drift results in synthesis of matrix components that are non-physiologic for articular cartilage and hence an anticipated inferior mechanical tissue
- Redifferentiation of the chondrocyte phenotype occurs under certain in vitro culture conditions:

Periosteum
- Limited clinical application
- 50-80% improved symptoms
- Size of isolated defects
- Age of patient

Mesenchymal cells as a means of gene therapy delivery
(Martinek, JBJS-Br, 2003)
- Ex vivo approaches in contrast to in vivo
- Stem cells (Grande et al, JBJS, 2003)

BMP-7 ,sonic hedgehog enhanced quality of repair tissue
- Chondrocytes (Hidaka et al, JOR, 2003)
- BMP-7: no difference in repair tissue at 8 months and no evidence of persistent implanted cells
- Periosteal cells

X. Tissue Engineering
"Tissue engineering cannot be viewed simply as a recapitulation of the embryonic differeniation" (Hunziker, Osteo and Cart, 2001)

XI. Clinical Comparisons
Mosaicplasty vs ACI? (Horas et al, JBJS, 2003)
Prospective randomized study
Both improved symptoms OC > ACI
ACI ‡ fibrocartilage
OC ‡ hyaline cartilage
Lack of integration

XII. Unanswered Questions:
? recreate mechanical properties
? Long term consequences

REFERENCES

1. Dell'Accio, F., et al., Expanded phenotypically stable chondrocytes persist in the repair tissue and contribute to cartilage matrix formation and structural integration in a goat model of autologous chondrocyte implantation. J Orthop Res, 2003. 21(1): p. 123-31.
2. Grande, D.A., et al., Stem cells as platforms for delivery of genes to enhance cartilage repair. J Bone Joint Surg Am, 2003. 85-A Suppl 2: p. 111-6.
3. Hidaka, C., et al., Acceleration of cartilage repair by genetically modified chondrocytes over expressing bone morphogenetic protein-7. J Orthop Res, 2003. 21(4): p. 573-83.
4. Horas, U., et al., Autologous chondrocyte implantation and osteochondral cylinder transplantation in cartilage repair of the knee joint. A prospective, comparative trial. J Bone Joint Surg Am, 2003. 85-A(2): p. 185-92.
5. Martinek, V., P. Ueblacker, and A.B. Imhoff, Current concepts of gene therapy and cartilage repair. J Bone Joint Surg Br, 2003. 85(6): p. 782-8.
6. Roberts, S., et al., Autologous chondrocyte implantation for cartilage repair: monitoring its success by magnetic resonance imaging and histology. Arthritis Res Ther, 2003. 5(1): p. R60-73.
7. Wakitani, S., et al., Human autologous culture expanded bone marrow mesenchymal cell transplantation for repair of cartilage defects in osteoarthritic knees. Osteoarthritis Cartilage, 2002. 10(3): p. 199-206.

BONE REPAIR AND BONE FUSION

J. Tracy Watson

I. BONE MORPHOGENESIS CASCADE – CLINICAL MANIPULATION OF CELL-BASED REPAIR PROCESS

Critical Cells:

Mesenchymal Stem Cells (MSCs) – upstream self-renewing stem cells that can be activated to form progeny that can go on to form multiple connective tissue phenotypes (i,e, connective tissue progenitors).

Connective Tissue Progenitors (CTPs) – defined as all cells that can be activated to proliferate and to form one or more connective tissue phenotypes (including bone). This includes self renewing MSCs as well as all down stream stem cells and progenitors.

Critical Cell Functions:

Activation
Attachment
Migration
Proliferation
Differentiation
Survival

1) Cell Attachment/migration –
   a. Binding of fibronectin from plasma to implants (e.g. demineralized bone matrix)
   b. Natural adhesion molecules in tissue matrices (collagen, fibronectin, osteonectin, osteopontin, bone sialoprotein)

   Facilitates mesenchymal stem cell (MSC) and connective tissue progenitor cell (CTP) attachment, migration, and proliferaton.....(this is the basis for cellular implantation.....i.e. cellular transplantation, concentration and implantation of autogenous MSC harvesting)
2) Activation/Proliferation/Mitogenesis – resulting from soluble factors (e.g. PDGF, EGF, FGF) or matrix bound signals from extracellular matrix.
3) Differentiation
   a. Chondro/osteoblast differentation and chondro/osteogenesis
   b. Angiogenesis and vascular invasion
   c. Endochondral bone formation
   d. Osteoinduction with bone morphogens (i.e. soluble, matrix bound or secreted factors)

   Osteoinduction = Stimulation of undifferntiated perivascular mesenchymal stem cells (MSC) and connective tissue progenitors (CTPs) leading to the formation of preosteoblasts and osteoblasts.

Current Strategies:

Cell Targeting
Cell Transplantation

II. PRACTICAL APPLICATIONS OF CELL-BASED APPROACHES

A. CELL TARGETING

Cell targeting includes methods that are used to enhance the performance of the local stem cells and progenitor cells that are present in our graft sites, without transplantation of additional cells.

These methods include the use of osteoconductive matrix materials, as well as biological stimulants that are discussed below.

Platelet Released Factors

Following acute fracture or operative interventions, platelets are activated by thrombin and binding to subendothelial collagen with the subsequent release of their granules into the wound environment. Platelet released factors include (TGF-_-1, PDGF-AB, IGF-1, EGF, VEGF) Some of these factors are being developed as possible therapeutic agents to be used and delivered as a single protein.

Platelet released factors have multiple biological effects:

Angiogenesis - formation of blood vessels
Activation/Proliferation/Migration of MSCs and CTPs
Chemotaxis – acute inflammatory signals - monocytes, macrophages, and the further aggregation of platelets…

The role of platelet released factors in enhancing activation, proliferation, and migration of MSCs and CTPs has been referred to as "osteo-PROMOTIVE"

This is distinguished from "osteo-INDUCTIVE" (defined below)

Platelet Concentrates / Platelet Gels

The ability to deliver a concentrated amount of platelets would intuitively help to contribute to these early stages of bone repair and thus "jump start" the entire fracture healing cascade. Based on this assumption several strategies for platelet concentration and delivery have been developed

Basic Science / Pre-Clinical Studies:

1) Platelet Stimulation of Osteogenic Activity
   Slater et al. J Orthop Res 1995;13:655-63. "The very large biological effect of a small volume of platelet supplement may have been a reflection of the interactive and possibly synergistic effects of the multiple platelet- derived growth factors." Authors conclusions: That platelets may play an important role in early healing of fractures and may be useful as a CHEAP autologous source of multiple growth factors to enhance osteoblast proliferation in vivo.
2) Large volume of additional initial work was performed in maxillofacial research evaluating effectiveness of augmenting bone formation around titanium dental implants documenting increased bone deposition with APG (autogenous platlet gel).
   a) Evaluation of larger alveolar, sinus and cranial defects treated with PRP alone demonstrated NO significant improvement radiographically or histomorphometrically in terms of bone formation and healing of these defects.
   b) Improved results were seen when APG was combined with various materials....autograft, allograft, CaSO4, HA, and TCP,.... in terms of defect healing. Results better than with the graft material alone (i.e without addition of APG)
3) Concept of Composite grafting utilizing APG as carrier for other materials. Ip, TH. Dent Imlantol Update 2003;14(2): 9-14 Clinical basis for "composite grafting".Utilizing iliac aspirates (concentrates) with combinatons of platelet gel as "carrier" and DBM composites. Clinical results with 78 patients and average 2 .5 year follow-up.
4) Exogenous TGF-_, and PDGF studied in several critical size defect models of bone regeneration, fracture healing, and distraction osteogenesis, with most studies showing increased bone or callus formation and increased mechanical stability. Additionally PDGF has been shown to be a potent mitogen stimulating periosteal derived cells. However the factors appear to be much less potent in terms

of the dramatic direct bone formation that occurs with the true BMP'S (BMP-2,BMP-4, BMP-7)
5) Positive wound healing effect secondary to mitogenic potency of PDGF on keratinocytes and endothelial cells. PDGF found to be a major proliferative and migratory stimulus for connective tissue cells during the initiation of wound repair processes. (Plastic surgery literature)

Platelet derived factors appear to act as a mitogenic and proliferative stimulus on the particular tissue at hand, and these target tissues respond by undergoing a generalized histogenesis of that particular type. These factors noted to have a global application and effect..i.e.will stimulate a whole variety of tissue types dependent on the location where the stimulus occurs...LOCATION SPECIFIC EFFECT....True BMP'S by contrast will form bone irregardless of the stimulus site...TISSUE SPECIFIC EFFECT

Clinical Studies:
Platlet gel applications - published
1) Six human studies using APG found in dental literature documenting increased bone deposition, bone regeneration, and augmentation of dental implant replacement and dental defects.
2) Orthopaedic spine surgery, 2 human clinical studies demonstrating statistical increase in fusion rates with PRP augmentation of graft composites.
3) Orthopaedic traumatology, (multiple case reports/ abstracts) documenting effectiveness of use of APG as carrier for various alloplastic graft substitutes and achieving enhanced graft incorporation.
4) Recent controversy

Current Clinical Options For Platelet Concentrates:
Conclusions:
1) Basic science literature strongly supports the positive effects and cellular stimulation by APG as a mechanism for bone repair as well as generalized stimulation of host tissue contacts.
2) Considered an Osteopromotive factor vs. true Bone Morphogenes which are Osteoinductive. Therefore is NOT indicated as a sole adjuvant to fracture healing and should be utilized in combination with various auto/alloplastic composites.
Safety and cost concerns of APG and true BMP's vs other adjuvant therapies
Few published prospective comparative studies currently lacking…

Bone Morphogenetic Proteins
Recombinant BMPs have a direct effect on the MSC and CTP populations inducting preferential differentiation onto tissue specific precursors....i.e. osteoblasts/ osteocytes. True "osteoINDUCTIVE" substances.

All these factors have to act thru a competent cells that have appropriate receptors for these factors.

These agents are sensitive to concentration, and require a therapeutic concentration to bel delivered to a site in order to have an optimal effect.

The carrier that is used to deliver these agents also influences efficacy. Bovine Collagen is used in both InFuse and the OP-1 device. The carrier serves to bind the factor and retain it at the site for a longer period of time. The carrier may also help to protect the protein from degradataion and to present the protein to cells in a desired conformation. The carrier may also serve to increase the effective concentration of the protein by concentrating it at the surface of the matrix.

Preclinical Experience
A large volume of work with BMPs have shown that these proteins can be purified and delivered into wound sites in rats, rabbits, dogs, goats, sheep, and non-human primates in a manner that significantly enhances the formation of new bone.

Clinical Experience
Two important clinical trials have been completed and have resulted in the release of BMP protein products for specific clinical applications. Several clinical trials are on going to evaluate the use of BMPs in other clinical settings.

Anterior Interbody Fusion Trial (BMP-2)
OP-1 Clinical Trial for treatment of established tibial non-unions (OP-1/BMP-7)

CELL TRANSPLANTATION
Cell transplantation can be done using autograft cancellous bone. Transplantation of cells in this way is remains the "gold standard" for bone grafting. However this results in significant morbidity, leading an increasing number of surgeons to look for alternative cell sources for transplantation.

Bone Marrow Aspirates
Bone marrow aspirates contain MSCs and CTPs that can provide a transplantable source of osteoblastic progenitors. By limiing aspiration volume to 2 ccs from any given needle site, the concentration of bone marrow derived cells that are capable of osteogenesis can be enhanced, by limiting dilution with peripheral blood (JBJS 79A:1699-709, 1997).

Preclinical Experience
Addition of bone marrow to a variety of bone grafting materials has been shown in an extensive literature to significantly enhance the performance virtually every bone grafting material, even in young healthy animals, in whom one would not expect the population of stem cells or progenitors to be deficient.

Clinical Experience
Connolly et al – Bone marrow was used as a bone graft to successfully heal tibial non-unions.

Bone Marrow Concentration using a Centrifuge

Preclinical Experience
Increasing the concentration of marrow derived nucleated cells significantly ehnahnced bone formation in an animal model. Connolly, J., R. Guse, et al. (1989). "Development of an osteogenic bone-marrow preparation." J Bone Joint Surg Am 71(5): 684-91.

Clinical Experience
Only small clinical series have been reported to date, using bone marrow concentrates prepared using a centrifuge (J. Connolly, P. Hernigou)

Bone Marrow Cell Selection and Retention

Preclinical Experience
Bone marrow-derived osteogenic stem cells and progenitor cells (MSCs/CTPs) can be rapidly concentrated and selected using the surface of some implantable biomaterials as an affinity column. This method increases the number of MSCs and CTPs that can be delivered into a graft site and also reduces the number of cells that these transplanted progenitors compete with for survival in the graft site.

Cellular grafts enhanced in this way have been shown to have greater efficacy than grafts prepared using bone marrow aspirates alone with the same matrix. (Muschler et al CORR 407: 102-118, 2003; Kadiyala, NASS 2002, Brodsky D, NASS 2003)

Clinical Experience

Only small clinical series have been reported to date, using bone marrow concentrates prepared using selective retention strategies. (Lieberman, et all NASS 2003)

BIBLIOGRAPHY:

1. Rasubala L, Yoshikawa H, Nagata K, Iijima T, Ohishi M. Platelet-derived growth factor and bone morphogenetic protein in the healing of mandibular fractures in rats.Br J Oral Maxillofac Surg. 2003 Jun;41(3):173-8.
2. Ip TH. Using platelet-rich plasma to enhance a composite graft in the maxillary sinus. Dent Implantol Update. 2003 Feb;14(2):9-14.
3. Danesh-Meyer MJ, Filstein MR, Shanaman R. Histological evaluation of sinus augmentation using platelet rich plasma (PRP): a case series. J Int Acad Periodontol. 2001 Apr;3(2):48-56.
4. Sanchez AR, Sheridan PJ, Kupp LI. Is platelet-rich plasma the perfect enhancement factor? A current review. Int J Oral Maxillofac Implants. 2003 Jan-Feb;18(1):93-103.
5. Schilephake H. Bone growth factors in maxillofacial skeletal reconstruction. Int J Oral Maxillofac Surg. 2002 Oct;31(5):469-84. Review.
6. Lieberman JR, Daluiski A, Einhorn TA. The role of growth factors in the repair of bone. Biology and clinical applications. J Bone Joint Surg Am. 2002 Jun;84-A(6):1032-44. Review.
7. Tischler M. Platelet rich plasma. The use of autologous growth factors to enhance bone and soft tissue grafts. N Y State Dent J. 2002 Mar;68(3):22-4.
8. Kim SG, Chung CH, Kim YK, Park JC, Lim SC. Use of particulate dentin-plaster of Paris combination with/without platelet-rich plasma in the treatment of bone defects around implants. Int J Oral Maxillofac Implants. 2002 Jan-Feb;17(1):86-94.
9. Bhanot S, Alex JC. Current applications of platelet gels in facial plastic surgery. Facial Plast Surg. 2002 Feb;18(1):27-33.
10. Anitua E. The use of plasma-rich growth factors (PRGF) in oral surgery. Pract Proced Aesthet Dent. 2001 Aug;13(6):487-93; 93.
11. Schmitz JP, Hollinger JO. The biology of platelet-rich plasma. J Oral Maxillofac Surg. 2001 Sep;59(9):1119-21.
12. Stefani CM, Machado MA, Sallum EA, Sallum AW, Toledo S, Nociti FH Jr. Platelet-derived growth factor/insulin-like growth factor-1 combination and bone regeneration around implants placed into extraction sockets: a histometric study in dogs. Implant Dent. 2000;9(2):126-31.
13. Lee YM, Park YJ, Lee SJ, Ku Y, Han SB, Klokkevold PR, Chung CP. The bone regenerative effect of platelet-derived growth factor-BB delivered with a chitosan/tricalcium phosphate sponge carrier. J Periodontol. 2000 Mar;71(3):418-24.
14. Lane JM, Tomin E, Bostrom MP. Biosynthetic bone grafting. Clin Orthop. 1999 Oct;(367 Suppl):S107-17.
15. Lowery GL, Kulkarni S, Pennisi AE. Use of autologous growth factors in lumbar spinal fusion. Bone. 1999 Aug;25(2 Suppl):47S-50S.
16. Anitua E. Plasma rich in growth factors: preliminary results of use in the preparation of future sites for implants. Int J Oral Maxillofac Implants. 1999 Jul-Aug;14(4):529-35.
17. Kim WJ, Mohan RR, Mohan RR, Wilson SE. Effect of PDGF, IL-1alpha, and BMP2/4 on corneal fibroblast chemotaxis: expression of the platelet-derived growth factor system in the cornea. Invest Ophthalmol Vis Sci. 1999 Jun;40(7):1364-72.
18. Arm DM, Tencer AF, Bain SD, Celino D. Effect of controlled release of platelet-derived growth factor from a porous hydroxyapatite implant on bone ingrowth. Biomaterials. 1996 Apr;17(7):703-9.
19. Andrew JG, Hoyland JA, Freemont AJ, Marsh DR. Platelet-derived growth factor expression in normally healing human fractures. Bone. 1995 Apr;16(4):455-60.
20. Nash TJ, Howlett CR, Martin C, Steele J, Johnson KA, Hicklin DJ. Effect of platelet-derived growth factor on tibial osteotomies in rabbits. Bone. 1994 Mar-Apr;15(2):203-8.
21. Canalis E, Varghese S, McCarthy TL, Centrella M. Role of platelet derived growth factor in bone cell function. Growth Regul. 1992 Dec;2(4):151-5. Review.
22. Servold SA. Growth factor impact on wound healing. Clin Podiatr Med Surg. 1991 Oct;8(4):937-53. Review.
23. Mustoe TA, Purdy J, Gramates P, Deuel TF, Thomason A, Pierce GF. Reversal of impaired wound healing in irradiated rats by platelet-derived growth factor-BB. Am J Surg. 1989 Oct;158(4):345-50.
24. Ross R, Raines EW, Bowen-Pope DF. The biology of platelet-derived growth factor. Cell. 1986 Jul 18;46(2):155-69. Review. No abstract available.
25. de Obarrio JJ, Arausz-Dutari JI, Chamberlain TM, The use of autologous growth factors in periodontal surgical therapy: platelet gel biotechnology – case reports. Int J Periodontics Restorative Dent. 2000 Oct;20(5)486-97.
26. Aghaloo TL, Moy PK, Freymiller EG. Investigation of platelet-rich plasma in rabbit cranial defects: A pilot study. J Oral Maxillofac Surg. 2002 Oct;60(10):1176-81
27. Kassolis JD, Rosen PS, Reynolds MA. Alveolar ridge and sinus augmentation utilizing platelet-rich plasma in combination with freeze-dried bone allograft: case series. J Periodontol. 2000 Oct;71(10):1654-61.
28. Slater M, et al. Involvement of Platelets in Stimulating Osteogenic Activity J Ortho Research 13:655-663, 1995.
29. Lariviere B, Rouleau M, Picard S, Beaulieu AD. Human plasma fibronectin potentiates the mitogenic activity of platelet-derived growth factor and complements its wound healing affects. Wound Repair Regen. 2003 Jan-Feb;11(1):79-89.
30. Marx RE, Carlson ER, Eichstaedt RM, et.al Platelet Rich Plasma, Growth Factor Enhancement for Bone Grafts Oral Surg and Enodontics June 1998,85(6)
31. Rosier RN, O'Keefe RJ, Hicks DG. The potential role of transforming growth factor beta in fracture healing. Clin Orthop. 1998 oct;(355 Suppl):S294-300.
32. Lammens J, Liu Z, Aerssens J, Dequeker J, Fabry G. Distraction bone healing versus osteotomy healing: a comparative biochemical analysis. J Bone Miner Res. 1998 Feb;13(2):279-86.
33. Yazawa M, Ogata H, Nakajima T, Mori T, Wantanabe N, Handa M. Basic studies on the clinical applications of platelet-rich plasma. Cell Transplant. 2003;12(5):509-18.
34. Uhl E, Rosken F, Sirsjo A, Messmer K. Influence of platelet-derived growth factor on microcirculation during normal and impaired wound healing. Wound Repair Regen. 2003 Sep-Oct;1195):361-7.
35. Gruber R, Karreth F, Frommlet F, Fischer MB, Watzek G. Platelets are mitogenic for periosteum-derived cells. J Orthop Res. 2003 Sep;21(5):941-8.
36. Cross KJ, Mustoe TA. Growth factors in wound healing. Surg Clin North Am. 2003 Jun;83(3):531-45, vi.
37. Gope R. The effect of epidermal growth factor & platelet-derived growth factors on wound healing process. Indian J Med Res. 2002 Nov;116:201-6.
38. Lowery GL, Kulkarni S, Pennisi AE, Use of Autologous Growth Factores in Lumbar Spinal Fusion Bone 25(2): 47-50, 1999.
39. Friedlander, et.al..Randomized Prospective Treatment of Tibial Non-unions: OP-1 vs Autograft. JBJS 83-A: S1-151, 2001
40. Govender, S. et.al. Recombinant Human Bone Morphogenic Protien-2 for The Treatment of Open Tibia Fractures. JBJS 93A: 234-240, 2002
41. Muschler. GF. et.al. Aspiration to Obtain Osteoblast Progenitor Cells from Human Bone Marrow: The Influence of Aspiration Volume. JBJS 79A: 1699-1708. 1997.

CAN KNEE ARTHROSIS BE PREVENTED FOLLOWING SPORTS INJURY? (P)

Moderator: Scott F. Dye, MD, San Francisco, CA (n)

A new orthopaedic theory, based on the principle of tissue homeostasis, predicts that the development of joint arthrosis following injury should be both predictable and preventable. This symposium will present the latest evidence from orthopaedic clinical and basic science, as well as molecular imaging demonstrating that the prevention of arthrosis of the sports injured knee is indeed possible. The principles presented in this symposium have broad implications within the field of orthopaedic surgery for the potential early detection, prevention and control of arthrosis.

I. Introduction, Persistent Loss of Osseous: A Precursor to Degenerative Knee Arthrosis
Scott F. Dye, MD, San Francisco, CA (n)

II. Structural/Anatomic Factors in the Development of Knee Arthrosis
Robert J. Johnson, MD, Burlington, VT (n)

III. Neuromuscular Factors in the Development of Knee Arthrosis
Edward M. Wojtys, MD, Ann Arbor, MI (n)

IV. Metabolic/Pathophysiologic Factors in the Development of Knee Arthrosis
Steven P. Arnoczky, DVM, Lansing, MI (n)

V. The Detection of Prevention of Post-Traumatic Knee Arthrosis: The Clinical Data
Scott F. Dye, MD, San Francisco, CA (n)

PERSISTENT LOSS OF OSSEOUS HOMEOSTASIS: A PRECURSOR TO DEGENERATIVE KNEE ARTHROSIS.

Scott F. Dye, MD

The development of post traumatic knee arthrosis (e.g., post-meniscal injury or post-anterior cruciate ligament rupture) is one of the most common conditions managed by orthopaedic surgeons worldwide.

The actual dynamics of the natural history of post-traumatic knee arthrosis are not known.

However, new orthopaedic theory, based on the principle of tissue homeostasis indicates that the development of post-traumatic arthrosis should be both predictable and preventable.

The tissue homeostasis theory was initially developed to provide a more rational explanation and treatment approach to patients with patellofemoral pain - that the current structural paradigm (e.g., chondromalacia patellae, and malalignment) could not.

Tissue homeostasis theory provides the added dimension of a dynamic biological perspective of living musculoskeletal systems.

The tissue homeostasis theory views all joints as living metabolically active biologic transmission systems evolutionarily designed to accept, redirect, and ultimately dissipate a variety of biomechanical loads.

A new definition of joint function that followed from the tissue homeostasis theory is that for truly normal function the involved musculoskeletal system must be able to generate (muscles as cellular engines), accept, redirect, and dissipate a range of loads and yet maintain tissue homeostasis while doing so.

A new method of representing this capacity arose from this perspective. The Envelope of Function is a load/frequency distribution which delineates that range of loads that can be safely withstood by a joint or musculoskeletal system and still maintain tissue homeostasis. This will be explained in fuller detail later.

A clinical example of post-traumatic post-treatment arthrosis is represented by the development of degenerative arthrosis following anterior cruciate ligament reconstructed knees.

A potentially vast epidemic of post-ACL reconstruction degenerative arthrosis is apparently occurring world wide.

Why is this happening if the rationale of ACL reconstruction is to "restore function" and "prevent the development of arthritis"?

Not all unreconstructed anterior cruciate ligament deficient knees develop degenerative arthrosis. Why not?

The answer is that the load transference capacity of the ACL deficient knee (the Envelope of Function) is rarely restored following ACL reconstruction, despite the achievement of seemingly normal structural/biomechanical characteristics (e.g., normal KT-1000, range of motion, muscle strength, etc.)

If a patient loads such a joint out of the Envelope of Function - i.e., into the zone of supraphysiologic overload - tissue homeostasis will be lost, documented in bone by a positive technetium bone scan. If sufficiently prolonged, this will result in the development of overt radiographically identifiable degenerative changes, i.e., Fairbank changes.

Yet, if the joint is loaded within it's Envelope of Function, tissue homeostasis theory predicts that resolution and indefinite maintenance of tissue homeostasis of the entire joint is possible without the development of osteoarthrosis. Many knees that lack a functional ACL and have not been reconstructed can remain free of degenerative changes even after 20 years, and beyond, despite manifesting abnormal clinical laxity (e.g., abnormal Lachman's or pivot shift tests.)

Best to avoid the development of overt degenerative arthrosis by tracking our patients post-treatment (including post-operatively) with technetium bone scintigraphy at 1-2 years and repeated as necessary, particularly if even slight symptoms are present.

FURTHER EXPLANATION OF THE TISSUE HOMEOSTASIS THEORY

The knee functions as a type of living biologic transmission whose function it is to accept and redirect a range of biomechanical loads and still maintain tissue homeostasis. Within the knee/transmission, the ligaments act as non-rigid adaptable linkages, the articular cartilage as bearings, and the menisci as mobile sensate bearings. The muscles function as molecular and cellular engines that in concentric contraction provide motive forces across the knee, and in eccentric contraction absorb biomechanical loads.

The anterior cruciate ligament function as a sensate adaptive non-rigid linkage within the biologic transmission. Damage to the ACL thus represents the loss of an important linkage within the transmission, leaving it vulnerable to increased functional laxity.

The genesis of painful knee arthrosis can follow overt trauma but most often begins with a loss of osseous homeostasis that precedes radiographic evidence (i.e., radiographically identifiable structural changes - joint space narrowing, development of osteophytes, etc.) Work by McBride and colleagues have provided experimental confirmation of this concept in an animal model.

Even structurally normal appearing post-operative ACL reconstructed knees can be easily loaded out of the Envelope of Function resulting eventually in the development of arthrosis. A positive technetium bone scan thus identifies joints at risk of the development of degenerative arthrosis before it happens -- this is at a time when it is still possible to reverse the development of overt degenerative changes.

A theoretical model of osseous homeostasis developed by myself and Dr Mailine Chew interrelates increased osseous remodeling in various biomechanical triggers. (See fig 1)

The Envelope of Function is a method to represent the capacity of the living knee (or any joint or musculoskeletal system) to generate, accept, transmit, and dissipate biomechanical loads. It is clear that a certain threshold of increased loading/frequency of loading is inductive of loss of tissue homeostasis. The range of safe loading (i.e., compatible and even inductive of tissue homeostasis) is defined by the Envelope of Function. This Envelope is a unique property of individual knees and musculoskeletal systems. As long as loading is transmitted within the Envelope of Function no loss of tissue homeostasis occurs.

Within a certain range of loading (the Envelope of Function) an individual patellofemoral joint maintains tissue homeostasis and can function normally indefinitely. However, when a sufficiently great load is placed across the patellofemoral joint (loading within the zone of structural failure), overt structural damage can occur,

e.g., fracture of the patella, that can obviously lead to irreversible symptomatic arthrosis. Not infrequently, however, such a fracture can heal without the initiation of chronic patellofemoral symptoms. Loading greater than within the Envelope of Function, but less than in the zone of structural failure is represented by loading within the zone of supraphysiologic overload. Single or multiple events of such excessive loading can lead to loss of tissue homeostasis of both cartilage and bone resulting in the development of irreversible degenerative changes of the patellofemoral joint. Experimental evidence in animal models confirms this possibility.

However, when a sufficiently great load is placed across the knee, loading within the zone of structural failure, overt structural damage can occur, e.g., fracture of the tibial plateau, that can, obviously, lead to irreversible symptomatic arthrosis.

Loading greater than within the Envelope of Function, but less than in the zone of structural failure is represented by loading within the zone of supraphysiologic overload. Single or multiple events of such excessive loading can lead to loss of tissue homeostasis of both cartilage and bone resulting in the development of irreversible degenerative changes of the patellofemoral joint. Experimental evidence in animal models confirms this possibility.

Four factors are believed to determine the Envelope of Function. These factors are:

- Anatomic/Structural
- Kinematic/Neuromuscular
- Physiologic/Metabolic
- Treatment
  - Non-operative
  - Operative

The Anatomic/Structural factors would include macro and micro morphology of the anterior cruciate ligament, the menisci, articular cartilages, limb alignment, height, and weight, etc.

Kinematic/Neuromuscular factors determine the actual motion of a joint under load, and would include the dynamic sequencing of millions of motor units that can properly dampen patellofemoral forces, especially in eccentric contraction. This dynamic sequencing is under significant control of the cerebellar feedback mechanisms.

Physiologic/Metabolic factors would include the genetically determined capacity of living cells to maintain tissue homeostasis and restore homeostasis following perturbing events.

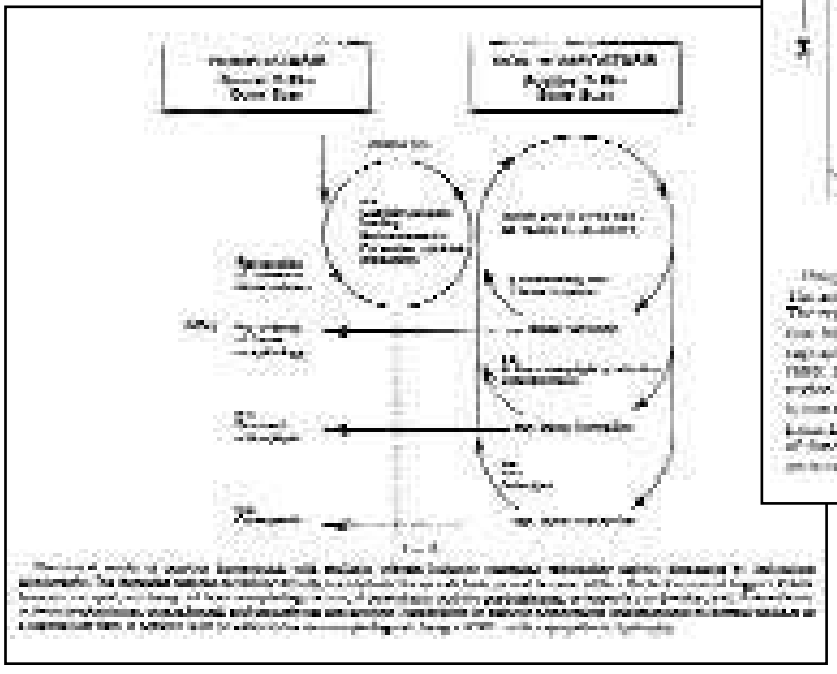
Treatment factors would include non-operative factors such as decreased loading, rehabilitation, anti-inflammatory approaches including oral non-steroidal anti-inflammatory medications and tissue cooling, as well as the use of bracing and modification of footwear, etc.

Operative factors would include arthroscopic ACL reconstruction, meniscectomy, meniscal repair, chondroplasty, synovectomy, osteotomy, etc..

The principle of treatment is to maximize the Envelope of Function for a given joint or musculoskeletal system as safely and predictably as possible. Many knees function quite well within their Envelope of Function without surgery, and without the development f degenerative arthrosis - especially if the loads are low enough, such as with bicycling and swimming, etc.

If surgery is chosen, it is only part of the treatment approach for such individuals, which includes careful post-operative rehabilitation within the Envelope of Function (i.e., a painless exercise program) and continued low-grade anti-inflammatory approach including anti-inflammatory medication and tissue cooling. Most importantly, the patient must adapt a lifestyle that results in loading within that individual joint's Envelope of Function.

Figure 1



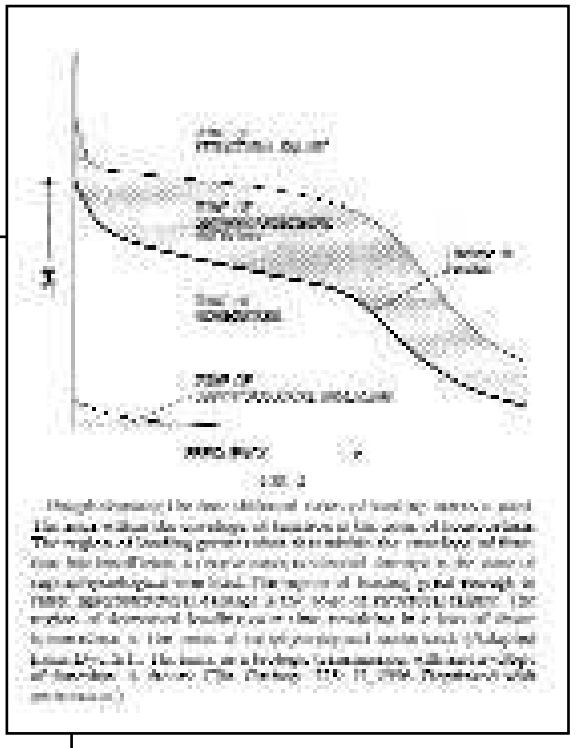


Figure 2

REFERENCES:

1. Bauer HC, Persson PE, Nilsson OS: Tears of the medial meniscus associated with increased radionuclide activity of the proximal tibia. Report of three cases. Internat Orthop., 13: 153-155, 1989.

2. Brandt KD, Scauwecker DS, Dansereau S, Meyer J, O'Connor B, et al: Bone scintigraphy in the canine cruciate deficiency model of osteoarthritis. Comparison of the unstable and contralateral knee. J Rheumatol, 24(1):140-5, 1997.

3. Daniel DM, Stone ML, Dobson BE, Fithian DC, Rossman DJ, Kaufman KR: Fate of the ACL-injured patient. A prospective outcome study. Am J Sports Med 22:632-644, 1994.

4. Deehan DJ, Salmon LJ, Webb VJ, Davies A, Pinczewski LA: Endoscopic reconstruction of the anterior cruciate ligament with an ipsilateral patellar tendon autograft. A prospective longitudinal five-year study. J Bone Joint Surg 82(7) Br:984-91, 2000.

5. Dieppe p, Cuchnaghan J, Young P, Kirwan J: Prediction of the progression of joint space narrowing in osteoarthritis of the knee by bone scintigraphy. Ann Rheumat Dis 52:557-563, 1993.

6. Dye SF: Radionuclide Imaging of the Knee. In: Knee Surgery, Current Practice, ed. by Aichroth P, Cannon WD. London: Martin Dunnitz, pp 38-44, 1992.

7. Dye SF: Patellofemoral Anatomy. In: The Patellofemoral Joint. ed. by Fox JM, Del Pizzo W. New York:: McGraw Hill. 1993, 1-11.

8. Dye SF, Chew M, McBride JT, Sostre G: Restoration of Osseous Homeostasis of the Knee Following Meniscal Surgery. Ortho Transact 16:725, 1992.

9. Dye SF, Chew MH: Restoration of osseous homeostasis after anterior cruciate ligament reconstruction. Am J Sports Med 1993, 21:748-750.

10. Dye SF: Functional Anatomy and Biomechanics of the Patellofemoral Joint. In: The Knee. ed. by WN Scott, St. Louis: Mosby. 1994, 381-389.

11. Dye SF: The knee as a biologic transmission with an envelope of function. Clin Orthop 1996, 325:10-18.

12. Dye SF, Vaupel GL, Dye CC: Conscious Neurosensory Mapping of the Internal Structures of the Human Knee without Intra-articular Anesthesia. Am J Sports Med 1998, 26:773-777.

13. Dye SF, Wojtys EM, Fu FH, Fithian DC, Gillquist J: Factors Contributing to Function of the Knee Joint after Injury or Reconstruction of the Anterior Cruciate Ligament. J. Bone Joint Surg 1998, 80A:1380-1393.

14. Dye SF, Stäubli HU, Beidert RM, Vaupel GL: The mosaic of pathophysiology causing patellofemoral pain: Therapeutic implications. Op Tech Sports 1999, 7:46-54.

15. Dye SF, Merchant A: Magnetic resonance imaging of articular cartilage in the knee. An evaluation with use of fast-spin-echo imaging. J Bone Joint Surg. 81(9):1349-50, 1999.

16. Dye SF: The use of technetium scintigraphy to evaluate early arthrosis of the knee. The Arthritic Knee CD-ROM. Brian Cole, MD, (ed), Rosemont, IL, AAOS Multimedia Productions, 2000.

17. Dye SF, Boll DH, Dunigan PE, et al: An Analysis of Objective Measurements Including Radionuclide Imaging in Young Patients with Patellofemoral Pain. Am J Sports Med 13:432, 1985.

18. Dye SF, Boll DA: Radionuclide Imaging of the Patellofemoral Joint in Young Adults with Anterior Knee Pain. Ortho Clin North Am 17:249-262, 1986.

19. Dye SF, Daniel JS, Fry PF, et al: Correlation of Increased Scintigraphic Activity and Patellar Osseous Pathology in Young Adults with Patellofemoral Pain. Ortho Transact 10:479, 1986.

20. Dye SF, Peartree PK: Sequential Radionuclide Imaging of the Patellofemoral Joint in Symptomatic Young Adults. Am J Sports Med 17:727, 1989.

21. Dye SF: The Role of Technetium Bone Scans in Orthopaedic Outcome Evaluation. Sports Med Arthroscopy Rev 10:220-228, 2002.

22. Hogervorst T, Pels Rijcken TH, van der Hart CP, De Lange ES, et al: Abnormal bone scans in anterior cruciate ligament deficiency indicate structural and functional abnormailties. Knee Surg Sports Traumatol Arthrosc. 8(3):137-42, 2000.

23. Hogervorst T, Pels Rijcken TH, Rucker D, van der Hart CP, et al: Changes in bone scans after anterior cruciate ligament reconstruction: a prospective study. Am J Sports Med Nov-Dec; 30(6):823-33, 2002.

24. Jomha NM, Borton DC, Clingeleffer AJ, Pinczewski LA: Long-term osteoarthritic changes in anterior cruciate ligament reconstructed knees. Clin Orthop 358:188-93, 1999.

25. Jomha NM, Pinczewski LA, Clingeleffer A, Otto DD: Arthroscopic reconstruction of the anterior cruciate ligament with patellar-tendon autograft and interference screw fixation. The results at seven years. J Bone Joint Surg 81(5) Br:775-9, 1999.

26. Kartus JT, Russell VJ, Salmon LJ, Magnusson LC, Brandsson S, et al: Concomitant partial meniscectomy worsens outcome after arthroscopic anterior cruciate ligament reconstruction. Acta Orthop Scand 73 (2):179-85, 2002.

27. Lotke PA, Ecker ML: Osteonecrosis-like syndrome of the medial tibial plateau. Clin Orthop June 176:148-53, 1983.

28. McBride JT, Rodkey WG, Brooks DE, Dye SF, Cowan C: Early detection of osteoarthritis using technetium 99 m MDP imaging, radiographs, histology and gross pathology in an experimental rabbit model. Orthop Trans 15:348-349, 1991.

29. Otto D, Pinczewski LA, Clingeffer A, Odell R: Five-year results of single incision arthroscopic anterior cruciate ligament reconstruction with patellar tendon autograft. Am J Sports Med., Mar-Apr; 26(2):181-8, 1998.

30. Pinczewski LA, Deehan DJ, Salmon LJ, Russell VJ, Clingeleffer A: A five-year comparison of patellar tendon versus four-strand hamstring tendon autograft for arthroscopic reconstruction of the anterior cruciate ligament. Clinical trial @ journal.AJSM.org.

31. Pinczewski LA, Russell VJ, Salmon LJ: Osteoarthritis after ACL reconstruction. A comparison of patellar tendon and hamstring tendon graft for ACL reconstruction over seven-years. Presented at AAOS Specialty Day, New Orleans, February 8, 2003.

32. Rothschild PA, Domesek JM, Dye SF, et al: MR Imaging of the Knee with a 0.064-T Permanent Magnet. Radiology 175:775-778, 1990.

STRUCTURAL/ANATOMIC FACTORS

Robert J. Johnson, MD

Definition
Arthrosis = Osteoarthritis

Osteoarthritis – (old term = "hypertrophic arthritis")
Primary – idiopathic
Secondary
- Metabolic conditions ∑ Anatomic abnormalities ∑ TRAUMA (post traumatic arthritis) ∑ Inflammatory

Sharma, In: Osteoarthritis 3rd Ed., WB Saunders, Philadelphia, 2001, pp 3-27

Arthrosis = Post Traumatic Osteoarthritis
Heterogeneous in its:
- Expression
- Variability in its progression
- Inconsistently defined and graded
- Makes comparison of its incidence and severity reported in our literature impossible

OA results from mechanical and biologic events that destabilize the normal coupling of degradation and synthesis of:
- Articular cartilage chondrocytes
- Extracellular matrix
- Subchondral bone
- All tissues of the joint

OA leads to:
- Softening, fibrillation, ulceration and loss of articular cartilage
- Sclerosis, deformation and eburnation of subchondral bone
- Osteophytes
- Subchondral cysts

12.1% of Americans between 25 and 75 have clinical signs and symptoms of O.A.
Sharma, In: Osteoarthritis 3rd Ed., WE Saunders, Philadelphia, 2001, pp 3-27

Post traumatic arthritis may be superimposed on already existing O.A. of other types

I. Ligament Damage: ACL
II. Cartilage Damage; II.a. Meniscal; II.b. Articular Cartilage
III. Meniscus, Articular Cartilage, and ACL Injury
IV. Knee Alignment
V. Body Weight

I. LIGAMENT DAMAGE: ACL
Anterior cruciate ligament reconstruction improves short term function in most patients
Frank & Jackson, JBJS 79A:1556-1576, 1997

Survey of 261 AAOS members
- 52.1% believe "ACL reconstruction reduces the rate of arthrosis in ACL-deficient knees"

Marx, et al., Arthroscopy 19:762-770, 2003

ACL injury followed by a "state of the art" ACL reconstruction too often leads to arthrosis.
A self-perpetuating cycle of structural changes within the graft produce.
1. Abnormal A-P laxity;
2. Abnormal articular cartilage stress;
3. Altered cartilage metabolism;
4. Destruction of articular cartilage;
5. Damage to menisci

No evidence that ACL reconstruction retards progression of arthrosis
Gillquist, Sports Med 27:143-56, 1999; Lomander, Roos, et al, Acta Orthop Scand 65:605-9, 1994
Fink, et al, J Sports Med. 22:304-9, 2001

Meta Analysis Involving 33 Clinical Follow-up Studies
The efficacy of ACL reconstruction in retarding the progression of OA was not substantiated
Lomander, Roos, et al, Acta Orthop Scand 65:605-609, 1994

Degenerative changes increase with time in unreconstructed ACL injuries
Hawkins, AJSM 14:205-210, 1986 ; Kannus, JBJS 69A:1007-1012, 198 ; Pattei, AJSM 17:430-435, 1989
Buss, AJSM 23:160-165, 1995; Fowler, AJSM 15:321-325, 1987

Prevalence of arthrosis after ACL reconstruction
- 13%-65% at 3-9 years

Gillquist, Sports Med 27:143-156, 1999

	PT Group		Hamstring Group	
	#	%	#	%
Normal	49	82	43	96
Near Normal	9	15	1	2 – barely detectable narrowing
Abnormal	2	3	1	2 – up to 50%
Severely Abnormal	0	0	0	0 – more than 50% narrowing

Pinczewski, et al, AJSM 30:523-536, 2002

Further Follow-up at 7 Years
Osteoarthritic changes increased to:
- Hamstring Group - 31%
- B-PT-B Group - 70%

Pinczewski, AOSSM Specialty Day 2003

ACL Disruption
- Radiographic evidence of OA at 6 year follow-up
- Rx non randomized
- No stratification of associated injuries
  - ACL reconstructed group 80%
  - Conservatively treated group 50%

Fink, Unfallchirurg 97:357-361, 1994

Reconstructed ACL-deficient knees had higher rate of arthrosis at 64 months than "Copers"
Daniel, et al, AJSM 22:633-644, 1994

Problems with Daniel's study
- Non randomized - selection bias
- Performance bias – several different reconstructions used

Daniel, et al, AJSM 22:633-644, 1994

ACL Disruptions: Proven by Arthroscopy
10-13 year follow-up
46 pts: P-PT-B - 1981-83 25 pts: Conservative RX
IKDC Radiographic Scores at 10-13 yr similar mild to moderate x-ray "degenerative changes"
- No significant difference between the groups
- Both worsen over time

Fink, Int J Spts Med 22:304-409, 2001

ACL Reconstruction
Does it restore normal kinematics?
- Not when IKDC "nearly normal" category for A-P translation is 3-5 mm side to side difference

Reconstructed ACL
1. Normal mix of large and small collagen fibrils is not achieved

2. Normal transition zones of fibrocartilage and calcified cartilage are not reproduced
3. Normal neurophysiology is not restored
4. Result of ACL reconstruction–"organized scar"–not a ligament.
Dye, et al, Inst Course Lec. 48 :1381-1393, 1999

II.a MENISCAL INJURY

The meniscus is a vestigial organ – taught in 1965

Fairbanks: suggested x-ray changes were due to loss of the weight bearing function of the meniscus
- Narrowing
- Flattening of condyles
- Osteophytes

Fairbanks, JBJS 30B:664-670, 1948

Late 1960's and Early 1970's
High incidence of arthrosis reported after total meniscectomy varied from 1-92% - appeared late
Appel, Acta Orthop. Suppl, 277, 1968; Johnson, JBJS 56A:719-729, 1974
Huckell, Canadian J Surg 8:254-260, 1965; Tapper, JBJS 51A:517-526, 1969

Validation of the Functional Importance of the Meniscus – 1970's
Fukubayaski, Acta Orthop Scand 51:871-879, 1980; Krause, JBJS 58A:599-604, 1976
Seedhom, Eng Med 8:220-228, 1979; Walker, Clin Orthop 109:184-192, 1975

Partial meniscectomy in patients with no other injury does not prevent degenerative arthrosis.
- Follow-up: 10-14 years

Scheller, Arthroscopy 17:946-952, 2001; Anderson-Molino, Arthroscopy 18:183-189, 2002
Hulet, JBJS 83B:29-32, 2001; Higuchi, Clin Orthrop 377:161-168, 2000;
Schimmer, Arthroscopy 14:136-142, 1998; Hoser, JBJS 83B:513-516, 2001

Partial meniscectomy in 146 patients with no other injury: 14 year follow-up
- 88% of Lysholm Scores – good and excellent
- Radiographic grade – no worse than unoperated knee

Burks, Arthroscopy 13:673-679, 1997

Meniscus repair vs meniscectomy in stable knees: 7 year follow-up: 144 patients
Repair group had better function and less arthrosis
Sommerlath, Int Orthop 15:347-350, 1991

Meniscus repair vs meniscectomy in stable knees: 13 year follow-up
60 patients – 30 in each group
Incidence and severity of arthrosis not different between the groups. P=0.06
Rockborn, Messner: Knee Surg Sports Traumatol, Arthrosc 8:2-9, 2000

Meniscal Allograft
- Theoretically should decelerate or prevent further degenerative changes
- Early results suggest optimism
- Efficacy still to be determined

Cole, Rodeo: Inst Course Lec 52:383-396, 2003

II.b ARTICULAR CARTILAGE INJURY

Damage to the articular cartilage induced by injury
= Post Traumatic Arthrosis. Thus it's presence means "arthrosis" exists

Articular cartilage damage may be difficult to attribute to injury.
- May be degenerative in origin
- Preexisted the injury

Articular cartilage damage may not be apparent following an injury (X-ray, MRI, scintigraphy, clinical examination or arthroscopy)
- Occult injury – cellular necrosis
- Becomes apparent long after injury

Cell death was not observed after impact of articular cartilage unless microscopic cracks occurred.
- Bovine bone

Lewis, J Orthop Res 21:881-887, 2003

Rehabilitation following anterior cruciate ligament reconstruction: a prospective, randomized, double blind comparison of accelerated versus non-accelerated programs
Johnson, AOSSM 2002

Results (Biomarkers of Cartilage Metabolism)
- Type II collagen degradation: COL II - _C Long mono – very little change
- Type II collagen synthesis: C-Propeptide of Type II collagen – not back to normal by 2 years
- Aggrecan turnover: 846 epitope of aggrecan on Chondrotin Sulfate – abnormal at 1 year – normal at 2 years

Discussion
- Both accelerated and non-accelerated rehabilitation are associated with ↑ synthesis of Type II collagen and proteoglycan turnover.
- Both programs appear to effect cartilage metabolism similarly
- These changes don't return to normal until after 1 year

III. MENISCUS ARTICULAR CARTILAGE, AND ACL INJURY

Cartilage "damage" associated with ACL Injury:
Acute: 15-40%
- Chronic: 79% (1 yr – 40%; 5 yr – 60%; 10 yr – 80%)

Levy, Orthop Clinics of N.A. 34:149-167, 2003

Affect on outcome of articular cartilage injuries in association with ACL injury.
- Hard to detect

Chondral Lesions in ACL Reconstructed Knees
- 52 ACL injuries with grade III-IV chondral lesions (mean–1.7 cm)
- Similar group with no chondral lesions
- Follow-up - 6.3 years.
  - IKDC subjective results were significantly better in normal cartilage group (range: 95.2-92.8)
  - No difference was noted in IKDC radiographic ratings

Shelburne, JBJS 85A Suppl 2:8-16, 2003

Occult Articular Cartilage Injury at Time of ACL Injury
Do MRI observed bone bruises seen after acute injury imply articular cartilage damage of significance?

Bone Bruise and ACL Reconstruction
- Cartilage Appeared Normal – no X-ray change
- 15 of 23 patients had persistence of ≠ MRI signal 6 years after ACL injury
- 13 had cartilage thinning over the lesion – lateral femoral condyle
- No clinical differences
- Proposed cause
  - Alteration in load bearing properties of bone
  - No mention of possible cartilage cell injury

Faber, Fowler, AJSM 27:489-494, 1999

ACL Injury
21 patients with 29 bone bruises on MRI before reconstruction

– 2 year follow-up MRI
- All 13 type I and 10 of 11 type II bruises resolved
- In all 5 type III (disruption of cortical surface) bone bruises were still present – cartilage thinning and cortical depression
- No correlation of MRI findings to IKDC scores

Costa-Paz, Arthroscopy 17:445-449, 2001

Many authors state that:
- ACL reconstruction protects the menisci and thus avoids later development of arthrosis

Unproven
Levy, Ortho Clin N. A. 34:149-187, 2003

10+ Follow-up of ACL Reconstructions in P-PT-B Cases
Degree of arthrosis related to amount of meniscus removed at Index surgery
Fink, Int J Spts Med 22:304-409, 2001

Arthrosis developing after ACL reconstruction associated with meniscal damage at Index Surgery
Develops late - 7-10 years

After ACL Reconstruction
Patients with meniscectomies at or before index surgery had greater amounts of arthrosis
Years of Follow-up: 7-17 years
Wu, Richmond, AJSM 30:845-850, 2002; Jomha, Clin Orthop 358:188-193, 1999
Jager, Zeitschrift fur Orthopadie 141:42-47, 2003; Chol, Revue de Chirurgie Orthoped 88:157-162, 2002
Aglietti, Knee Surg. Sports Traumatol, Arthroscop 5:138-144, 1997, Shelburne, AJSM 28:446-452, 2000
Anderson, AJSM 22:620-626, 1994

After ACL Reconstruction
Patients with meniscectomies at or before index surgery had no greater amounts of arthrosis
Years of Follow-up: 5-8 years
Järvelä, Kannus, Arthroscopy 17:818-825, 2001; Kornblatt, Warren, AJSM 16:444-448, 1988; Howe, AJSM 19:447-457, 1991; Otto, Pinczewski, AJSM 26:181-188, 1998; Drogset, AJSM 30:851-856, 2002

5-15 Year Follow-up: B-PT-B
7.6 Year Mean – 482 pts
Patients who had more meniscus and articular cartilage damage at surgery had more arthritic (x-ray) and subjective symptoms at follow-up.
In order of importance, articular cartilage damage, partial or total meniscectomy, and partial or total lateral meniscectomy affect the objective and subjective results.
Shelburne, AJSM 28:446-452, 2000

Meniscal and Articular Surface Status at Time of ACL Reconstruction
10.4 yr mean follow-up: B-PT-B in 63 pts.
- Radiographic abnormalities more common in those with meniscectomy
- No significant relationship between articular cartilage injury and functional outcome
- Didn't relate articular cartilage lesions to follow-up x-rays

Wu, Richmond, et al, AJSM 30:845-850, 2002

Meniscus and Articular Surface Status at Time of ACL Reconstruction
8 year near follow-up; B-PT-B in 100 pts
- Primary articular cartilage lesion – important predisposition for development of OA
- No such correlation with primary meniscus lesions

Drogset AJSM 30:851-856, 2002

IV. KNEE ALIGNMENT
Varus or Valgus – affect on functional decline in knee OA
230 patients – mean age 64
- Definite osteophyte presence (Kellgren/Lawrence radiographic grade ≥ 2)
- At least some difficulty with "knee – requiring" activity
- Outcome measure of progression – one grade ≠ in joint space narrowing
- Follow-up 18 months

Varus Alignment – 4 fold increase in odds of medial progression
28 (31%) of 89 varus knees 9 (9%) of 102 non varus knees
Valgus Alignment – 4.9 fold increase in odds of lateral progression
19 (22%) of 88 valgus knees 5 (5%) of 103 non valgus knees
More than 5° varus or valgus – significantly greater advancement of functional deterioration than those with less than 5°
Sharma, et al, JAMA 286(2):188-195, 2001

Sharma's Study
- 1st to demonstrate risk of progression of OA ∑ Detectable in as little as 18 months

Can this be generalized to sports injuries in younger patients with malalignment?

Physiologic Varus or Valgus Malalignment and Sports Injury to the Knee
- When associated with damage to ligaments, meniscus and/or articular cartilage are assumed to be related to the development of arthrosis
- Exactly how and how often – unknown
- Unrecognized laxity of secondary restraints
- Especially when coupled with varus or valgus malalignment – Associated with ACL graft failure and the development of arthrosis

Noyes, AJSM 28:282-296, 2000; Stein, Wickiewicz, Orthop Clin N. Am. 34:169-181, 2003
Williams, Warren, J Knee Surg 16:9-16, 2003

- ACL injury coupled with varus malalignment requires a high tibial osteotomy or ACL reconstruction will fail and arthrosis will develop
- Chronic ACL laxity with a varus knee and meniscus damage is almost invariably associated with arthrosis

V.BODY WEIGHT
Primary Risk Factors for the Development of OA
- Obesity
- Joint injury
- Vigorous physical activity
- Based on cross-sectional studies–true risk can not be determined

Felson, Arthritis Rheum 40:728-733, 1997; Cooper, Am J Epidemiol 147:516-522, 1998
Gelber, Am J Med 107:542-548, 1999; Cheng, Nurse Pract 53:315-, 2000

Strong association between a high BMI in males in their 20's and 30's and incidence of OA later in life
Gelber, Am J Med 107:542-548, 1999

Can Arthrosis be Prevented Following Sports Injury?
Conclusion
Following major injury to the ligaments (especially the ACL) menisci and the articular cartilage there is little evidence that prevention of arthrosis can be assured by present treatment techniques.
Following ACL Injury and Reconstruction
We can not say that arthrosis can be prevented.
If ACL function is restored, the menisci preserved and articular cartilage damage minimal it appears that the development of arthrosis can be minimized or delayed but not necessarily prevented.

THE DETECTION AND PREVENTION OF POST-TRAUMATIC KNEE ARTHROSIS - THE CLINICAL DATA

Scott F. Dye, MD

Persistent loss of osseous homeostasis precedes overt degenerative changes within joints. This is currently best documented in the medial compartment of the knee.

Case #1 is a 42-year-old male with a medial meniscus tear and normal x-rays. The bone scan is positive in the medial compartment, manifesting loss of osseous homeostasis despite normal structural morphology of the osseous components of the knee.

Following a partial medial meniscectomy of the left knee, instead of improving the bone scan, the follow-up bone scan shows worsening in the medial compartment that is associated with the findings of advanced Fairbank changes at 15 months. (The patient is heavy-set, which may have accelerated the natural history of his degenerative arthrosis.) Nonetheless, the persistently positive bone scan indicated the region in the knee that eventually developed overt degenerative changes.

Case #2 is a 32-year-old male with a chronic anterior cruciate ligament deficient left knee with a medial meniscus tear. Pre-operative bone scan reveals loss of osseous homeostasis in the medial compartment, reflecting the pathophysiologic price being paid within the medial compartment secondary to the structural factors and loading of this left knee. Pre-operative radiographs of the knee are normal.

A repeat bone scan at 4 months status post bone patellar tendon bone ACL reconstruction and partial medial meniscectomy reveals generalized increased uptake within the left knee showing that major surgery represents a substantial metabolic perturbation to the knee. (The knee doesn't know the difference between major surgery and an ax attack.)

A third bone scan at 21 months post-operatively shows complete resolution of the pre-operative medial compartment activity, with some residual tibial tunnel activity remaining.

A fourth and final bone scan at 13 years post-operatively is fully normal, and the companion radiographs taken concurrently are normal, showing that no degenerative changes have occurred.

It is therefore possible to achieve full restoration of osseous homeostasis even in chronic ACL deficient knees with medial meniscus tears, out to at least 13 years post-operatively, barring a new injury.

Case #3 is a 28-year-old male with a classic symptomatic medial meniscus tear, showing increased bone scan activity, with normal bone signal on MRI and normal radiographs of the right knee.

Seven-years status post partial medial meniscectomy the bone scan has returned to full normalcy, representing restoration of osseous homeostasis. The knee remains free of degenerative changes, manifested by normal radiographs.

Case # 4 is a 53-year-old male with established symptomatic degenerative arthrosis of the patellofemoral joint of the left knee, showing expected increased patellofemoral uptake on bone scan.

Four years and 8 months following a gentle patellofemoral synovectomy and cartilage stabilization, followed by post-operative physical therapy within the Envelope of Function for this particular knee, reveals a bone scan that has improved. The radiographs show no progression of degenerative arthrosis.

This case demonstrates that even established degenerative arthrosis of the knee can become metabolically improved, without progression, with safe, gentle therapy.

An arthrosis matrix is shown in Figure 1, and demonstrates the possible combinations of bone scan activity and radiographic degenerative changes, which allows one to better understand the particularly complex non-linear development of degenerative joint disease. This is probably true for all joints. An example of changes in the cervical spine will be shown, time permitting.

Most importantly, joints that manifest loss of osseous homeostasis, even in the face of normal radiographs, are at risk of degenerative changes and can be considered in a category of pre-arthrosis.

I believe we are on the threshold of a new era in orthopaedic surgery whereby, taking into account the tissue homeostasis characteristics of living musculoskeletal systems, one will better understand the underlying pathophysiologic dynamics of the development of degenerative arthrosis.

We also need to be able to manifest soft tissue homeostasis characteristics (through PET or functional MRI, etc.)

However, if one begins to include the restoration of tissue homeostasis in the treatment goal of our orthopaedic patients, then many joints can be saved from the development of degenerative arthrosis.

The ultimate goal is biological control of damaged musculoskeletal systems at the cellular and molecular level, perhaps through some genetic alteration factors, as well. Much of the research presented at the Orthopaedic Research Society is of this nature.

The tissue homeostasis theory and Envelope of Function provides a conceptual framework within which one can interrelate discoveries at the subcellular level all the way up to the macro-clinical condition. It provides clarity and a way forward for future research.

REFERENCES:

1. Bauer HC, Persson PE, Nilsson OS: Tears of the medial meniscus associated with increased radionuclide activity of the proximal tibia. Report of three cases. Internat Orthop., 13: 153-155, 1989.
2. Brandt KD, Scauwecker DS, Dansereau S, Meyer J, O'Connor B, et al: Bone scintigraphy in the canine cruciate deficiency model of osteoarthritis. Comparison of the unstable and contralateral knee. J Rheumatol, 24(1):140-5, 1997.
3. Daniel DM, Stone ML, Dobson BE, Fithian DC, Rossman DJ, Kaufman KR: Fate of the ACL-injured patient. A prospective outcome study. Am J Sports Med 22:632-644, 1994.
4. Dieppe p, Cuchnaghan J, Young P, Kirwan J: Prediction of the progression of joint space narrowing in osteoarthritis of the knee by bone scintigraphy. Ann Rheumat Dis 52:557-563, 1993.
5. Dye SF: Radionuclide Imaging of the Knee. In: Knee Surgery, Current Practice, ed. by Aichroth P, Cannon WD. London: Martin Dunnitz, pp 38-44, 1992.
6. Dye SF, Chew M, McBride JT, Sostre G: Restoration of Osseous Homeostasis of the Knee Following Meniscal Surgery. Ortho Transact 16:725, 1992.
7. Dye SF, Chew MH: Restoration of osseous homeostasis after anterior cruciate ligament reconstruction. Am J Sports Med 1993, 21:748-750.
8. Dye SF: The knee as a biologic transmission with an envelope of function. Clin Orthop 1996, 325:10-18.
9. Dye SF, Wojtys EM, Fu FH, Fithian DC, Gillquist J: Factors Contributing to Function of the Knee Joint after Injury or Reconstruction of the Anterior Cruciate Ligament. J. Bone Joint Surg 1998, 80A:1380-1393.
10. Dye SF: The use of technetium scintigraphy to evaluate early arthrosis of the knee. The Arthritic Knee CD-ROM. Brian Cole, MD, (ed), Rosemont, IL, AAOS Multimedia Productions, 2000.
11. Dye SF: The Role of Technetium Bone Scans in Orthopaedic Outcome Evaluation. Sports Med Arthroscopy Rev 10:220-228, 2002.
12. Hogervorst T, Pels Rijcken TH, van der Hart CP, De Lange ES, et al: Abnormal bone scans in anterior cruciate ligament deficiency indicate structural and functional abnormalities. Knee Surg Sports Traumatol Arthrosc. 8(3):137-42, 2000.
13. Hogervorst T, Pels Rijcken TH, Rucker D, van der Hart CP, et al: Changes in bone scans after anterior cruciate ligament reconstruction: a prospective study. Am J Sports Med Nov-Dec; 30(6):823-33, 2002.

THE ACL INJURY REVISITED: UNDERSTANDING THE INJURY, OUTCOMES OF TREATMENT, ISSUES IN REHABILITATION, AND PREVENTATIVE STRATEGIES (CC)

Moderator: Annunziato Amendola, MD, Iowa City, IA (n)

This symposium is intended to review the most current research and information regarding the understanding of the ACL injury and sequelae, prevention and intervention strategies, treatment outcomes and rehabilitation rather than emphasizing technical aspects of Anterior Cruciate Ligament Reconstruction.

I. ACL and Arthritis: Incidence, Etiology, Management Algorithm
Annunziato Amendola, MD, Iowa City, IA (n)

II. The ACL Injury: Mechanism, Neuromuscular Control, Occult Associated Injuries
Peter J. Fowler, MD, London, Canada (n)

III. Outcomes of ACL Injury and Reconstruction
William A. Grana, MD, Tucson, AZ (a – Arthrex, Smith & Nephew, dj Orthopaedics, e – Breg, Smith&Nephew)

IV. Intervention Strategies for ACL Prevention
Elizabeth A. Arendt, MD, Minneapolis, MN (n)

V. Effect of ACL Surgery and Rehabilitation on Neuromuscular Control of the Knee
Glenn N. Williams, PT, Newark, DE (a – Foundation for Physical Therapy)

ACL AND OA : PREVALENCE , AND TREATMENT ISSUES TO CONSIDER

Annunziato Amendola, MD

1) Sequelae of ACL Injury
- a) Meniscal tears
- b) Osteochondral contusions
- c) Joint deterioration with time
  - i) Abnormal joint mechanics
  - ii) Abnormal neuromuscular function
- d) Inflammatory synovial fluid environment

2) Development of OA Post ACL Injury
- a) Secondary OA
  - i) 60-90% incidence of OA post ACL injury 10-15 years post injury
  - ii) data from retrospective cross sectional studies
- b) Untreated ACL Deficiency
  - i) 60-90% incidence of progressive meniscal tears, articular injury, and radiographic OA
- c) Post ACL reconstruction
  - i) Progressive arthroscopic and radiographic OA
  - ii) Not as severe as untreated ACL deficiency

3) Characteristics of OA associated with ACL Injury
- a) Wear Pattern with Chronic anterior subluxation
  - i) Posterior wear (ACL Deficient) vs mid-anterior wear (ACL intact)
- b) Importance of sagittal tibial alignment (slope)
  - i) Increased posterior slope predisposes to anterior subluxation
  - ii) Slope may be used in assessing and treating chronic deficiency +/- OA
- c) Relationship of ACL injury and axial alignment
  - i) Malalignment (varus) not well tolerated with ACL deficiency
- d) Treatment – The Importance of Alignment in OA and instability

Malalignment + Arthrosis	Malalignment + Instability	Malalignment + Arthrosis + Instability	Malalignment + Cartilage / Meniscal Transplantation

4) Assessment of OA , joint overload in ACL Deficiency
- a) Detailed history and physical exam
  - i) Need to determine activity level, disability vs instability(predominant symptoms)
  - ii) Assessment of instability
    - Chronic subluxation vs reducible
  - iii) In-office gait analysis
    - Thrust; compensatory mechanisms
- b) Radiographs:
  - i) Routine Series :
    - standing AP
    - standing tunnel
    - lateral
    - intra-patellar
    - Standing hip to ankle x-ray (target area is weight-bearing axis) – most important for pre- operative planning
- c) MRI to assess articular / meniscal defects

5) Treatment Algorhythm
- a) Factors to consider
  - (1) Age, activity level, extent of disease, associated deficits, response to treatment, contraindications to operative intervention
- b) Options
  - (1) Rehabilitation, bracing, realignment,ACL/ collateral reconstruction,meniscal transplant,articular resurfacing,unicompartmental, TKJR
- c) Indications for surgery
  - (1) Symptomatic patient
  - (2) Failure of aggressive non operative rehabilitation protocol to control symptoms and progression of disease

6) SUMMARY
- a) OA is a significant sequelae of ACL tears and associated injuries, and post reconstruction
- b) Malalignment associated with degenerative change combined with instability is common
- c) Effective management of these combined problems requires an understanding of the pathoanatomy and biomechanics
- d) Treatment involves restoring alignment , biomechanical stability and joint homeostasis.

REFERENCES

1. Brown, G., Amendola, A., Radiographic evaluation and pre-operative planning for high tibial osteotomy; Osteotomies About the Knee: Operative Techniques in Sports Medicine. David Drez Jr., Jesse C. Delee Editors; Giancarlo Puddu, Guest Editor. Volume 8. Number 1. January 2000
2. Clatworthy, M., Amendola, A., The anterior cruciate ligament and arthritis: Clinics in Sports Medicine, Volume 18. Number 1. January 1999
3. Naudie D, Roth S, Dunning C, Amendola AS, Giffin JR, Johnson JA, Chess D, King GJW., The effect of opening wedge high tibial osteotomy in the posterior cruciate ligament deficient knee. Canadian Orthopaedic Association. London, Ontario. June 1 – 4th 2001
4. A. Amendola, J. R. Giffin, D.W. Sanders, J. Hirst, J.A. Johnson Osteotomy for Knee Instability: The Effect of Increasing Tibial Slope on Anterior Tibial Translation. American Orthopaedic Society for Sports Medicine Specialty Day, San Francisco, California . March 3, 2001
5. Markoff KL, Bargar WL, Shoemaker SC, et al. The role of joint load in knee stability. J Bone Joint Surg 70A: 977-982, 1988.
6. Noyes FR, Barber-Westin SD, Hewett TE. High tibial osteotomy and ligament reconstruction for varus angulated anterior cruciate ligament-deficient knees. Am J Sports Med 28(3): 282-296, 2000.
7. Hughston JC, Jacobsen KE. Chronic posterolateral rotatory instability of the knee. J Bone Joint Surg 67A: 351-359, 1985.
8. Dejour H, Walch G, Chambat P, et al. Active subluxation in extension: a new concept of study of the ACL deficient knee. Am J Knee Surg 1:204-211, 1988.
9. Dejour H, Neyret P, Bonnin M. In: Fu F, Knee Surgery. Baltimore, MD: Williams & Wilkins, 859-875, 1994.
10. Coventry MB. Osteotomy of the upper portion of the tibia for degenerative arthritis of the knee: a preliminary report. J Bone Joint Surg 47A: 984-990, 1965.
11. Dejour H, Neyret P, Boileau P, et al. Anterior cruciate reconstruction combined with valgus tibial osteotomy. Clin Orthop 299:220-228, 1994.
12. Neyret, P, Donell ST,Dejour H, Results of partial meniscectomy related to the state of the ACL.Review at 25-35 yrs. JBJSB 1993 36-40
13. Noyes FR,et al The symptomatic ACL deficient knee, Part I: Long term functional disability in athletically active individuals JBJSB 1983 154-62
14. Mcdaniel WJ, Dameron TB, The Untreated ACL Rupture CORR 1983: 153-68
15. Kannus P. Jarvinen M, Post Traumatic ACL Insufficiency as a cause of OA in a Knee Joint Clin Rhematol 1988:251-60
16. Sherman M, Warren RF, et al A clinical and Radiographic analysis of 127 ACL insufficient Knees CORR 1988:229-37
17. Sommerlath K, et al , Long term course after treatment of ACL ruptures.9-16 years follow up.AJSM 1991; 156-62
18. Lohmander LS, Roos H, Knee Ligament Injury, surgery and osteoarthrosis . Truth od Consequenses? Acta Orth Scand 1994 605-609

19. Roos H, Adalberth T, Dahlberg L, Lohmander LS : Osteoarthritis of the knee after injury to the ACL or meniscus: the influence of time and age Ostearthritis and Cartilage 1995, Dec 261-67.

20. Johnson RJ, Eriksson E, et al, 5-10 yr follow up evaluation after reconstruction of the ACL;CORR 1984;122-40

21. Daniel DM, Stone ML, et al Fate of the ACL injured patient. A prospective outcome study; AJSM 1994 ;632-44

22. Fetto JF, Marshall JL, The natural history and diagnosis of ACL Insufficiency; CORR 1980; 29-38.

23. Kannus P, Jarvinen M, Long term Prognosis of conservatively treated Acute knee ligament injuries in competitive and spare time sportsmen. Int J Sports Med 1987, 348-51.

24. Bonnin M, PhD Thesis 1994

25. Brandsson S;Karlsson J, Eriksson BI, Karrholm J, Kinematics after tear of the ACL:ActaOrthp Scand 2001, Aug,372-8

26. Ferretti A, Conteduca F, De Carli A, Fontana M, Mariani PP, OA of the knee after ACL Reconstruction Int Orthpaedics, 1991 367-71

27. Cameron ML, Fu FH, Paessler HH, Schneider M, Evans CH : Synovial fluid cytokines as possible prognostic indicators in the ACL Deficient knee ; Knee Surg Sports Traumatol Assoc 1994; 38-44

28. Taskiran E, et al, articular cartilage homeostasis After ACL reconstruction; Knee Surg Sports Traumatol Arthrosc, 1998, 93-98

29. Murrell GA, Maddali S, Horovitz L, Oakley SP, Warren RF; The Effects of time course after ACL injury in correlation with meniscal and cartilage loss; Am J of Sports Med 2001 9-14

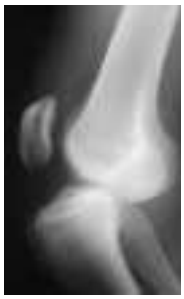
THE ACL INJURY: MECHANISM, NEUROMUSCULAR CONTROL, OCCULT OSTEOCHONDRAL LESIONS

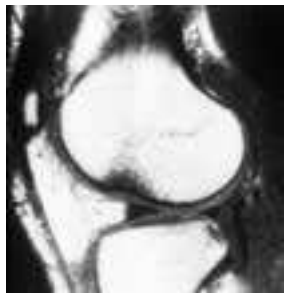
Peter J. Fowler, MD

1. MECHANISM OF INJURY

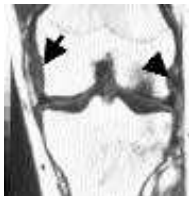
Active

- most common mechanism
- rapid deceleration
- untoward landing
- shoe-surface interface a factor in many instances





- anterior tibial dislocation by quads
- bone bruises mirror extent of damage
- interstitial damage to 2° restraints
- more damage laterally



Passive

- not as common as previously thought
- usually foot planted, patient blind-sided
- if valgus stress, medial instability must precede ACL injury *Kennedy & Fowler, JBJS 53A 1971*

2. NEUROMUSCULAR CONTROL

Questions

– What is the degree of disability from neurosensory loss?
– Can neurosensory loss be restored ?
– Does retaining the ACL attachment preserve mechanoreceptors?
– Do mechanoreceptors grow back?

Current Literature

Reider B. et al. Arthroscopy 19(1), 2003: 2 - 12

– Prospective, 26 patients, pre and post-op proprioceptive testing
– ACL reconstruction has a significantly positive impact on early and progressive improvement in proprioception

Bonfin R. et al. Arch Phys Med Rehabil 84, 2003: 1217

– Proprioceptive testing in 10 ACL reconstructed vs. 10 non-injured subjects
– Sensory and motor changes observed following ACL rupture and reconstruction

Tusuda et al. Knee Surg, Sports Tramatol, Arthrosc. 11, 2003:63-67

– Analysis of changes in hamstring EMGs elicited by stimulation of B-PT-B reconstructed ACL in 3 patients
– ACL- hamstring arc re-established in 2/3 patients

Ageberg E. Journal of Electromyography and Kinesiology, 12, 2002: 205 –212

– Review of current knowledge
– Complete recovery of neuromuscular function is unlikely following ACL injury or reconstruction

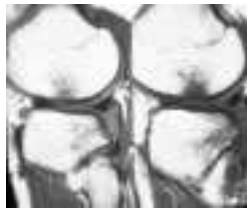
Georgoulis AD. et al. Knee Surg, Sports Tramatol, Arthrosc. 9, 2001:364-368

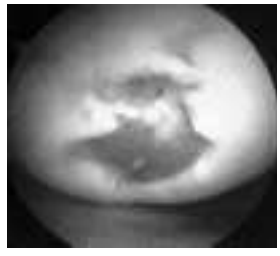
– Histological exam of ACL stump of 17 patients 3 months – 3.5 years post injury
– If torn ACL heals to PCL (15/17 patients) mechanoreceptors are present at 3 years post injury

OCCULT SUBCHONDRAL LESIONS (BONE BRUISES)

- Present in 48 – 94% of ACL injuries
  Vellet et al. Radiology 178 1991
  Rosen et al. Arthroscopy 7(1) 1991
  Speer et al. Am J Sports Med 20(4) 1992
  Graf et al. Am J Sports med 21 1993
- Faber K et al. Occult osteochondral lesions associated with ACL rupture: A 6 year MRI follow-up study, Am J Sports Med 27(4) 1999
  – 6 year follow-up, 23 patients with MRI detected bone bruises
  – Permanent osteochondral sequelae in 2/3 of patients reviewed
- Parker et al. Occult osteochondral lesions associated with ACL rupture: A 12 year MRI follow-up study. AOSSM Specialty Day, Dallas Texas, February 16, 2002
  – 13 year follow-up, 19 of 23 patients from 1999 study
  – No further thinning in region of original bruises
  – General progression of OA, especially medial
  – Persistent / new subchondral bone changes (fibrosis/sclerosis)

  Main Findings
  – Subchondral and Marrow Lesions
  – Almost _ resolved from index MRI (most in the 1st 6 years)
  – Persisted in 26%
  – Progressed: LFC in 26%; LTP in 5%
  – No remodeling of impaction injury
  – Some degeneration is determined at the time of injury
  – How much ?
  – How can we change this?





OUTCOMES OF ACL INJURY AND RECONSTRUCTION

William A. Grana, MD

- **Introduction**
  - Why look at outcomes?
    - Critically evaluate results
    - Determine defining factors in results
    - Make changes in surgical technique and results
  - Difficult task to compare studies
    - Varying surgical techniques
    - Different grafts
    - Varying rehabilitation
    - Varying patient populations
- **ACL Evaluation**
  - Evolution of Injury includes the Laxity >Impairment> Disability>Handicap
  - Laxity leads to Failure of Proprioception, Loss of Muscular Control, and Recurrent Instability
- **ACL Outcomes Depend on Proper Treatment Selection**
  - Indications for nonoperative treatment vs operative treatment
  - Which Patient gets which Treatment
  - Remember Jack Hughston's maxim: "There's nothing so bad it can't be made worse by surgery"
- **Non-Operative Issues**
  - Buss, Wickiewicz, et al. AJSM March 1995
  - 55 Patients >30 years of age, followed 4 years
  - 85% felt no need for surgery
  - 70% continued moderate demand sports
  - Cicotti and Lombardo JBJS, 1994
  - 52 Patients 40-60 years of age
    - 83% Satisfaction without Surgery
- **Need Guided Rehabilitation**
- **Modified Activity**
  - Some patients in any age group may need surgery !
  - Bracing value is controversial
  - As non operative management appears to be of some value
  - Postop there is some evidence that it may be unnecessary
  - Academy study says that in select population braces not needed
- **ACL Selection Issues**
  - Daniel et al. Outcomes of ACL Treatment AJSM 1994
    - 236 knees / 91 reconstructed
    - Need for Reconstruction Associated with:
    - Participation in High Risk Sports
    - Younger Age Patient
    - Laxity Difference of > 7 mm
- **Nonoperative Issues**
  - Most Patients can be treated nonoperatively at first
  - Problem: Athlete who waits and then develops instability will have insufficient time to prepare for next season
  - Operate on: Acute injury in the young patient who participates in high risk sports and chronic injury with instability
- **Retrospective Studies**
  - BTB
    - Buss, Warren et al., 1993
      - Aglietti 1992
      - Howe, Johnson, et al. 1991
      - Bach, 1994
        - 2-5 years follow-up
        - 85-90% stable £ _4mm difference
        - >90% return to function
        - Complications in 15-40% (LOM, PF Pain)
- **Retrospective Studies**
  - STG
    - Sgaglione, 1993
    - Anderson, 1994
    - Grana, 1992
      - 2-5 years follow-up
      - 85-90% stable ≤#4mm difference
      - 90% return to function
      - Complications in 15%
- **Retrospective Comparisons**
  - BTB vs STG
    - Otero and Hutchinson, 1993
      - Compared 56 BTB to STG both acute & chronic
      - Limitations were different rehabilitations
      - Results were less laxity in BTB, but function about the same
      - Complications manipulated 17 BTB and 30% had PF pain
      - Concluded BTB better
    - Holmes et al, 1991
      - Compared 27 BTB and 48 STG both acute and chronic
      - Varied rehab and EA for STG
      - Acute results equal
      - Chronic BTB better, with 50% of STG unsatisfactory
- **Prospective Comparisons**
  - BTB vs STG
    - Warren et al., 1994
    - 95 acute cases only
    - NSD in function, laxity, reoperation
    - BTB more swelling, pain, LOM
  - Alternating Cases: BTB vs STG
    - Aglietti, 1994
    - 60 cases
      - 30 BTB, 30 STG
      - BTB more stable but NSD
      - 80% of BTB vs 43% STG returned to sport
      - More LOM and PF pain in BTB
      - Preferred BTB except in older, PF problems, and for revision
  - Randomized BTB vs STG
    - Marder, 1991
    - O'Neill, 1998
    - Corry, 1999
      - NSD in laxity, function, or subjective complaints
      - More PF pain, LOM in BTB
      - Slightly greater laxity in STG
  - Allograft vs Autograft Hamstrings
    - AAOS Mtg 2003 Paper 058
      - Schepsis et al., Boston
      - Compared Prospectively the results of autograft and allograft reconstruction 29/41
      - Functional and objective criteria showed NSD
        - IKDC scores 86.9 vs 84.9
      - Follow up was 29 months avg
- **Meta-Analysis**
  - Comparing BTB to STG
- **Effects of Rehabilitation and Return to Activity on Outcome**
  - Aggressive Rehabilitation

- Raises expectations of patients
- ATCs and PTs encourage this approach
- 3-4 month return to activity expected
- Is this reasonable based on what we know?
  - Do results bear out efficacy?
  - Stable knee, but more arthrosis?

– Still learning about the effects of reconstruction
- Time to achieve full NM performance
- Time to achieve full proprioceptive function

– Paessler et al. Paper 119 AAOS Mtg 2003
- Evaluated contralateral tendon harvest and found no benefit donor site Sx are shifted to contralateral Side

– Yoshiya et al. Paper 120 AAOS Mtg 2003
- Although the hamstring tendons regenerate the isometric strength at 110 degrees of flexion only reaches 60% of normal side

– Schmidt and Clare, AAOS Mtg 2001, Failure of Hamstring Reconstructed Knees
- 11/330 failed avg 9.5 months after
- 5/11 failures were doing high impact activity at 4 weeks

- **Outcomes and Timing of Surgery**
  – 2 aspects of timing
  - Long term concerns if wait past 6 weeks
  - Chronic do less well due to articular cartilage and meniscal injury
  - Do not wait in face of symptoms
  - Daniel's classic paper exposed the effects of waiting
  - Do reconstruction early to avoid the effects of chondral injury, meniscal tear, and arthritis

  – Effects of Waiting to Operate in the Face of Symptoms
  - Jomha, Pinczewski, et al. CORR Jan., 1999
  - Sernet et al. Knee Surg Sports Traumatol Arthrosc, 7(3), 1999
  - Marcacci, et al. AJSM, 23(6), 1995

  – Operate early to prevent the effects of meniscal tear, chondral injury, and arthritis

- **ACL Outcomes vs Gender**
  – Impression that females do less well and especially with STG
  - Barber-Westin, Noyes AJSM, 1997
    - 6% failure in females
    - 4% failure in males
    - No difference in overall results
    - Opinion ---greater potential for meniscal and articular damage in females

  – Impression that females do less well and especially with STG
  - Noojin et al.
  - STG did not return to same level as BTB
  - STG more laxity
  - Women with STG did not do as well as Men with STG
  - Impression that females do less well and especially with STG
    - Pinczewski (Corry 1999)
    - Females with STG to females with BTB
    - Greater laxity in STG group
    - More kneeling pain in BTB
    - Goradia and Grana, Arthroscopy 2001
    - 93% normal or nearly normal
    - No difference in gender results

- **ACL Outcomes**
  – Variety of ways to look at results
  – Important to choose a method and evaluate critically for each surgeon
  – You must look at your results with appropriate outcomes instruments
  – Know your own outcomes

REFERENCES:

1. Aglietti P, Buzzi R, Zaccherotti G: Patellar tendon versus doubled semitendinosus and gracilis tendons for anterior cruciate ligament reconstruction. Am J Sports Med 22: 211-7, 1994.
2. Aglietti P, Buzz R, D'Andria et al: Long-term study of anterior cruciate ligament reconstruction for chronic instability using the central one-third patellar tendon and a lateral extraarticular tenodesis. Am J Sports Med 20(1): 38-45, 1992.
3. Anderson AF, Snyder RB, Sr Lipscomb AB: Anterior cruciate ligament reconstruction using the semitendinosus and gracilis tendons augmented by the losee iliotibial band tenodesis. A long-term study. Am J sports Med 22: 620-6, 1994.
4. Bach BR, Jones GT, Sweet FA, et al: Arthroscopy-assisted anterior cruciate ligament reconstruction using patellar tendon substitution. Two- to four-year follow-up results. Am J Sports Med 22: 758-67, 1994.
5. Barber-Westin SD, Noyes FR, Andrews M: A rigorous comparison between the sexes of results and complications after anterior cruciate ligament reconstruction. Am J Sports Med 25: 514-26, 1997.
6. Buss DD, Min R, Skyhar M, et al: Nonoperative treatment of acute anterior cruciate ligament injuries in a selected group of patients. Am J Sports Med 23(2): 160-5, 1995.
7. Buss DD, Warren RF, Wickiewicz TL et al: Arthroscopically assisted reconstruction of the entire anterior cruciate ligament with use of autogenous patellar-ligament grafts. Results after twenty-four to forty-two months. J Bone Joint Surg 75A: 1346-55, 1993.
8. Ciccotti MG, Lombardo SJ, Nonweiler B, et al: Non-operative treatment of ruptures of the anterior cruciate ligament in middle-aged patients. Results after long-term follow-up. J Bone Joint Surg 76A: 1315-21, 1994.
9. Corry IS, Webb JM, Clingeleffer AJ, Pinczewski LA: Arthroscopic reconstruction of the anterior cruciate ligament: A comparison of patellar tendon autograft and four-strand hamstring tendon autograft. Am J Sports Med 27(4): 444-54, 1999.
10. Daniel DM, Stone ML, Dobson BE, et al: Fate of the ACL-injured patient: A retrospective outcome study. Am J Sports Med 22(5): 632-44, 1994.
11. Goradia VK, Grana WA: A comparison of outcomes at 2 to 6 years after acute and chronic anterior cruciate ligament reconstructions using hamstring tendon grafts. Arthroscopy 17(4): 383-92, 2001.
12. Grana WA, Hines R: Arthroscopic Assisted Semitendinosus Reconstruction of the Anterior Cruciate Ligament. Am J Knee Surg 5(1): 16-22, 1992.
13. Holmes PF, James FL, Larson RL, et al: Retrospective direct comparison of three intraarticular anterior cruciate ligament reconstructions. Am J Sports Med 19: 596-99, 1991.
14. Howe JG, Johnson RJ, Kaplan MJ, et al: Anterior cruciate ligament reconstruction using quadriceps patellar tendon graft. Part I. Long-term follow-up. Am J Sports Med 19: 447-57, 1991.
15. Jomha NM, Pinczewski LA, Clingeleffer A, et al: Arthroscopic reconstruction of the anterior cruciate ligament with patellar-tendon autograft and interference screw fixation. The results of seven years. J Bone Joint Surg 81(5): 775-9, 1999.
16. Kaplan MJ, Howe JG, Fleming B, et al: Anterior cruciate ligament reconstruction using quadriceps patellar tendon graft. Part II. A specific sport review. Am J Sports Med 19: 458-62, 1991.
17. Marcacci M, Zaffagnini S, Lacono F, et al: Early versus late reconstruction for anterior cruciate ligament rupture. Results after five years of followup. Am J Sports Med 23: 690-3, 1995.
18. Marder RA, Raskind JR, Carroll M: Prospective evaluation of arthroscopically assisted anterior cruciate ligament reconstruction. Patellar tendon versus semitendinosus and gracilis tendons. Am J Sports Med 19: 478-84, 1991.
19. O'Neill DB: Open lateral retinacular lengthening compared with arthroscopic release. A prospective, randomized outcome study. J Bone Joint Surg 75A(12): 1756-69, 1997.
20. Noojin FK, Barrett, GR, Hartzog CW, et al: Clinical comparisons of intraarticular anterior cruciate ligament reconstruction using autogenous semitendinosus and gracilis tendons in men versus women. Am J Sports Med 28: 738-9, 2000.
21. Otero AL, Hutcheson L: A comparison of the doubled semitendinosus/gracilis and central third of the patellar tendon autografts in arthroscopic anterior cruciate ligament reconstruction. Arthroscopy 9(2): 143-8, 1993.
22. Sernet N, Kartus J, Kohler K, et al: Analysis of subjective, objective and functional examination tests after anterior cruciate ligament reconstruction. A follow-up of 527 patients. Knee Surg Sports Traumatol Arthosc 7(3): 160-5, 1999.
23. Sgaglione NA, Del Pizzo W, Fox JM, et al: Arthroscopically assisted anterior cruciate ligament reconstruction with the pes anserine tendons. Comparison of results in acute and chronic ligament deficiency. Am J Sports Med 21: 249-56, 1993.

PREVENTATIVE STRATEGIES TO ACL INJURY: RATIONALE AND IMPLEMENTATION

Elizabeth A. Arendt, MD

I. Non-Contact Anterior Cruciate Ligament Injuries: Risk Factors and Prevention Strategies
- A Consensus Conference was held at Hunt Valley, MD on June 10, 1999
- Sponsored by AAOS, AOSSM, NCAA, and NATA
- Organized by Letha Y Griffin, MD, PhD, and Elizabeth A. Arendt, MD
- There were 19 participants
- Reviewed research to date. Focused on
  - Anatomic risk factors
  - Hormonal risk factors
  - Biomechanical/neuromuscular risk factors
- Reviewed videos on non-contact ACL injuries
- Reviewed existing neuromuscular programs
- Goals:
  - To increase awareness of the Aat risk@ population
  - To stimulate increased research efforts

II. Hunt Valley Consensus Conference, June 1999
- Videos of non-contact ACL injuries (concentration on mechanism of injury)
  - 54 videos of ACL injuries were collected for consensus conference
  - 22/54 in basketball, 15 women, 5 men, 2 ?
- Three mechanisms were identified
- ACL injured at stop/push off
  - Knee flexed
  - Knee in valgus, external rotation.
- ACL injured on landing
  - Knee slightly flexed
  - Knee in valgus, external rotation
- ACL injured at jump stop
  - Knee slightly flexed
  - Knee in valgus, external rotation
  - Subject jumped to a stop, prior to jump to shoot
- Videos of ACL Injuries: Conclusion on mechanisms
- Most common mechanisms at injury were landing from a jump, and a jump stop
- Injured leg was usually not extended, but less than 30∞ flexion

III. Research Needs: Non-Contact ACL Injuries
- What is the mechanism of injury in non-contact injuries to the ACL?
  - Video data conflicts with in vitro data concerning ACL failure mechanisms
- Knee biomechanics (in vitro)
  - External loads of valgus and external rotation do not load the ACL between 10∞ and 30∞ of flexion
  - Quadriceps activation can load the ACL between 10∞ and 30∞ flexion. This is increased if there is no hamstrings activation.

IV. Consensus Statements: Biomechanical Risk Factors, June 1999
- At this time, neuromuscular factors appear to be the most important reason for the differing ACL injury rates between males and females
- Strong quadriceps activation during eccentric contraction may be a major factor in non-contact ACL injury
- Factors common to many ACL injuries is landing on foot rather than toes, awkward dynamic body movements, perturbation prior to injury
- Common risks appear to be deceleration, cutting, changing directions, and/or landing from a jump

V. Vermont Ski Safety Program (education only)
- Background: High-risk positions for knee injury were identified.
- Ski slope personnel from 20 area ski slopes participated in a video tape education program aimed at recognizing high risk lower extremity knee positions in skiing. Video tape also demonstrated an effective response to these positions.
- 62% decrease in serious knee injury over 2 year period studied.

VI. Neuromuscular Training Programs, Henning-Griffs Program
- Based on a 10-year study of female basketball non-contact ACL injuries
- Focused on changing the quad-cruciate interaction
- Most common injury mechanisms (video review)
  - Planting and cutting (29%)
  - Straight knee landing (28%)
  - One step stop with knee hyperextended (26%)
- Program focused on drills to change mechanisms
  - Plant and cut to rounded turn on bent knee
  - Straight knee landing to a bent knee landing
  - One step stop with knee straight to multiple step stop with knee bent
- 89% decrease in injury rates over 2 years in Division 1 female basketball teams

VII. Neuromuscular Training Programs, Caraffa Program
- 300 control and 300 participating semi-pro and amateur soccer players in Italy
- Program: A 5 phase balance board program involving increasingly difficult balance skills, preseason 20 minutes a day for 30 days
- Control players: 1.15 ACL injuries/team/year
- Study players: 0.15 ACL injuries/team/year

VIII. Neuromuscular Training Programs, Wedderkopp's Program
- 11 control and 11 participating European female team handball players
- Program: An ankle disk program involving balance drills, 10-15 minutes a day for all practices for one 10 month season
- Control teams: injury rate (controls) 5.9% < participating team's players

IX. Neuromuscular Training Programs: Cincinnati Program
- Background: plyometric jump skills can decrease peak landing forces, and varus and valgus moment arms at the knee
- A phased program done 3 days a week for 6-8 weeks preseason.

- Technique phase: teach proper jump technique
- Fundamental phase: build strength, power, agility
- Performance phase: focus on altering maximum vertical jump height

■ 1263 female high school athletes in the sports of volleyball, basketball, and soccer
■ Participating athletes experienced a 2-4 fold decrease in serious knee injures compared to controls

X. Neuromuscular Training Programs, Frappier Program (Fargo, ND)

■ Based on sports-specific cardiovascular conditioning, plyometrics, sport cord drills, strength training, and flexibility customized to the sport
■ Female high school, age 14-18: control group (N=258), trained group (N=47)
■ Trained group had significantly lower incidence of injuries when compared with untrained group
■ Incidence of ACL injuries in trained group (2.4%) < untrained group (3.1%)

XI. Neuromuscular Training Programs, the Santa Monica Program (PEP)

■ The program: 15 minutes of drill work at the beginning of practice 2-3 times a week for 12 weeks
■ 5 part program:
- Increase flexibility
- Increase strength
- Increase agility
- Perform Plyometrics

■ Study group composition
- Female soccer players age 14-18 years
- Trained group: 1041 players (52 teams)
- Age and skill matched controls: 1902 players (95 teams)

■ Study results
- Trained group: 2 MRI confirmed ACL tears (0.19%)
- Control group: 32 confirmed ACL tears (1.6%)
- 83% reduction of ACL injury in control group

XII. Neuromuscular Training Programs, The Norwegian Awareness Program

■ Training program
- 3 types of exercises with progressive skill training emphasizing balance, landing, and cutting maneuvers.
- 5 weeks of training, 2-4 times per week preseason, then 1 time a week through the season (October through April)

■ Study group:
- Female handball players during season 1999/2000, all three divisions, club through elite programs

■ Study results:
- Some reduction in ACL injuries in all 3 divisions, especially at the elite division
- Only 29% of the teams were compliant with the program
- New and more sports-related training program was created, including:
  - Handball related exercise, including fake passes, two-leg landing, and less static exercises
  - Increase the number of two-person drills
  - Increase knowledge of why the drills were being done, which improved motivation for the players

■ Study results for year 2:
- An awareness program reduced ACL injuries in Norwegian team handball by 40% overall and 50% at the elite level.

XIII. Research Needs: Non-Contact ACL Injuries

■ What are strategies for preventing non-contact ACL injuries?
■ What do all these programs have in common?
- Proprioception training
- Identifying at risk motions and positions
  - Train avoidance techniques when possible
  - Educating players of at risk positions
- Training programs that enhance body control, in particular rotational control of the limb
  - Pelvifemoral muscles (hip extension, hip abduction, abdominals)
  - Emphasis on proper athletic technique for landing, pivoting activities
- Concerns
  - No at risk factor except gender has been identified
  - Why these programs work and what is changed pre-post training not specifically identified
  - Only Norwegian programs looked at compliance and matched this to outcomes

REFERENCES

1. CARAFFA A, CERULLI G, PROJETTI M, et al, "Prevention of Anterior Cruciate Ligament Injuries in Soccer. A Prospective Controlled Study of Proprioceptive Training". Knee Surgery, Sports Traumatology, Arthroscopy 4:19-21, 1996.
2. ETTLINGER CF, JOHNSON RJ, SHEALY JE, "A Method to Help Reduce the Risk of Serious Knee Sprains Incurred in Alpine Skiing". American Journal of Sports Medicine 23:531-7, 1995.
3. GRIFFIN LY, AThe Henning Program@, Prevention of Non-Contact ACL Injuries 1999; 13:93-96.
4. HEWETT TE, RICCOBENE JV, LINDENFELD TN, AThe Cincinnati Sportsmetrics Training Program@ Prevention of Non-Contact ACL Injuries 1999;15:101-106.
5. HEWETT TE, RICCOBENE JV, LENDENFELD TN, "The Effect of Neuromuscular Training on the Incidence of Knee Injury in Female Athletes". American Journal of Sports Medicine 24:699-706, 1999.
6. JOHNSON RJ, AThe ACL Injury in Female Skiers@, Prevention of Non-Contact ACL Injuries 1999;16:107-111.
7. MANDELBAUM BR, The Caraffa Program@, Prevention of Non-Contact ACL Injuries 1999;14:97-100.
8. WEDDERKOPP N, KALTOFT M, LUNDGAARD B, et al, "Prevention of Injuries in Young Female Players in European Team Handball. A Prospective Intervention Study". Scandinavian Journal of Medicine and Science in Sports 9:41-7, 1999.

NEUROMUSCULAR FUNCTION IN THE ACL DEFICIENT AND RECONSTRUCTED KNEE

Glenn N. Williams, PT, ATC, PhD

I. Introduction
- Approximately 50 studies exist on neuromuscular function on this topic
- Most common methods of studying neuromuscular function:
  - Threshold to detection of passive movement & joint position sense
  - Muscle responses to loads applied to the knee
  - Motion analysis studies
- Voluntary muscle control in the ACL deficient and reconstructed knee has received little attention (specific)

II. Assessment of Voluntary Muscle Control
- Target-matching protocol
- Electromyography
- Specificity Index
- Obtain a profile for each muscle

III. ACL Deficient vs. Uninjured Knee
- Impaired quadriceps control
- Vastus lateralis is profoundly affected
- Increased co-contraction
- Knee stiffening strategy used to compensate for poor quadriceps control
- Impaired quadriceps control is observed in both static & dynamic tasks
- Hallmark is quadriceps activity (especially vastus lateralis) when atypical and seemingly counterproductive

IV. Muscle Morphology in ACL Deficient Knee
- Noteworthy quadriceps atrophy occurs rapidly
- Vastus lateralis & vastus medialis affected to a greater degree than rectus femoris
- Effect on Type I muscle > Type II muscle
- Neuromuscular findings may be related to altered muscle physiology

V. Neural Factors that may Affect Muscle Control in the ACL Deficient Knee
- Increased compliance of connective tissues may alter length / force-feedback from muscle receptors
- Decreased afferent input from joint receptors as a result of the ACL injury?

VI. Morphology- Function Paradox after ACL Reconstruction w/ ST-GRA grafts
- Semitendinosus & Gracilis muscle volume ~40% lower than pre-surgery values, but patients back to playing at same level with excellent outcomes
- ~14% reduction in total hamstrings volume
- Effect on quadriceps & hamstrings musculature is similar; thus, there is balance
- Semimembranosus & biceps femoris appear to compensate
- Long-term effects in those without regeneration?
- Neural control?

VII. Voluntary Muscle Control in the ACL Reconstructed Knee
- Vastus lateralis & lateral gastrocnemius control improve significantly
- Effect of surgery vs. rehabilitation or simply being more active?
- Little impact on semitendinosus & gracilis control
- Tendons that regenerate generally reinsert 1 to 4 cm proximally, which may alter the muscles length-tension properties and force generation capacity

REFERENCES

1. Williams GN, Barrance PJ, Snyder-Mackler L, Axe MJ, Buchanan TS: Specificity of muscle action after anterior cruciate ligament injury. J Orthop Res 21(6):1131-1137, 2003
2. Williams GN: Neuromuscular function in the anterior cruciate ligament deficient and reconstructed knee. Doctoral dissertation (University of Delaware), 2003
3. Buchanan TS, Lloyd DG: Muscle activation at the human knee during isometric flexion-extension and varus-valgus loads. J Orthop Res. 15(1):11-17, 1997
4. Borsa PA, Lephart SM, Irrgang JJ, Safran MR, Fu FH: The effects of joint position and direction of joint motion on proprioceptive sensibility in anterior cruciate ligament-deficient athletes. Am J Sports Med 25(3):336-340, 1997
5. Reider B, Arcand MA, Diehl LH, Mroczek K, Abulencia A, Stroud CC, Palm M, Gilbertson J, Staszak P: Proprioception of the knee before and after anterior cruciate ligament reconstruction. Arthroscopy 19(1):2-12, 2003
6. Wojtys EM, Huston LJ: Neuromuscular performance in normal and anterior cruciate ligament-deficient lower extremities. Am J Sports Med 22(1):89-104, 1994
7. Beard DJ, Kyberd PJ, O'Connor JJ, Fergusson CM, Dodd CA: Reflex hamstring contraction latency in anterior cruciate ligament deficiency. J Orthop Res 12(2):219-228, 1994
8. Rudolph KS, Axe MJ, Buchanan TS, Scholz JP, Snyder-Mackler L: Dynamic stability in the anterior cruciate ligament deficient knee. Knee Surg Sports Traumatol Arthrosc 9(2):62-71, 2001
9. Limbird TJ, Shiavi R, Frazer M, Borra H: EMG profiles of knee joint musculature during walking: changes induced by anterior cruciate ligament deficiency. J Orthop Res 6(5):630-638, 1988
10. Lieber RL, Friden JO, Hargens AR, Danzig LA, Gershuni D: Differential response of the dog quadriceps muscle to external skeletal fixation of the knee. Muscle Nerve 11(3):193-201, 1988
11. Edgerton VR, Roy RR, Allen DL, Monti RJ: Adaptations in skeletal muscle disuse or decreased-use atrophy. Am J Phys Med Rehabil 81(11):S127-147, 2002
12. Kaneko F, Onari K, Kawaguchi K, Tsukisaka K, Roy SH: Electromechanical delay after ACL reconstruction: an innovative method for investigating central and peripheral contributions. J Orthop Sports Phys Ther 32(4):158-165, 2002
13. Nakagawa Y, Totsuka M, Sato T, Fukuda Y, Hirota K: Effect of disuse on the ultrastructure of the achilles tendon in rats. Eur J Appl Physiol Occup Physiol 59(3):239-242, 1989
14. Nichols TR, Cope TC, Abelew TA: Rapid spinal mechanisms of motor coordination. Exerc Sport Sci Rev 27:255-284, 1999

TENDON REPAIR AND REGENERATION: CHALLENGES AND OPPORTUNITIES FOR ENGINEERED TISSUE CONSTRUCTS (AAOS/ORS)

Moderator: Joseph P. Iannotti, MD, Cleveland, OH (n)

Tendon injury and repair often results in incomplete healing or scarring with compromised function. This symposium will involve discussion of the biologic enhancement of the healing process. Discussion will include the use of growth and differentiation factors, mechanical conditioning, cell based therapies and biologic scaffolds.

I. Functional Tissue Engineering for Tendon Replacement: Defining the Design Parameters
David L. Butler, PhD, Cincinnati, OH (n)

II. Extracellular Matrices as Scaffolds for Enhancement of Tendon Repair: Pre-Clinical and Clinical Trials
Stephen Badylak, MD, Pittsburgh, PA (a – DePuy Inc)

III. Scaffolds, Cells and Growth and Differentiation Factors in Tendon Tissue Engineering
Albert J. Banes, PhD, Chapel Hill, NC (a, b, d, e – Flexcell Intl. Corp.)

IV. In Vitro Mechanical Conditioning to Direct Cell Growth and Differentiation Into Fuctional Tissues
David Kaplan, PhD, Medford, MA (a, d – Tissue Regeneration, Inc)

FUNCTIONAL TISSUE ENGINEERING FOR TENDON REPLACEMENT: DEFINING THE DESIGN PARAMETERS

Joseph P. Iannotti, MD

Tendinosis and Tears: An Opportunity for Biologic Enhancement of the Clinical Result

Joseph P. Iannotti MD, Ph.D
Chairman, Department of Orthopaedic Surgery
The Cleveland Clinic Foundation
Professor, Cleveland Clinic Lerner School of Medicine

Type of Tissue

- Dense collagenous matrix
- Poor vascularity
- Low cell number
  - Local stem cells
- High functional demands: Load bearing material even at rest

Faculty

- David Butler, PhD
  - Department of Biomedical Engineering
  - University of Cincinnati
- Stephen Badylak, MD, PhD, DVM
  - Department of Surgery
  - McGowan Institute for Regenerative Medicine University of Pittsburgh

Pathogenesis of Rotator Cuff Tears

- Trauma
  - Repetitive overuse
  - Single event trauma
  - Impingement: Neer
- Aging
  - Senescent degeneration
- Intrinsic disease
  - Vascularity

Most tendon tears are the result of a combination of these factors.

Faculty

- Dr. Albert J. Banes
  - Director of Research, Department of Orthopaedics
  - University of North Carolina at Chapel Hill
- David Kaplan PhD
  - Professor and Chairman
  - Department of Biomedical Engineering
  - Tufts University

Human Tendon Tissue: Role of Aging

- Histopathologic changes in 891 spontaneously ruptured tendons (Achilles, quadriceps and patella)
- 34% of 445 intact tendons:
  - Hypoxic degeneration
  - Mucoid degeneration
  - Tendolipomatosis
  - Calcification
  - Changes in tendon associated with aging

Kannus and Jozsa JBJS 1991

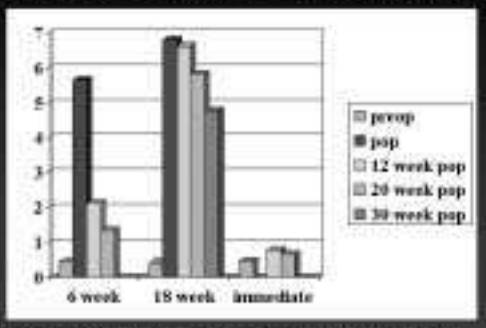
Human Rotator Cuff Tendon: Effect Hypovascularity

- Decreased vascularity of the tendon
- Hypoxic degeneration
- Cell death
- Disorganization of the matrix

Greatest histologic changes on the articular surface of the tendon were there is the poorest blood supply

Hans Uhthoff

Delayed RCR: Lipid Content in Muscle

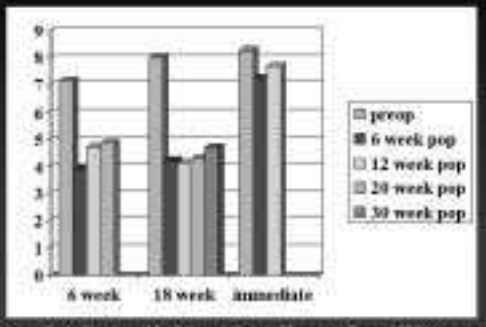


- 80% lipid is interstitial and 20 % within muscle fibers

Pathogenesis Trauma: Rat Shoulder Model: Soslowsky

- Tendonosis
  - Thickened tendon
  - Disorganized matrix
  - Increased cellularity
  - Decreased mechanical properties
  - Biochemical changes
    - New matrix formation
- When is this reversible??

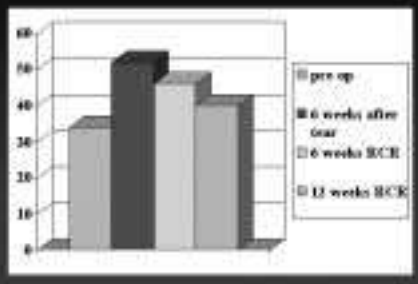
Delayed RCR: Muscle Force



Gerber, Fuchs, Steinhaus, MacGillivray, Ahrens, Warner and Tetzlaff. ASES open meeting 2002 (Nice Award)

Muscle Atrophy: MRI Grade

Tendon Material Properties

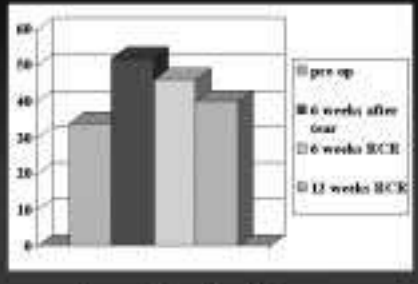


- Increase in tendon stiffness
- Improves after repair

Characteristics of a chronic large and massive cuff tear

- Tendon retraction
- Fair to poor tissue quality
- Difficult to mobilize and high tissue tension
- Severe muscle atrophy
- High failure rate of the tendon to heal after traditional repair

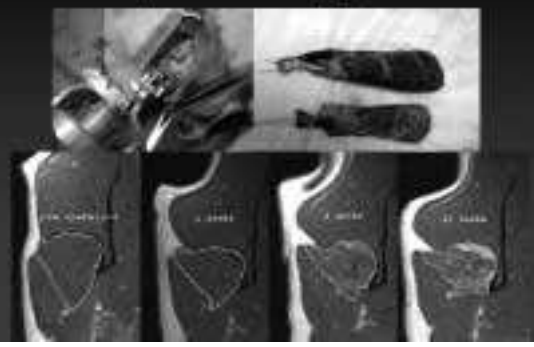
Tendon Material Properties



- Increase in tendon stiffness
- Improves after repair

Dog Model Of Chronic Rotator Cuff Tears

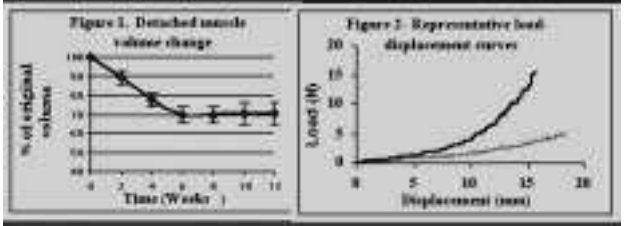
The relationship of muscle atrophy and tissue stiffness



Reported Results After RCR for Full Thickness RCR

- Generally reported 85-95% good and excellent results
  - Patient satisfaction
  - Pain relief
  - Functional activities for ADL and light leisure activity

Muscle Atrophy and Mechanical Properties



Why Do We Consider Using a Biologic Device to Augment RCR

- 30- 50% of chronic two tears fail to heal when evaluated by US, Arthrography or MRI
- Fortunately most of these patients are clinically improved
- But many would have done better with better strength if the tendon would heal.

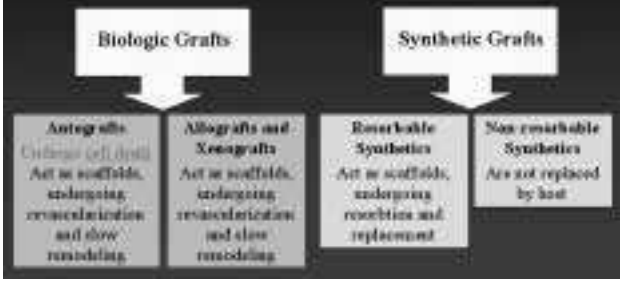
Infraspinatus muscle properties

	Control shoulder	Study shoulder	P value
Volume (ml)	79.7±12.8	61.7±11.8	<0.001
Length (cm)	13.1±0.3	13.1±0.3	<0.001
Stiffness 1 (N/mm)	8.12±0.94	8.38±0.94	<0.001
Stiffness 2 (N/mm)	8.65±0.10	7.97±0.22	<0.001
Modulus 1 (kPa)	45±10	37±13	<0.001
Modulus 2 (kPa)	418±39	311±43	<0.001

*Mean ± SD *Adjusted means ± SE

Tendon Injury and Repair

In the United States over 30,000 tendon repair procedures are performed annually



Chronic Tendon Tears: A disease of the tendon and muscle

- Both require study and biologic solutions to fully realize the clinical challenges for recovery of the clinical problem.

Options for a bioscaffold tissue augmentation device

- Current products on the market
  - Small intestine submucosa (SIS Restore, DePuy)
  - Human dermis (Graft jacket, Wright Medical)
  - Bovine fetal dermis (Tissue Mend, Stryker)
- Restore is the only product with preclinical and clinical trials
- Concept: acellular bioscaffold that has inductive and conductive properties

Options for Tissue Scaffolds

- **Cellular** (Patellar Tendon Autografts, Bone Grafts)
- Acellular (Type I collagen, Allodern, SIS, OrthoMend)

- **Synthetic** (PLGA, Titanium)
- Biologic (Collagen, Alginate, ECM, SIS, Allodern, Ortho mend)

- **Non-Resorbable** (PeriGard, PTFE, Porcine Heart Valves)
- Resorbable: (ECM, Collagen, PGA, SIS, Allodern, Orthomend)

- **Cross-linked** (Contigen, Porcine Heart Valves)
- Non Cross Linked (SIS, UBS-ECM, Hyaluronic acid, Allodern, Orthomend)

Clinical Results

- FDA approved for tendon and RCT small to massive as devices not as a biologics.
- Approx 10K Restore cases used in US for tendon augmentation.
- Not to be used for tendons that are not repairable.
- Immune reaction to foreign proteins low incidence.
- Clinical value not defined yet; clinical trials underway for some of the products.

Summary

- Tendon tears are often a result of a degenerative process.
- The surgical repair is limited by the quality of the tissues and the decreased biologic potential associated with a diseased tendon.
- Chronic tears are associated with muscle atrophy which has a limit ability to be reversed.
- Muscle atrophy results in an adverse mechanical environment that increases the likelihood for clinical failures.
- The opportunities for biologic enhancement of the tendon repair offer promise for improved clinical results.

EXTRACELLULAR MATRICES AS SCAFFOLDS FOR ENHANCEMENT OF TENDON REPAIR: PRE-CLINICAL AND CLINICAL TRIALS

David Butler, MD

Functional Tissue Engineering for Tendon Replacement: Defining the Design Parameters

David Butler, Natalia Juncosa, Greg Boivin, Marc Galloway, Matt Dressler, Jason Shearn, Victor Nirmalanandhan, John West, Cindi Gooch

Departments of Biomedical Engineering and Pathology and Lab Medicine, University of Cincinnati, Cincinnati, Ohio
Cincinnati Sports Medicine and Orthopaedic Center, Cincinnati, Ohio

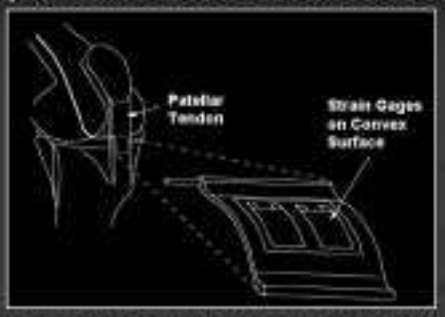
In Vivo Forces In Normal Tendon

- Patterns
  - Remain non-zero throughout gait [Juncosa et al, 2003; Korvick et al, 1996; Malaviya et al, 1998; West et al, in press]
  - More complex in two-joint than one-joint muscles [Juncosa et al, 2003; West et al, in press]
- Peak Forces
  - Increase with speed/intensity of activity [Komi et al, 1992; Herzog et al, 1983; Prilutsky et al, 1994; Malaviya et al, 1998; Juncosa et al, 2003; West et al, in press; Korvick et al, 1996]
  - Vary with species and tissue location [Biewener et al, 1988; Juncosa et al, 2003; Korvick et al, 1996; Malaviya et al, 1998; West et al, in press]
  - Larger than for ligament [Holden et al, 1994; Korvick et al, 1996]
- Rates of Rise and Fall in Force as Important
  - Also increase with speed/intensity [Herzog et al, 1983; Juncosa et al, 2003; Komi et al, 1992; Prilutsky et al, 1994; Malaviya et al, 1998; West et al, in press]

Tendons Are Difficult to Repair

- Large, rapidly applied forces challenge repair
  - Variable structural biomechanical properties
  - Slow return in material properties
  - Threat of re-injury
- Inaccurate tensioning of the repair
  - Affect its function in the joint *in vivo*
- Patterns of *in vivo* forces not well known
  - Makes the design of effective repairs and reconstructions more difficult

Loading Demands Measured with Implantable Force Transducers

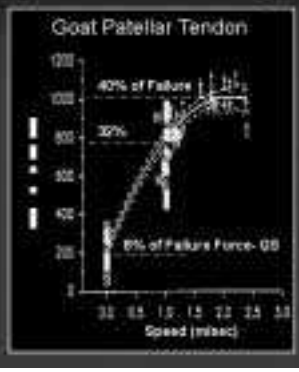


[Fu et al, 1991; Glos et al, 1993; Korvick et al, 1996; Holden et al, 1994; Malaviya et al, 1998; Juncosa et al, 2003; West et al, in press]

Objectives

- *In Vivo* Forces (IVFs) in Normal Tendon
  - Patterns, peaks and rates of rise and fall
- IVFs to Design Tissue Engineered Repairs
  - Functional tissue engineering "roadmap"
  - Different treatment approaches
- Introduce Functional Tissue Engineering Parameters (FTEPs) into Roadmap
  - *In vivo* deformation (IVD) plus IVF to evaluate repair stiffness
  - Differential fiber length
  - Variations in relative positions of insertions

Tendon Force Increases with Speed of Activity



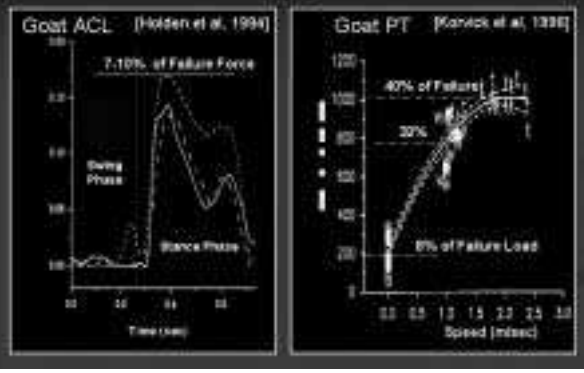
[Korvick et al, 1996]

Peak Force Percentages Vary with Species and Location

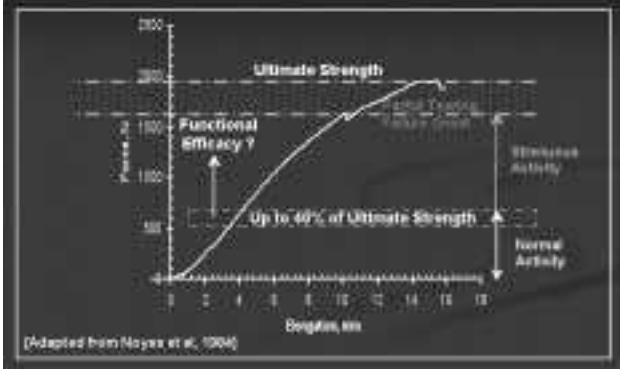
- Goat (Trotting)
  - PT (40%) [Korvick et al, 1996]
- Rabbit (Inclined Hopping)
  - FDP (28%) [Malaviya et al, 1998]
  - Achilles (19%) [West et al, in press]
  - PT (11%) [Juncosa et al, 2003]
- Rat
  - Ankle Extensor (25%) [Biewener et al, 1988]

FTE "Road Map"

Forces Larger in Tendon than Ligament



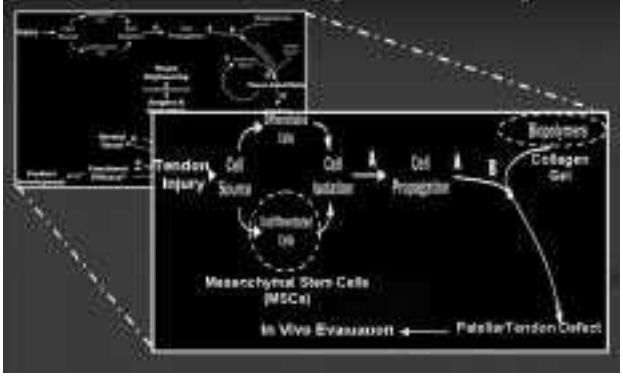
Tendons are Loaded Up to 40% Along Force-Elongation Curve



Peak IVFs Increase with Inclination of Surfaces

- Goat PT (Level vs Inclined Ramp)
  - 20% increase [Korvick et al, 1996]
- Rabbit (Level to Inclined Hopping)
  - PT (22% increase) [Juncosa et al, 2003]
  - FDP (64% increase) [Malaviya et al, 1998]
  - Achilles (30% increase) [West et al, in press]

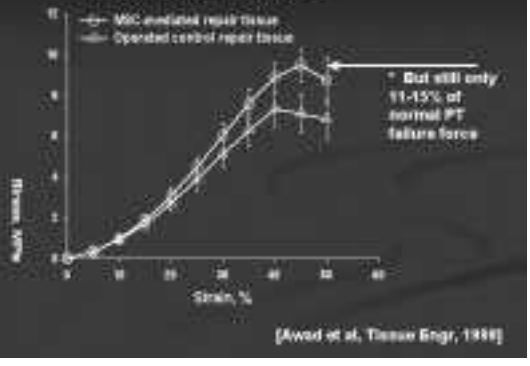
FTE Roadmap- MSCs and Collagen Gel Only



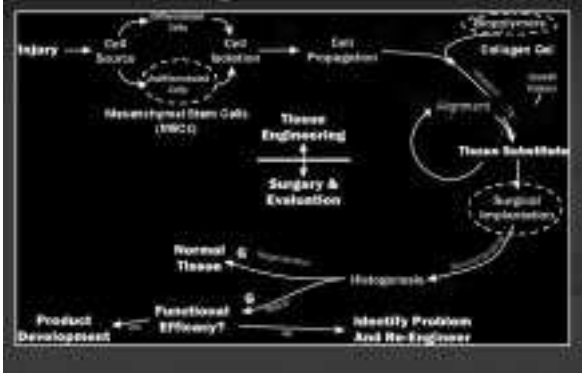
Objectives

- *In Vivo* Forces (IVFs) in Normal Tendon
  - Peak values, rates of rise and fall, and patterns
- IVFs to Design Tissue Engineered Repairs
  - Functional tissue engineering "roadmap"
  - Different treatment approaches
- Introduce Functional Tissue Engineering Parameters (FTEPs) into Roadmap
  - *In vivo* deformation (IVD) and tangent stiffness
  - Differential fiber length
  - Variations in relative positions of insertions

Cell Therapy Improves PT Repair Biomechanics*



Roadmap- MSCs+Gel+Alignment & Surgical Evaluation

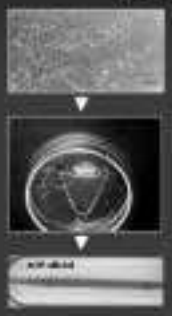


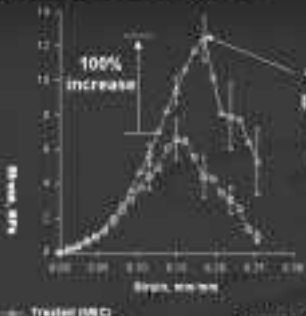
New Approach- Mimic In Vivo Strains to Constructs in Culture

20 implants in 5 silicone dishes in 5 stations under computer control

More precise control of in vivo strains to 6 constructs and independent force recording

MSC-Seeded Implants Improve AT Repair Biomechanics *





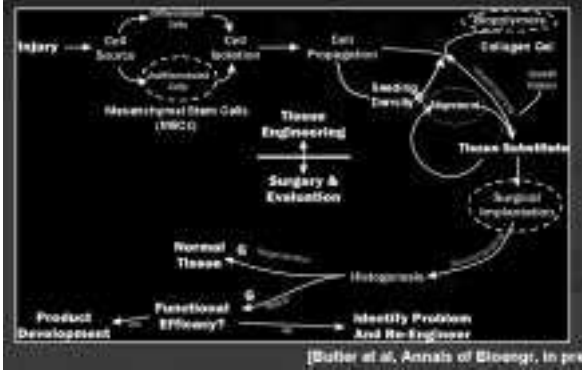
*But still less than design limit for IVFs

[Young et al., JOR, 1998]

Objectives

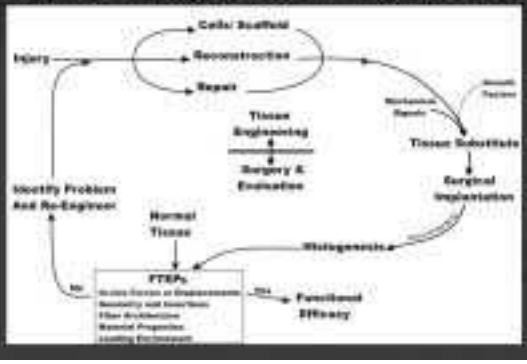
- *In Vivo* Forces (IVFs) in Normal Tendon
  - Peak values, rates of rise and fall, and patterns
- IVFs to Design Tissue Engineered Repairs
  - Functional tissue engineering "roadmap"
  - Different treatment approaches
- Introduce Functional Tissue Engineering Parameters (FTEPs) into Roadmap
  - Differential fiber length
  - IVF plus *in vivo* deformation (IVD)
    - *In vivo* tangent stiffness
  - Variations in relative positions of insertions

Roadmap- Vary Cell Seeding Density



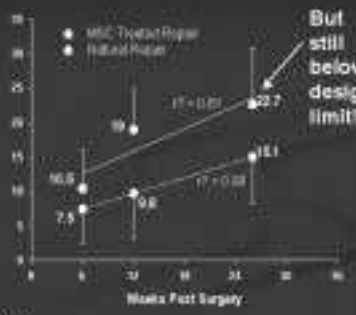
[Butler et al, Annals of Bioengr, in press]

Improve Repair with Functional Tissue Engineering Parameters



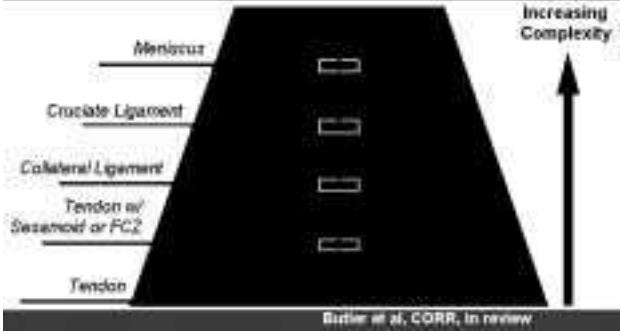
Increasing Cell Density Does not Further Improve PT Repair Results

However, cell-seeded repairs still stronger and stiffer than natural repairs and improved at faster rate



Awad et al, JOR, 2003

Tendons have Less Tissue Complexity but Still have 4 FTEPs



Butler et al, CORR, In review

Longer Fibers have Lower Tendon Stiffness

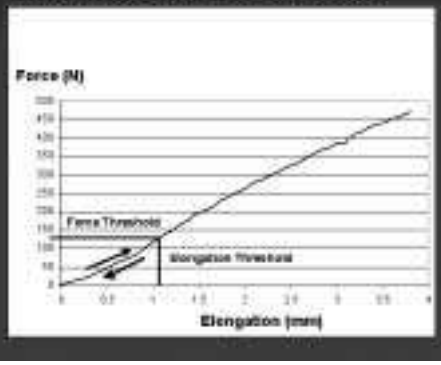
Structure	Length (mm)
Patellar Tendon	44.5-57.8[1]
PT-Anterior Band	73.1[1]
PT-Posterior Band	44.8[1]

[1] Butler et al, 1986 [2] Basso, Amis, Race, 2008

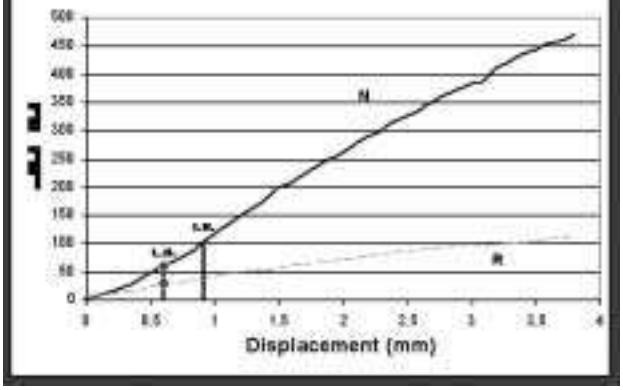
How Should The Repair Curve Be Compared To The Normal Curve Within The Threshold Of Different Activity Levels?

- Based on Equivalent Elongations

Force-Elongation Curve is In Vivo Mechanical "Signature"



Based on Equivalent Elongations



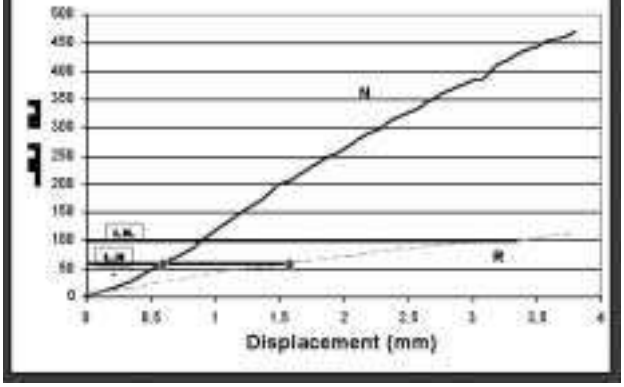
How Should The Repair Curve Be Compared to the Normal Curve within the Threshold of Different Activity Levels?

- Based on Equivalent Forces

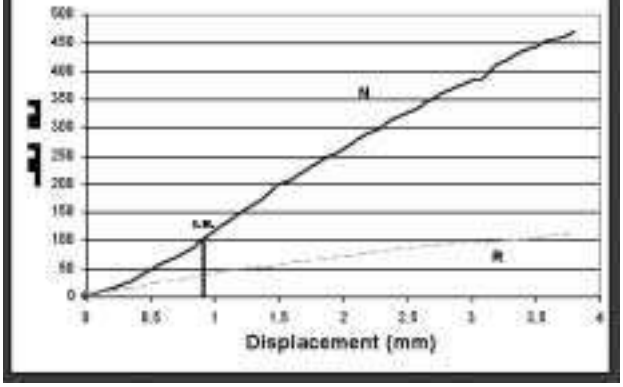
How Should The Repair Curve Be Compared To The Normal Curve Within The Threshold Of Different Activity Levels?

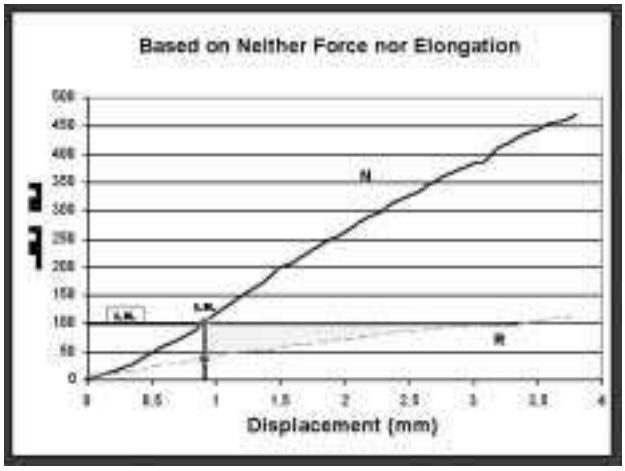
- Based on Neither Force nor Elongation

Based on Equivalent Forces



Based on Neither Force nor Elongation

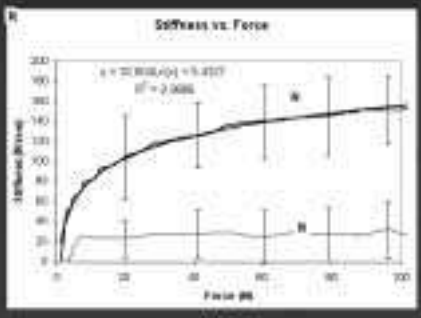




Future Studies

- Measure in vivo forces, stresses, displacements in specific tendons in animals
- Deliver simulated in vivo signals to "tissue engineered" constructs in animals
- Use FTEPs to evaluate effectiveness of these cell-based and scaffold-based therapies to repair and reconstruct damaged tissues
- Develop similar technologies for patients

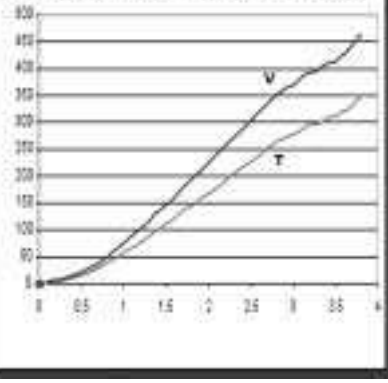
Comparing Stiffnesses in the In Vivo Force Range



Acknowledgments

- NIH AR46574, AR42618 and EB002361
- VA Merit Grant (G. Boivin)
- Cincinnati Sportsmedicine Research and Education Foundation

Variations in Relative Positions of Insertions on Tendon Forces



Effect of Patellar Tilt on Tendon Force and Stiffness?

Thank You

TENDON REPAIR AND REGENERATION: CHALLENGES AND OPPORTUNITIES FOR ENGINEERED TISSUE CONSTRUCTS

Stephen Badylak, MD

Naturally Occurring Scaffold Materials

- Purified Collagen (e.g., Contigen™, Regen Meniscus)
- Harvested Tissues (e.g., pericardium, fascia lata, heart valves)
- Extracellular (acellular) Matrix (Restore™, CuffPatch™, Graftpatch™, Graftjacket™, Alloderm™)

Methods of Protein Crosslinking

- Glutaraldehyde (eg, porcine heart valves)
- Carbodiimide (eg, CuffPatch™, GraftPatch™)
- Dehydrothermal and Cryopreservation (Graftjacket™, Alloderm™)
- Photo-oxidation

Composition of ECM Scaffolds

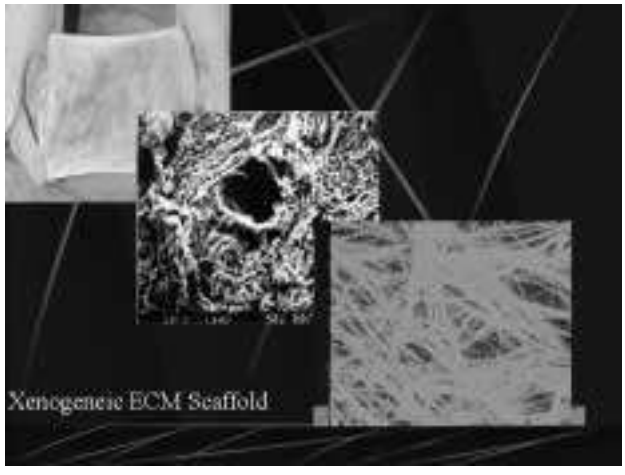
- Structural Proteins (e.g., collagen, laminin)
- "Connecting Molecules" (GAGs)
- Bioactive Molecules (TGF-beta, VEGF, bFGF, etc)
- Binding Molecules (eg, decorin, perlecan, etc)

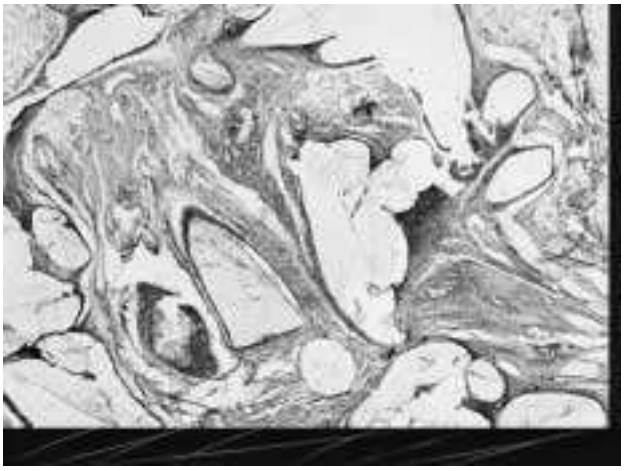
Biologic Response to ECM Bioscaffolds

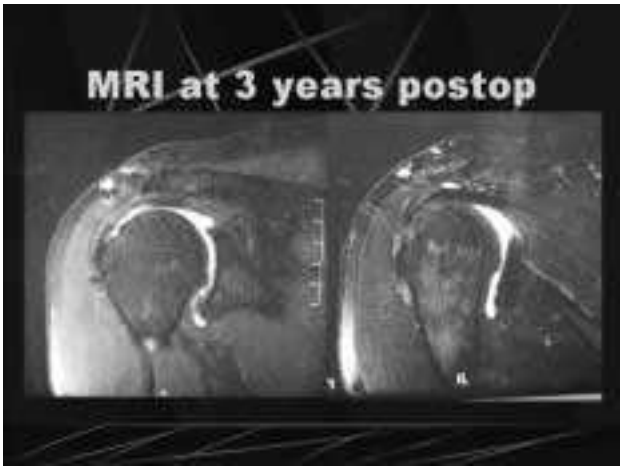
- Immediate cellular infiltration (mainly PMNs for first 48-60 hours)
- Immediate scaffold degradation
- Immediate release of ECM degradation products
- Accumulation of mononuclear cells
- Angiogenesis
- Deposition of host derived neo-ECM
- Differentiation and organization of host derived cells and matrix

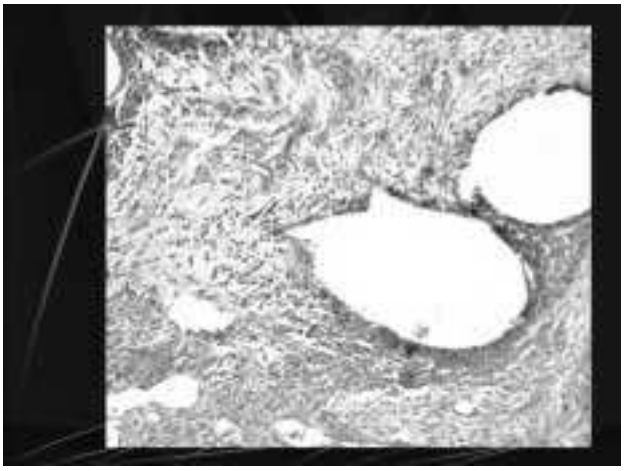
Effects of Protein Crosslinking

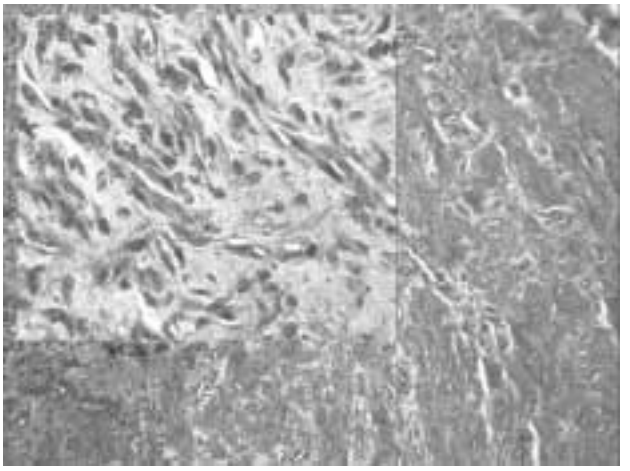
- "Caps" antigenic epitopes (inert)
- Increases biomaterial strength
- Significantly reduces cellular infiltration
- Inactivates bioactive molecules
- Significantly slows or eliminates degradation

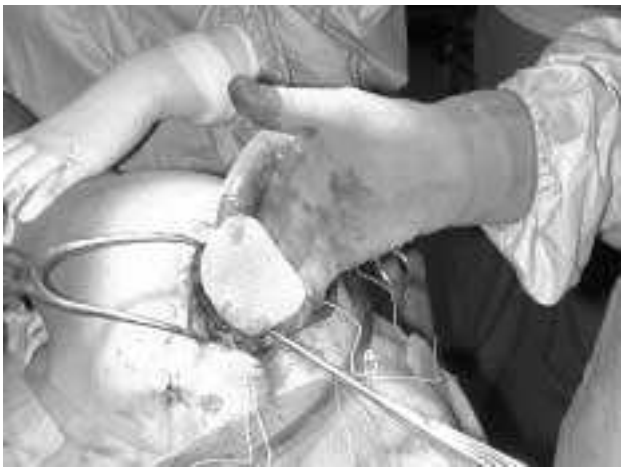


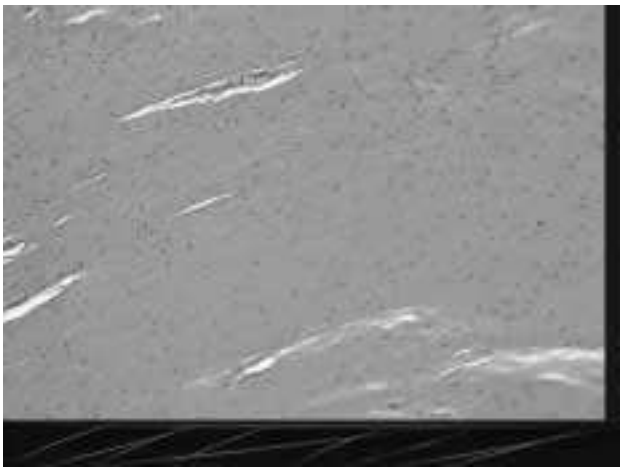



MRI at 3 years postop

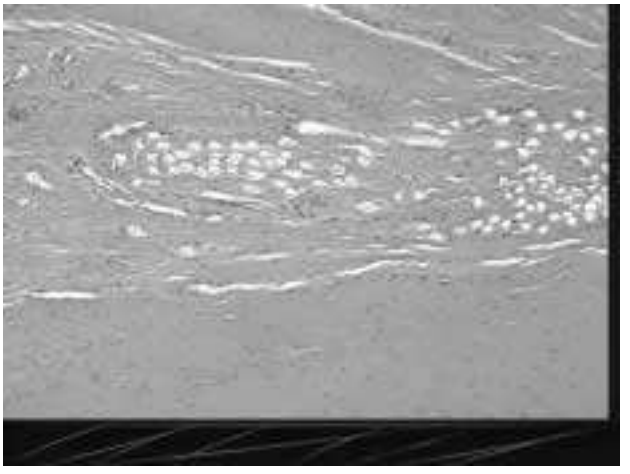


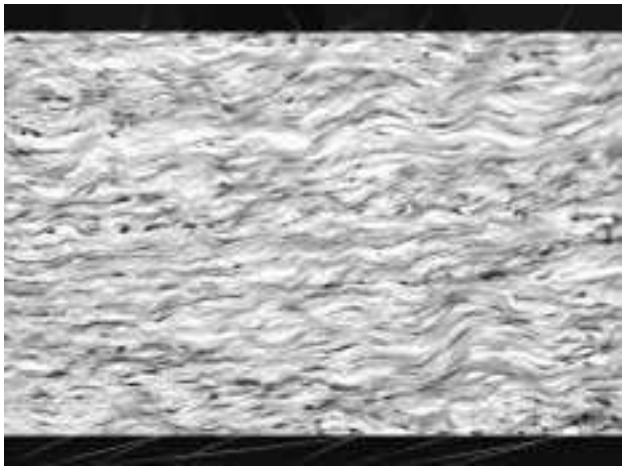






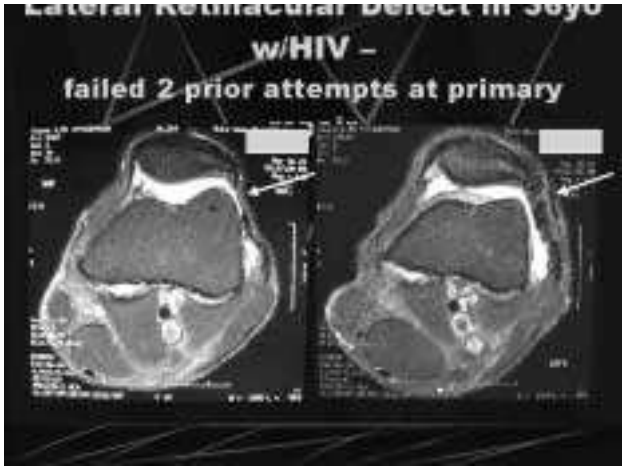

49 yo 1 yr s/p repair massive
RCT with Restore

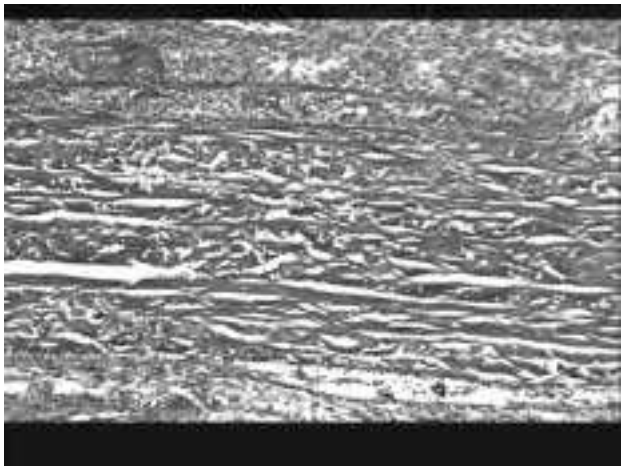


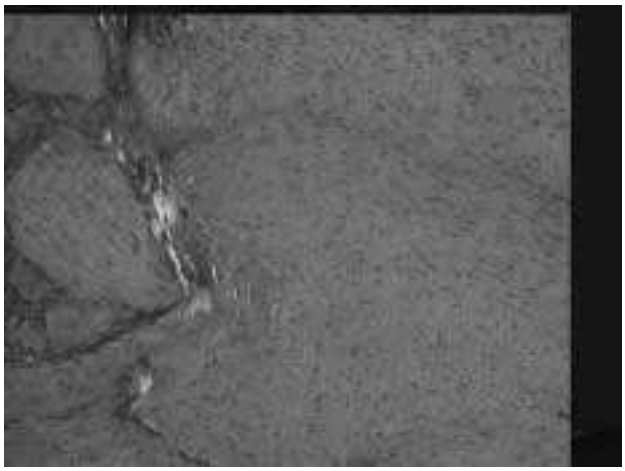


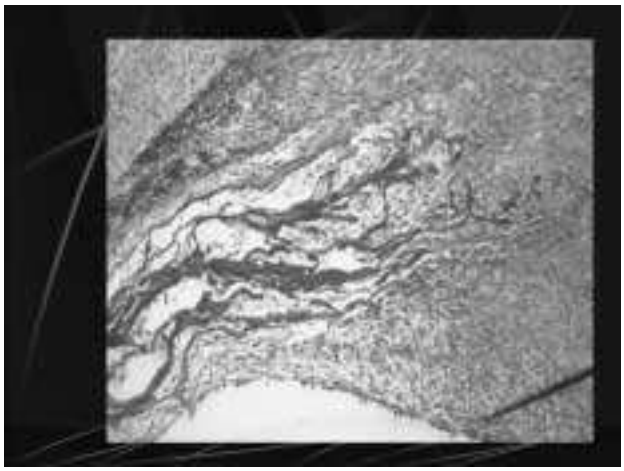
QUESTIONS

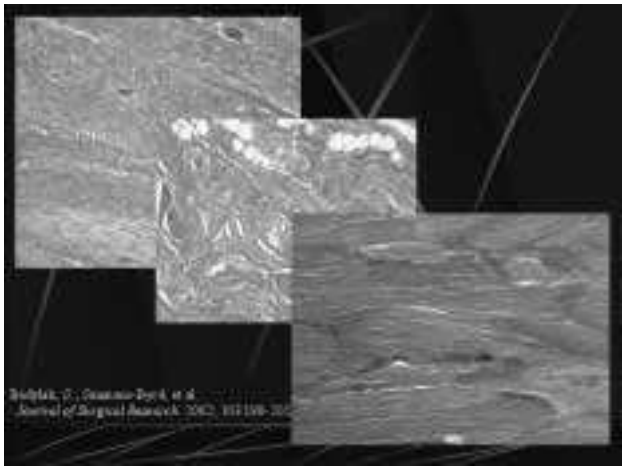
- Rate of Scaffold Degradstion?
- Strength of Scaffold Over Time?
- Source of Cells That Remodel the Bioscaffold?
- Fate of Bioactive Molecules within the ECM?











What is the Rate of Scaffold Degradation?

- 60-120 days, depending upon location, loading, and scaffold configuration

What is the Change in Strength of the Resorbable SIS Scaffold Over Time?

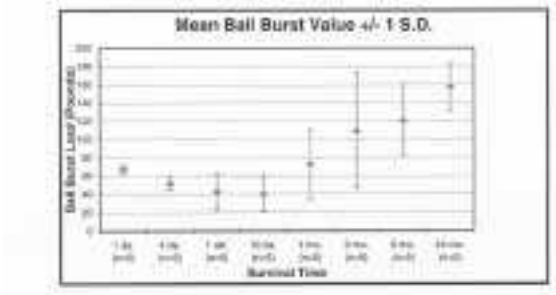
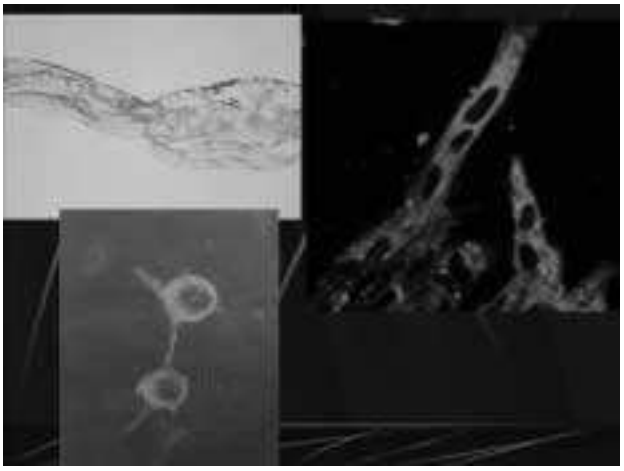
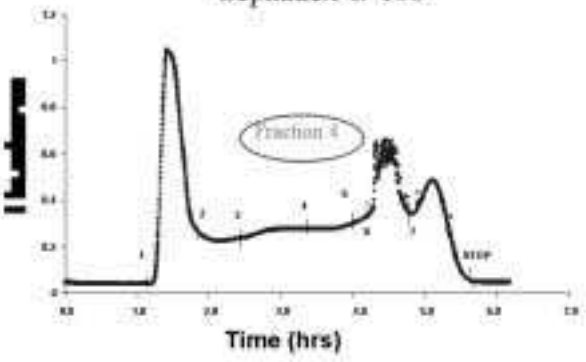


Figure 3.

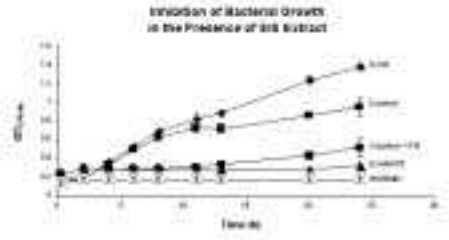


ECM Extract Chromatography on Sephadex G-100



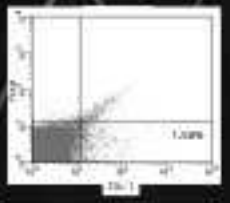
Source of Cells that Populate the Remodeling RESTORE scaffold?

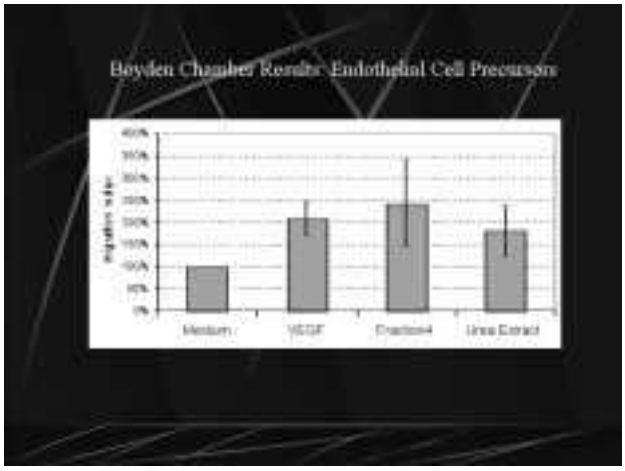
- Mixture of adjacent cells and circulating cells
- NOTE: a percentage of the remodeling cells originate in the bone marrow as multipotential progenitor cells



What is the Fate of the Bioactive ECM Molecules?

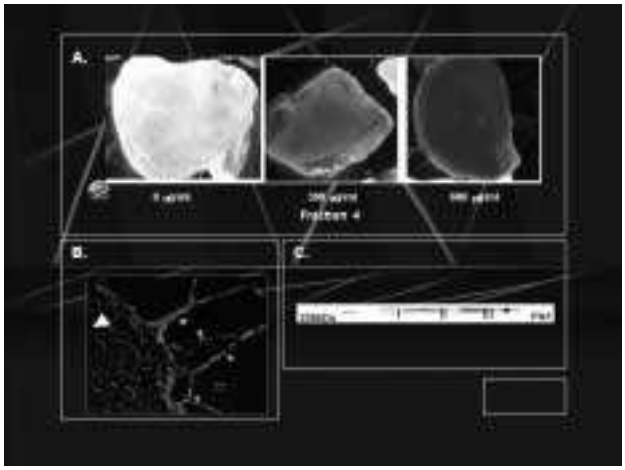
Isolate Endothelial Cell Precursors





Summary of ECM Scaffold Remodeling

- The ECM is an acellular biologic scaffold for tissue repair
- ECM bioscaffolds induce constructive remodeling of damaged or missing tissues
- ECM bioscaffolds are totally resorbable; degradation essential for remodeling effects
- There is no immune rejection of xenogeneic ECM scaffolds
- Remodeling of ECM bioscaffolds is associated with environmental "stressors"



Summary

- All ECM scaffolds are not created equal
- Crosslinking creates inert biomaterials
- Degradation is rapid with noncrosslinked ECM scaffolds
- Degradation is critical for the bioinductive properties observed in vivo

Clinical Correlates:

- **Block proinflammatory cytokine expression/activity..**
- **improve patient recovery, ROM, strength?**

HOW??

1. physical therapy- timed with the "correct" load regimen
2. Use drug therapy to block MMP expression- ATP, low Ca^{2+}, Gd^{2+}, other

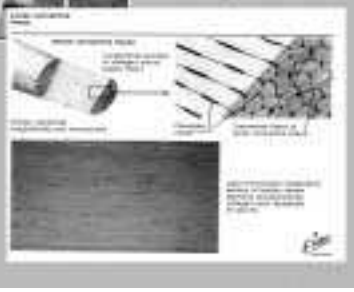
Tissue Engineering is in a "Planet of the Apes" Stage.

Few victories, many "failures".

How might we design a better body with stronger tendons?

Tendons differ in size, composition and strain fields. Compare Achilles to Flexor digitorum profundus.

Also species differences in response to load.



Rat tail tendon model- Local strains differ from bulk tissue strain, gauged by interfascicular distance. Collagen fibrils slide past each other. Endotenon may be strained most. Arnoczky, JOR, 02; Screen, WCB, 02.

Tissue Engineering body parts...

What have we tried?

What has worked?

Where are we with tendons?

Growth factors known to affect tendon cell metabolism from Goh etal., review on Tissue Engineering tendons and ligaments Tissue Engineering 9: S-31-S-44, 2003.

ACHILLES TENDON REPAIR

Achilles tendon surgery.
Attending: Dr. Tim Taft UNC Orth
Resident: Dr. Anthony Russo UNC Orthopaedics

Growth factors known to affect tendon cell metabolism from Goh etal., review on Tissue Engineering tendons and ligaments Tissue Engineering 9: S-31-S-44, 2003.

Materials used in tendon repairs

Hypotheses:

- Mechanical load to engineered connective tissues can be stimulatory… or inhibitory…depending on the "dose" and synergy with cytokines
- Mechanical load can block proinflammatory gene expression in tendon cells, even if cells are stimulated with a powerful inducer-IL-1b
- Let's look at some literature examples..

Modeling/Remodeling factors-(Fixagens, Breakagens)-

Cell contractility
Matrix remodeling
Express new genes
Matrix expression
DNA synthesis
Cell Division

Rapid stop signals
mRNA down regulation
Decreased cell adhesion
Decreased matrix expression
Matrix catabolism (MMP, aggrecanase activation)
Decreased cell division
Apoptosis
Reduced biomechanical strength

-Overuse/repetitive motion disorder: Loss of tendon structural and biomechanical integrity
-Characterized by acute or chronic pain and matrix degeneration. Activation of MMPs?
-Tendon fibroblast-derived IL-1β production: ATP signal modulation?

Cyclic tensile strain blocks proinflammatory gene expression, blocks COX-2 expression, PGE2 secretion, collagenase expression

Tissue Engineering Principle

Bigo da Plano-crane art at a loading dock illustrating a tensegrity principle.

One can manipulate the intrinsic strain in cells and a forming tissue by modulating the cell's connections to its matrix or by modulating the internal strain (actual or perceived) with or without the synergistic or antagonistic action of applied mechanical loading.

Matrix metalloproteinase activities and their relationship with collagen remodelling in tendon pathology

MMP-1 activity increased in ruptured supraspinatus tendons

Increases with age.

Some Principles of Tissue Engineering for Connective Tissues

1. Cells fabricate, organize and strengthen a matrix by a mechanism described as "structural tensioning" driven by "tractional structuring".
2. Cells maintain their own setpoint for a basal intrinsic strain level determined in part by their connectivity to the substratum, internal architecture that balances the external and internal forces and their propensity to move along the matrix and organize it.
3. Thus cells develop an "intrinsic strain" for a given extrinsic strain and attempt to modulate their cell-matrix contacts, pseudopod lengths, degree and types of cytoskeletal organization and modulus of elasticity based on the intrinsic strain value.

Signaling Stimuli to Load: Receptors/Pathways.. +/- Regulation

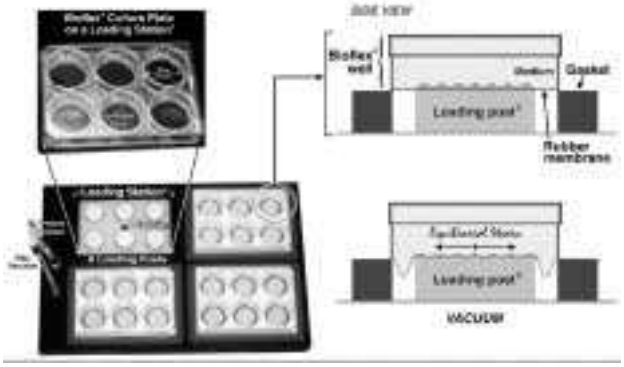
- Receptors:
- a. Growth Factor receptors-PDGF, TGF-b, IGF-I, EGF, FGF, BMPs-2, 4,5,6,12,13
- b. Cytokine receptors-TNF, IL1b, PGE
- c. P₂purinoceptors-Purines, Pyrimidines- ATP, ADP, AMP, A, UTP, regulators-NTPases
- d. Adrenoceptors- α,β adrenergic receptors- α1,α2,β, norepinephrine, epinephrine, other catecholamines
- e. Estrogen/androgen receptors-
- f. Parathyroid hormone receptors-
- g. Prostaglandin receptors-
- h. Ion Channels- Classes: voltage gated, stretch activated, cassette-type, gap junctions- Ca^{2+}, ATP/O, Na, K
- i. Integrins- α1β1, α1β/

Load..how important is it?

How can you apply load?

How do cells regulate responses?

Equibiaxial Stretching with the Bioflex® Rubber Bottom Culture Plate on a Loading Station



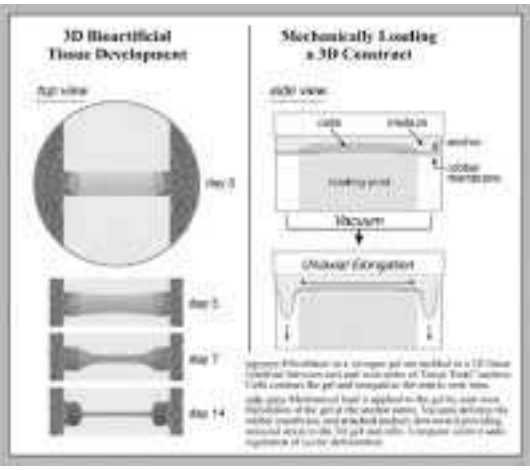
Bioartificial Tendons (BATs)

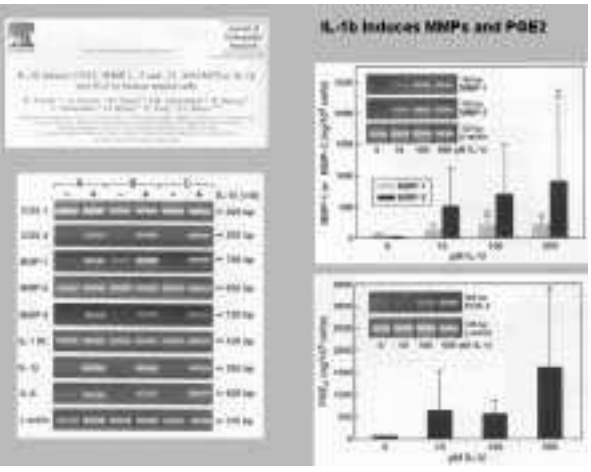
***Banes et al*, 2003: Bioartificial Tendons: A Model Tissue Engineered 3D System for Testing Tenocyte Responses to Drugs, Cytokines and Mechanical Load. 2003, AAOS Symposium on Tissue Engineering, chapter in press & web publication.**

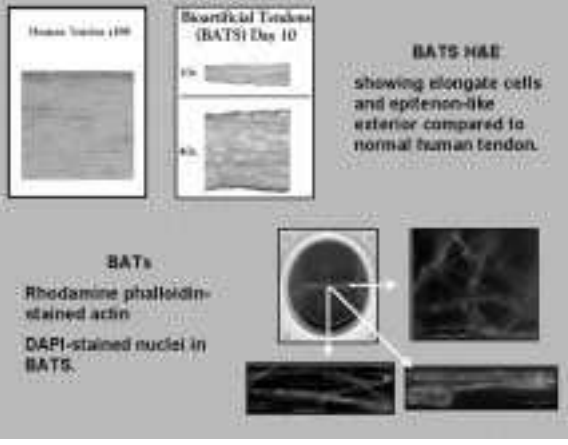
Garvin et al, 2003: A Novel System for Engineering Bioartificial Tendons and Application of Mechanical Load, in press J. Tissue Engineering.

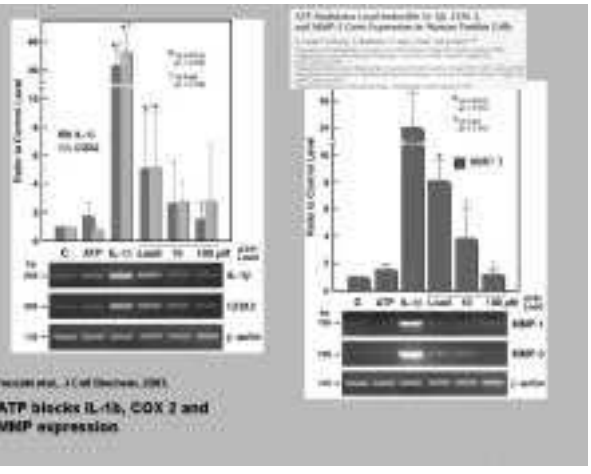
Tsuzaki/Bynum et al., 2003: Nandrolone Decanoate and Load Increase Remodeling and Strength in Human Supraspinatus Bioartificial Tendons, AJSM, in press.

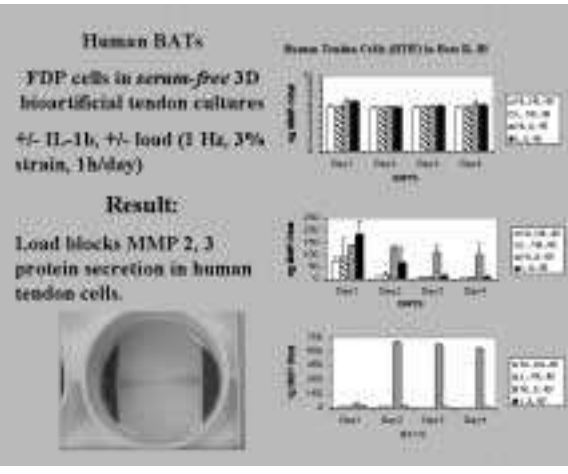
MMPs... Also for remodeling matrix





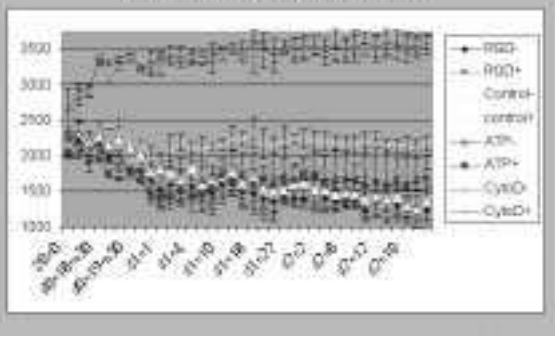




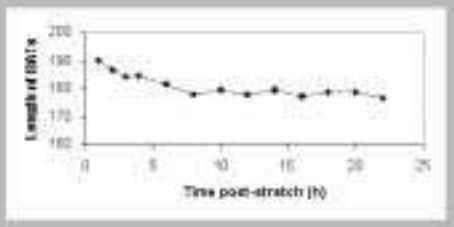


hBATs +/- IL-1b: Affects on 3D Gel Contraction/Remodeling

Cytochalasin D, an actin filament disruptor, REALLY blocks contraction as does IL-1B, RGD+IL-1b and ATP + IL-1b

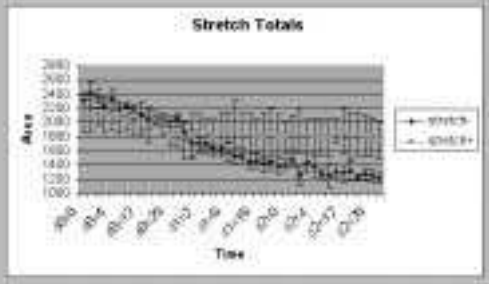


hBATs: Recover Tension Post-Stretch with IL-1b

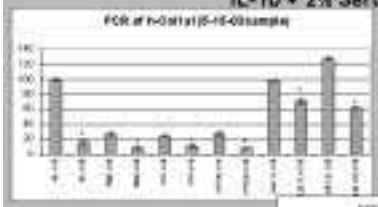


IL-1b induces elasticity in hBATs, ie elastic recovery after stretching.

hBATs: IL-1b and Stretch Retard 3D Gel Contraction/Remodeling



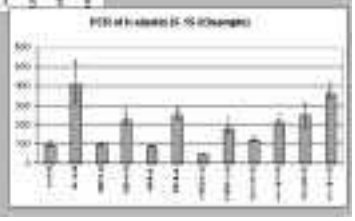
3D BATs: Collagen Gene is "off" but Elastin is "On" by IL-1b + 2% Serum



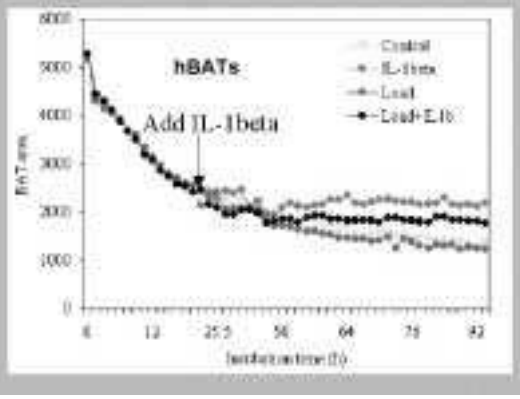
COL 1 down Elastin up.

IL-1b, RGD, ATP, Cyto D

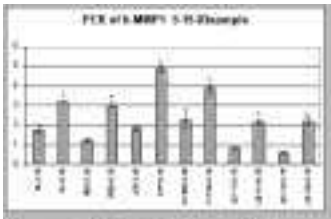
Load protects or "normalizes" against IL-1b!



IL-1b can Block BAT Remodeling Post-Contraction

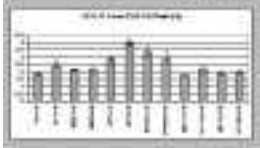


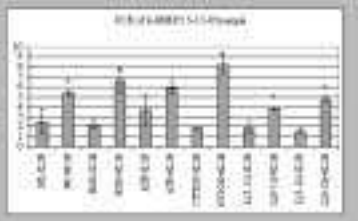
hBATs: IL-1b + 2% Serum Effect on MMP RNA



IL-1b increased MMP 1 even with RGD, ATP, Cyto D or load.

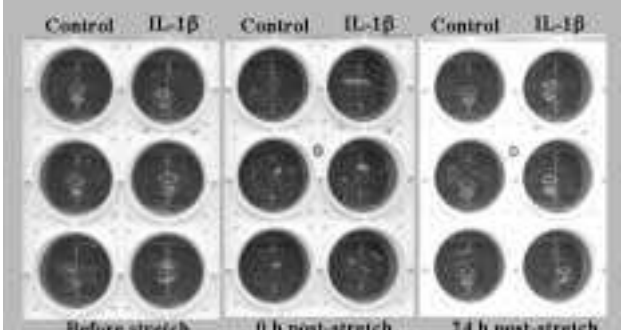
MMP 1 up with all.



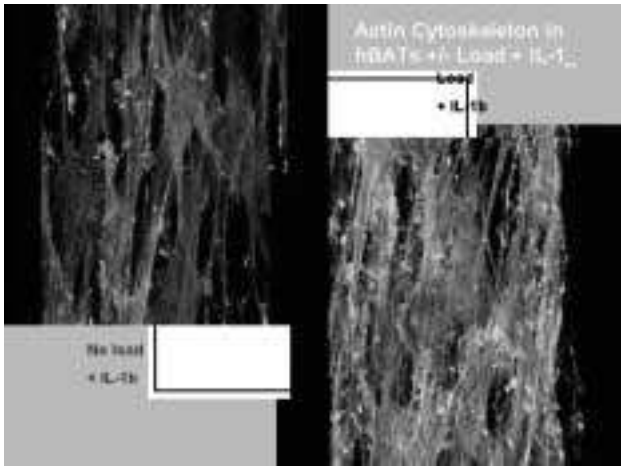


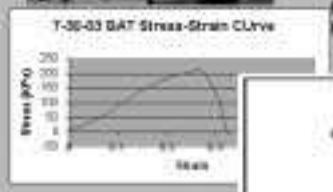
MMP 2 not so affected.

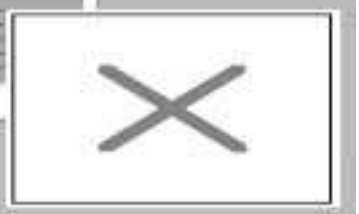
hBATs: IL-1β increases Elastic Recovery



Loading condition: 15% elongation, 1 Hz, 1 h







hBAT Biomechanics

IL-1b reduces BAT strength.

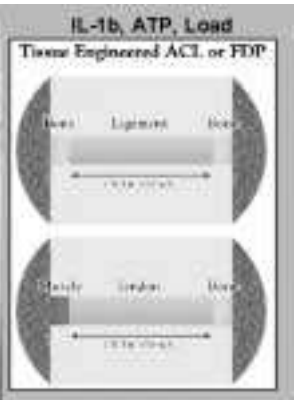
Ascorbate increases BAT strength.

IL-1b effect is Not reversed by ascorbate.

Conclusions:

- **Tensile load can block proinflammatory gene expression in tendon cells and BATs (bioartificial tendons).**
- **Cell shape control matters, role for actin, α-actinin, titin?..but IL-1b can overcome these.**
- **Drugs such as ATP, Gd2+ and low Ca2+ can reduce or block load-induced responses, suggesting a role for purinoceptors and calcium channels in load response.**
- **Basis for "intelligent", loading regime to modulate tissue engineered tendon.**

IL-1b, ATP, Load



We can build tendons, muscles and ligaments-they are weak.

TUFTS

Functional Tissue Engineered Ligaments

Gregory Altman, Jingsong Chen, Rebecca Horan, Jodie Moreau, Dan Branemo, Adam Collette, Vladimir Volloch, John Richmond, Paul Weitzel, Gordana Vunjak-Novakovic, David L. Kaplan
Tufts University
4 Colby Street
Medford, Massachusetts 02155
Phone: 617-627-3251; Fax: 617-627-3231; Email: david.kaplan@tufts.edu

II. Approach - mimic the physiological and mechanical environment of the knee *in vitro*

Utilize

Human adult progenitor cells

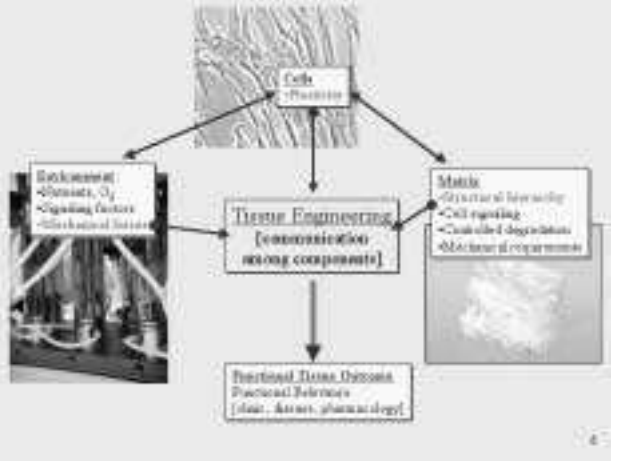
Novel bioreactors to provide mechanical signaling along with a suitable biochemical environment

Novel biomaterial matrices to match ACL mechanical requirements

I. The Need

Clinical – improved outcomes

Biomaterials – improved options



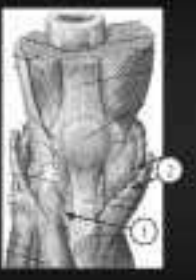
Current Treatment Options

Autologous Tendon Graft
[Patellar or Hamstring tendons]

Allogenic Tendon Graft
[Cadaveric tendon tissues - patellar, quadriceps, achilles]

Synthetic Materials
[Teflon, Dacron, Polyester]

Issues: stress shielding, site morbidity, fatigue life, tissue ingrowth



Phase III – The Questions

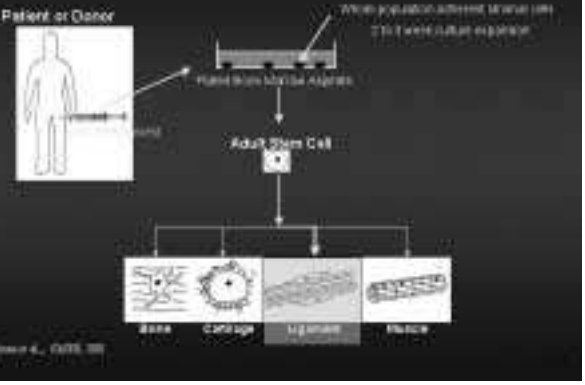
Can mechanical forces induce stem cell differentiation?

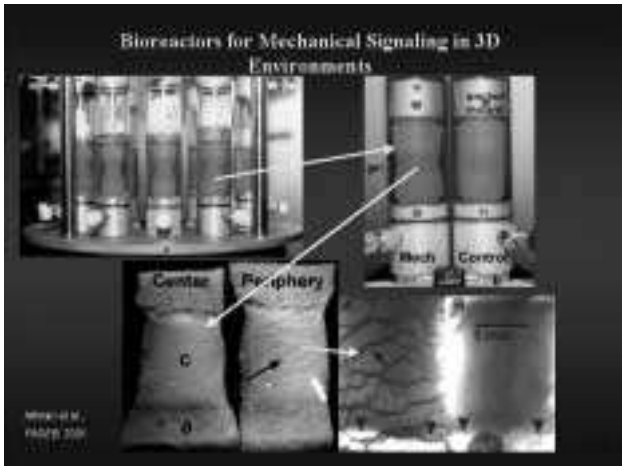
Do stem cells respond selectively to mechanical forces?

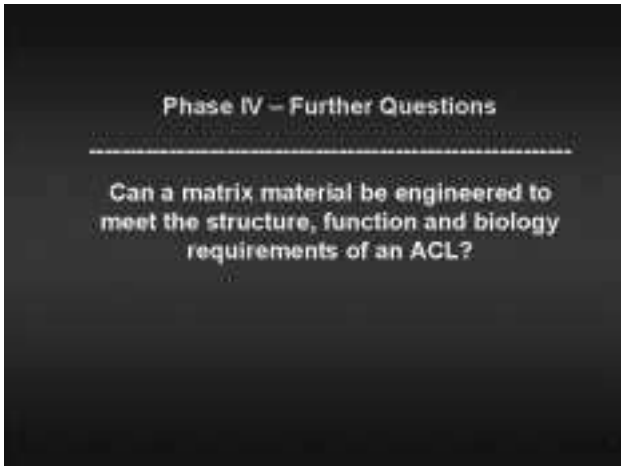
ACL Matrix Requirements

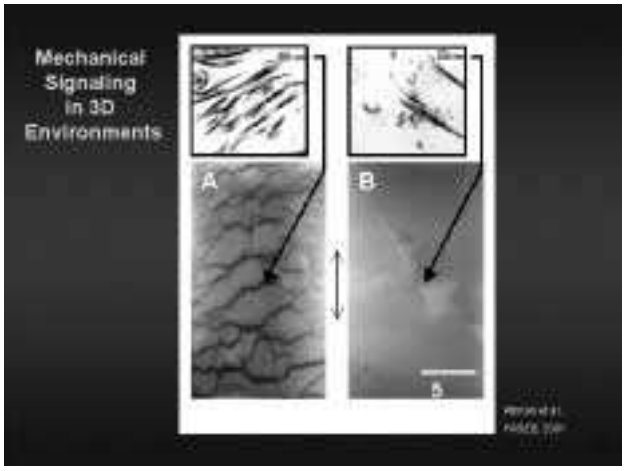
- Produce and maintain immediate stabilization
- Low risk for infection or disease transmission
- Biocompatible - Non-immunogenic, Non-inflammatory
- Support host tissue ingrowth
- Direct host tissue ingrowth
- Biodegrade following *in vivo* stabilization
- Maintain mechanical integrity prior to degrading

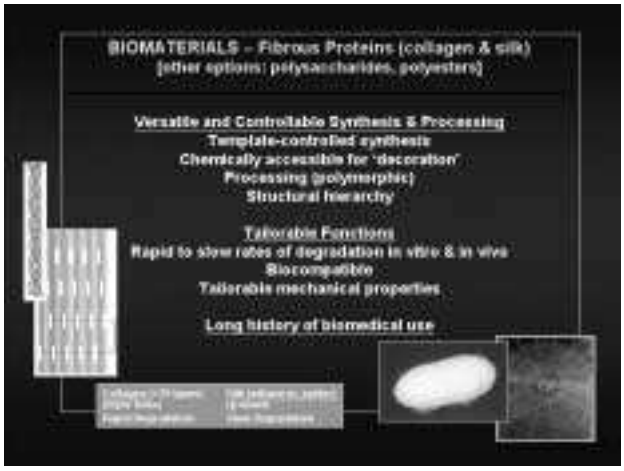
Cell Source

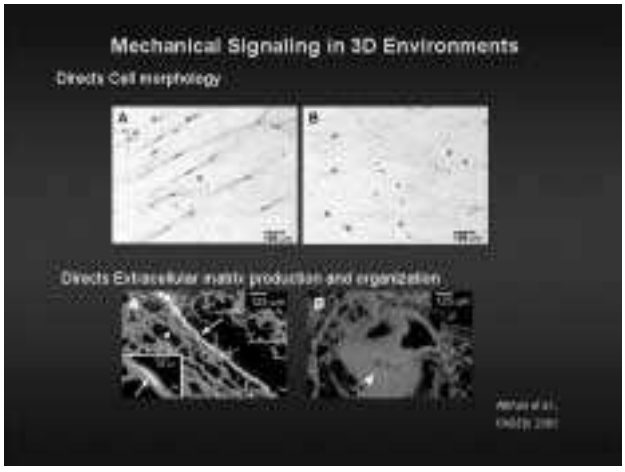


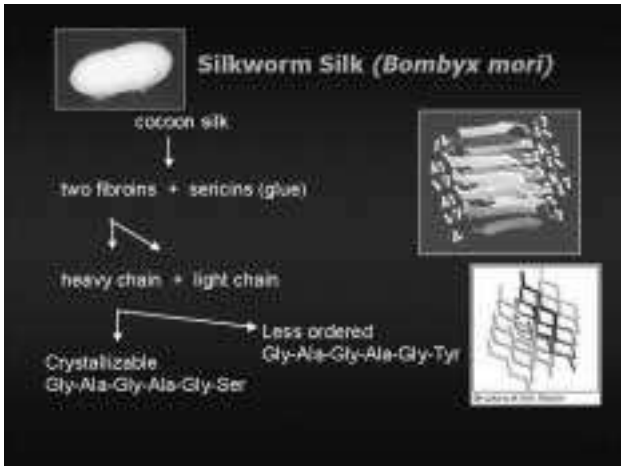

Bioreactors for Mechanical Signaling in 3D Environments
Center
Periphery
Mech
Control

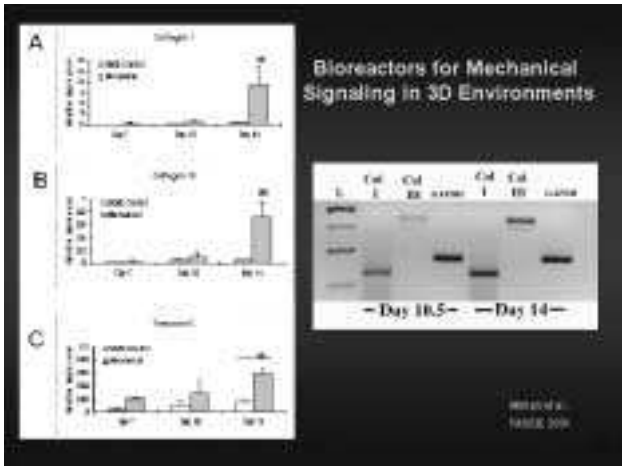

Phase IV – Further Questions
Can a matrix material be engineered to meet the structure, function and biology requirements of an ACL?

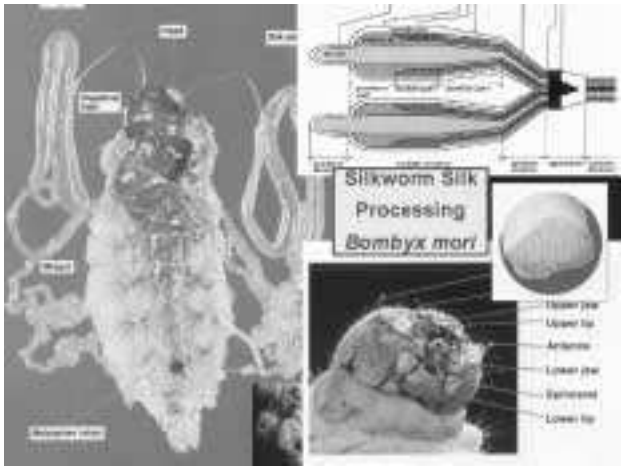

Mechanical Signaling in 3D Environments
A
B

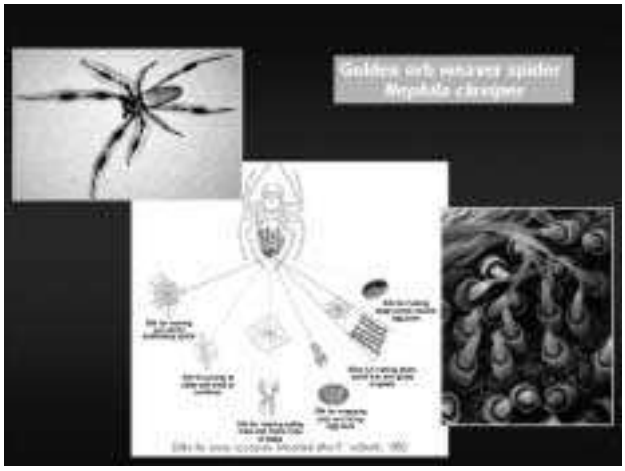

BIOMATERIALS – Fibrous Proteins (collagen & silk)
[other options: polysaccharides, polyesters]
Versatile and Controllable Synthesis & Processing
Template-controlled synthesis
Chemically accessible for 'decoration'
Processing (polymorphic)
Structural hierarchy
Tailorable Functions
Rapid to slow rates of degradation in vitro & in vivo
Biocompatible
Tailorable mechanical properties
Long history of biomedical use

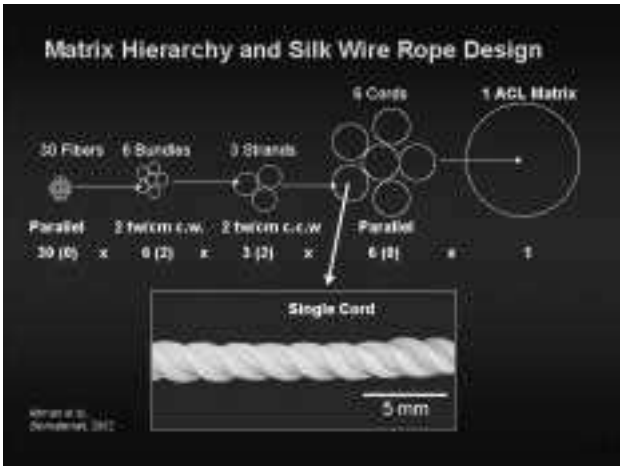

Mechanical Signaling in 3D Environments
Directs Cell morphology
A
B
Directs Extracellular matrix production and organization

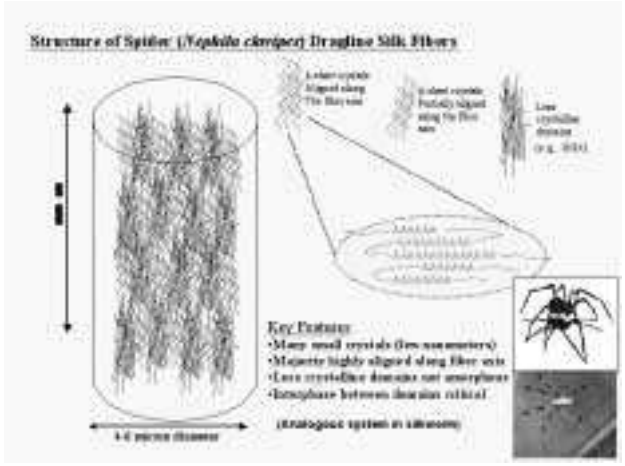

Silkworm Silk (Bombyx mori)
cocoon silk
two fibroins + sericins (glue)
heavy chain + light chain
Less ordered
Gly-Ala-Gly-Ala-Gly-Tyr
Crystallizable
Gly-Ala-Gly-Ala-Gly-Ser

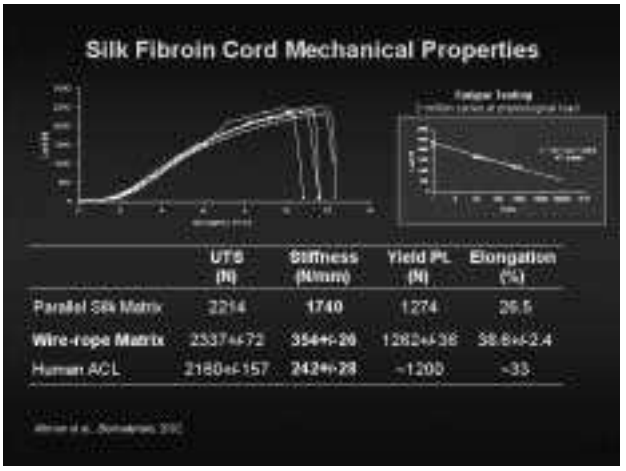

A
B
C
Bioreactors for Mechanical Signaling in 3D Environments
Day 10.5
Day 14


Silkworm Silk
Processing
Bombyx mori



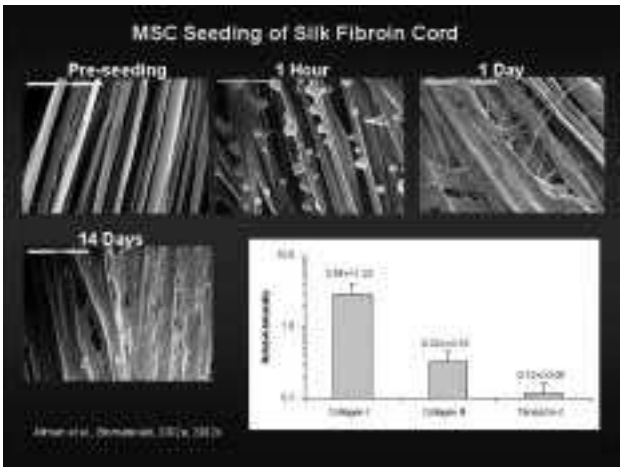


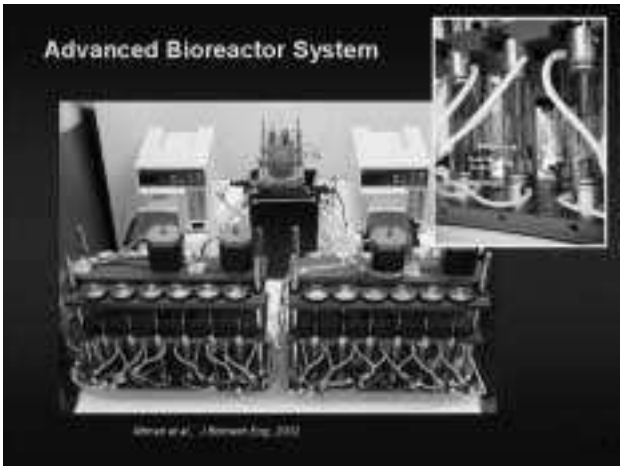


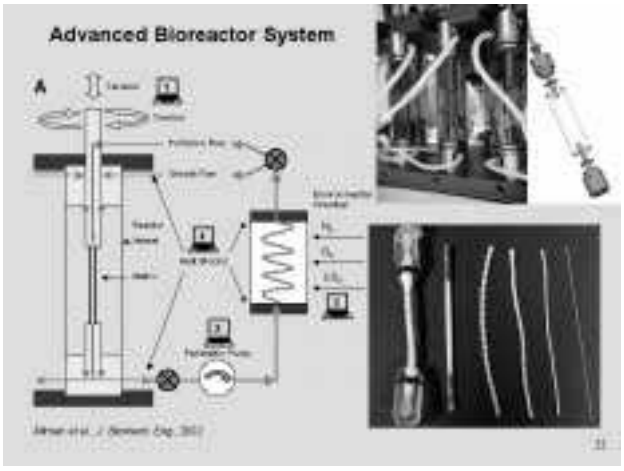


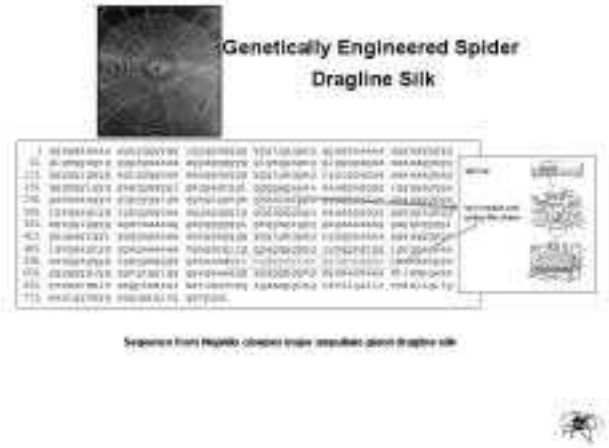
Benefits with Silks

- Used in Wound Ligation for over 1,000 Years
- Protein Based
- FDA Approved Biomaterial
- No Known Bioburdens
- Non-Antigenic
- Equivalent or Lower Inflammatory Response
- Biocompatible Wear Debris
- Excellent Strength, Fatigue Life and Flexibility
- Long-term Biodegradable *in vivo*
- Inexpensive/Easy to Manufacture





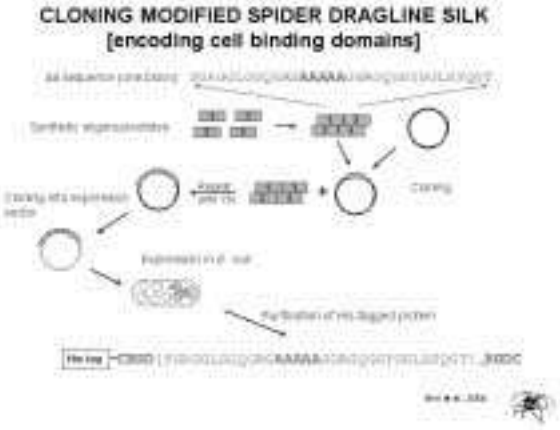




Phase V – Responses in vivo

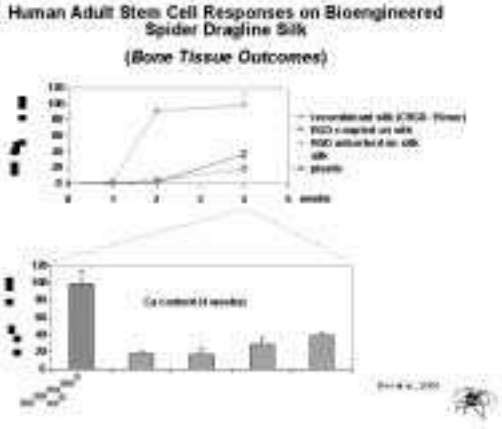
Degradation

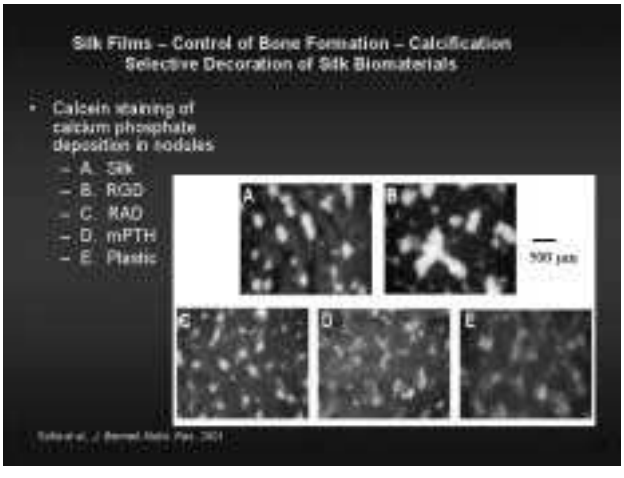
Tissue ingrowth

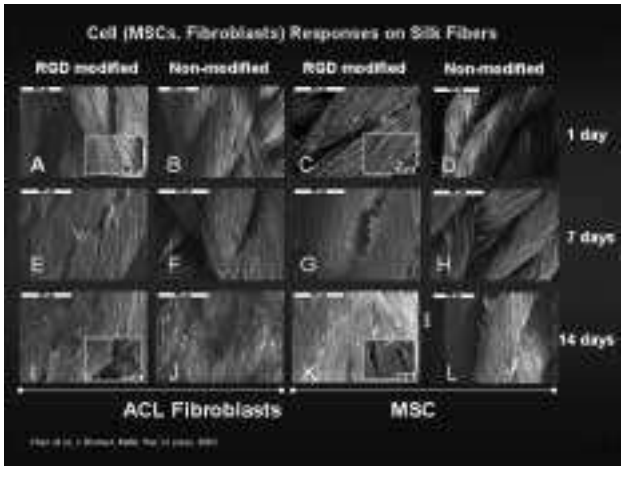


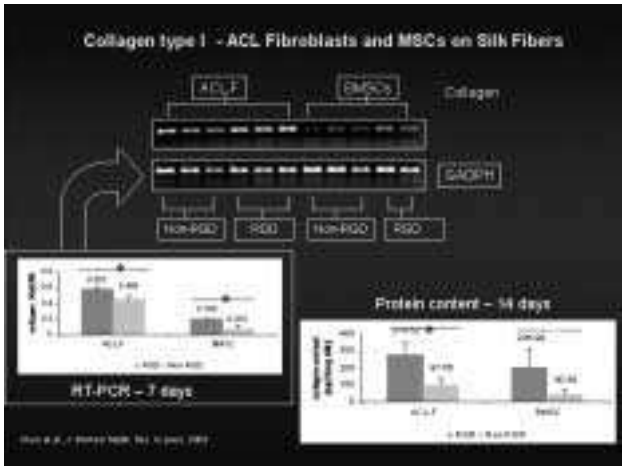
Phase VI – Ongoing Improvements

- Surface modification of fibers
- Designer silks to optimize tissue outcomes
- Additional material morphologies
- Degradability of matrices
- Cell sources – comparative analysis
- Optimization of mechanical forces
- Optimization of growth conditions
- Comparisons with collagen
- Baseline Markers – biochemical/genetic

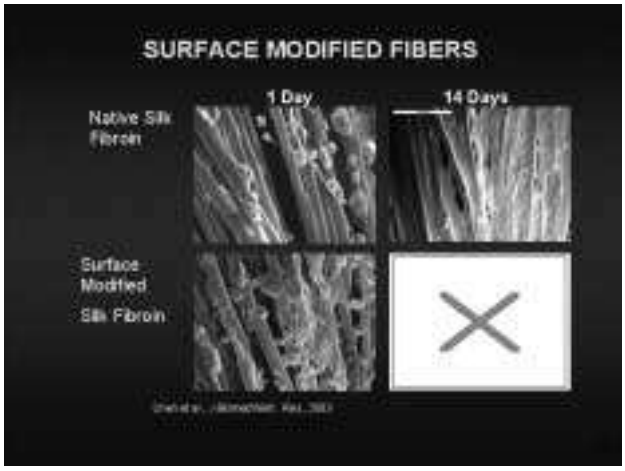


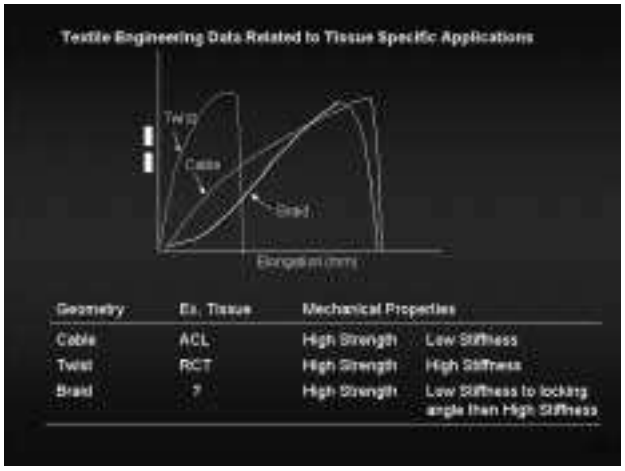


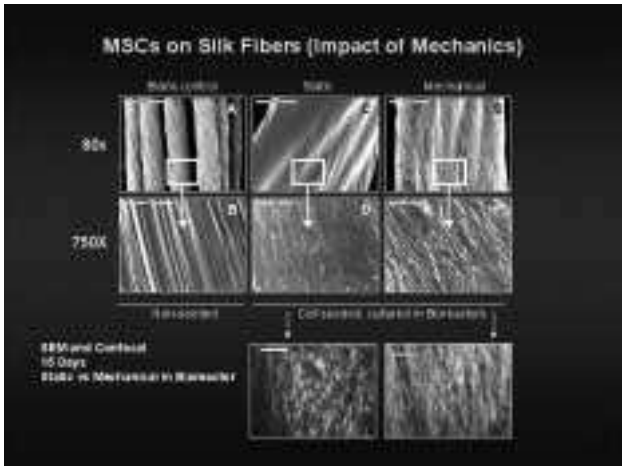


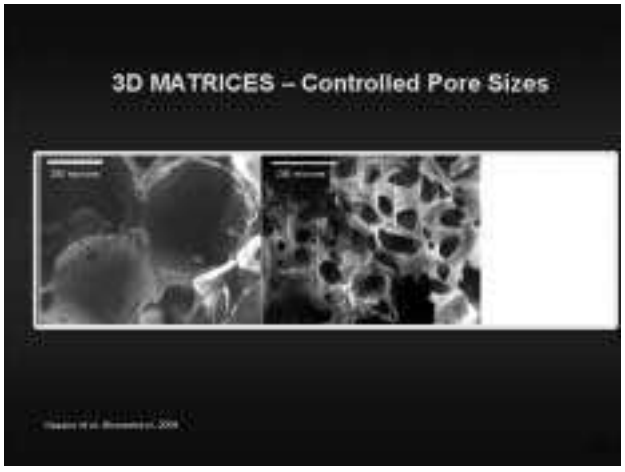

Collagen type I - ACL Fibroblasts and MSCs on Silk Fibers
ACL F
BMSCs
Collagen
GAPDH
Non-RGD
RGD
Non-RGD
RGD
RT-PCR – 7 days
Protein content – 14 days

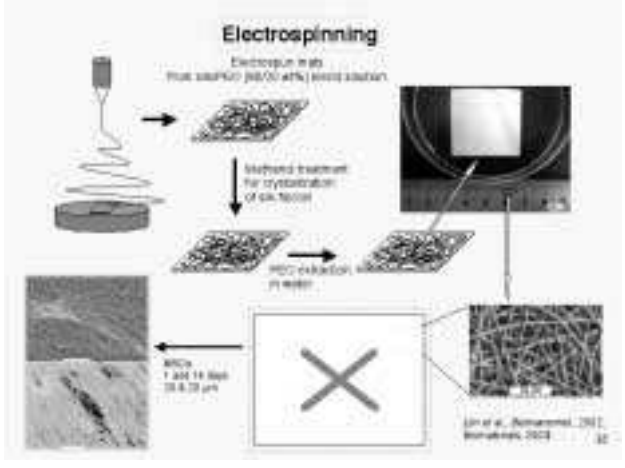

Mechanical Properties of Various Geometries

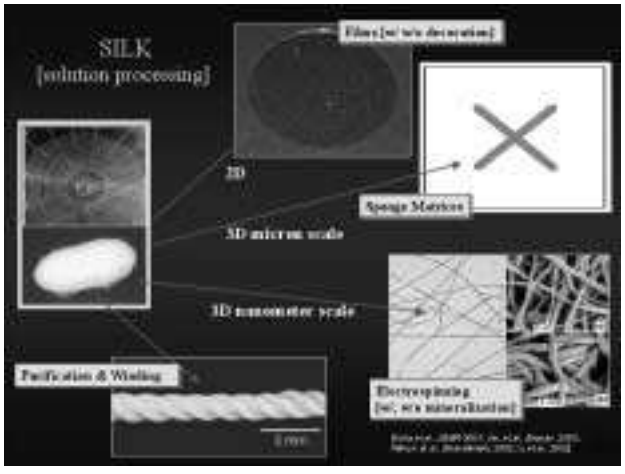

SURFACE MODIFIED FIBERS
1 Day
14 Days
Native Silk Fibroin
Surface Modified Silk Fibroin


Textile Engineering Data Related to Tissue Specific Applications
Twist
Cable
Braid
Elongation (mm)
Geometry
Ex. Tissue
Mechanical Properties
Cable
ACL
High Strength
Low Stiffness
Twist
RCT
High Strength
High Stiffness
Braid
?
High Strength
Low Stiffness to locking angle then High Stiffness

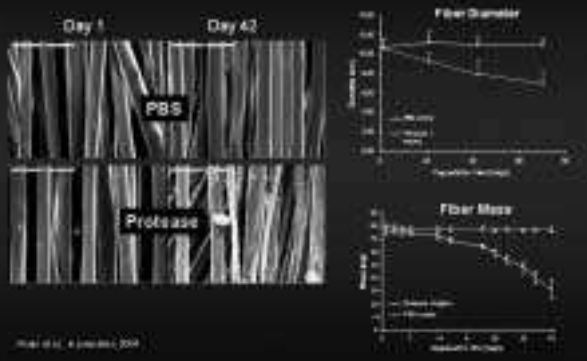

MSCs on Silk Fibers (Impact of Mechanics)
Static control
Static
Mechanical
80x
750X
Non-seeded
Cell-seeded, cultured in Bioreactors
MSCs and Control
15 Days
Static vs Mechanical in Bioreactor


3D MATRICES – Controlled Pore Sizes


Electrospinning


SILK
[solution processing]
Fibers [w/ w/o decoration]
3D
Sponge Matrices
3D micron scale
3D nanometer scale
Purification & Wicking
Electrospinning
[w/ w/o materials/drugs]

Degradation of Silk Fibers – in vitro

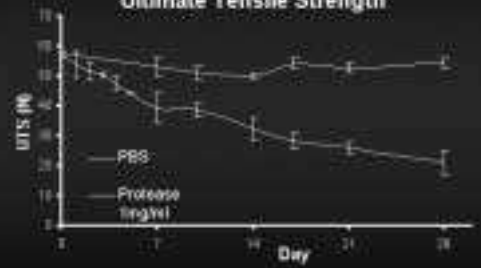


Biochemical Strategy

Factors

- Serum/medium type
- Growth Factors
  - bFGF-II
  - EGF
  - TGF-_1
  - IGF-II
  - Insulin
  - bFGF-TGF (b>T)
  - EGF-TGF (E>T)
  - TGF + Insulin (TGFIns)

Silk Degradation *In Vitro*



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NSF-DMR
NSF-DBI
TRI

Wound Healing Response "Baseline"
[mechanism of matrix synthesis and degradation]

- 33 patients
- Predictor (independent) variables:
  - Gender
  - Age (18 – 55)
  - Post-injury period (2 mo – 24 mo)
  - Scar reattachment condition (none, tibia, PCL)
- Response (dependent) variables:
  - ECM markers (collagen type I, collagen type III, biglycan, decorin)
  - MMP markers (MMP-1, -2, -9)
  - TIMP marker (TIMP-1)

LIMITED EXPOSURE FRACTURE PLATING TECHNIQUES – THE CURRENT TOPIC OF GREATEST INTEREST IN ORTHOPAEDIC TRAUMA (R)

Moderator: Marc F. Swiontkowski MD, Minneapolis, MN (n)

There is widespread interest in the development of percutaneous/limited exposure plating techniques of fracture stabilization on the part of surgeons and implant manufacturers. What are the biologic rationale and the biomechanical justification? Do these make clinical sense? This symposium will answer these questions as well as address areas where these techniques may be the treatment of choice.

I. Introduction
Marc F. Swiontkowski, MD, Minneapolis, MN (n)

II. Biological Rationale for Limited Metaphyseal/Disphyseal Exposure, and Limited Contact Plates
Emil H. Schemitsch, MD, Toronto, ON, Canada (n)

III. Biomechanical Rationale for Locking Plates – Are They Really Better?
Sean E. Nork, MD, Seattle, WA (n)

IV. What About the Proximal Tibia – Are These Techniques Worthwhile?
Phillip J. Kregor, MD, Nashville, TN (a - Synthes USA, AO Foundation)

V. Are These Plates Ever Better than a Retrograde Nail for a Distal Femur Fracture?
Peter A. Cole, MD, St. Paul, MN (a, b – Synthes USA, Zimmer Trauma Inc)

VI. What is the Status of the Clinical Research Behind these Implants in Surgical Techniques? What Kind of Studies are Needed?
Michael J. Bosse, MD, Charlotte, NC (*)

CONTROVERSIES IN UPPER EXTREMITY OPERATIVE FRACTURE MANAGEMENT – DEBATABLE TOPICS (Y)

Moderator: Jesse B Jupiter MD, Boston, MA (a – AO Foundation)

A series of debates will address controversies in upper extremity fractures and enable the participant to appreciate different options from internationally renowned upper extremity fracture surgeons.

I. ORIF Proximal Humerus Fractures; IM Nail Diaphyseal Humerus Fractures
Norbert Sudkamp, MD, Freiberg, Germany (n)

II. Percutaneous Pin Fixation Proximal Humerus Fractures; Arthroplasty Proximal Humerus Fractures; ORIF Radial Head Fractures
Ralph Hertel, MD, Berne, Switzerland (b – AO Foundation)

III. Nonoperative Treatment of Proximal Humerus Fractures; External Fixation Distal Radius Fractures
Margaret M. McQueen, MD, Edinburgh, Scotland (a – Stryker Howmedica)

IV. ORIF Humeral Shaft Fractures; Arthroplasty Distal Humerus Fractures
Michael D. McKee, MD, Toronto, ON, Canada (a – Stryker Biotech, e – Zimmer)

V. ORIF Distal Humerus Fractures; Replace Comminuted Radial Head Fractures, ORIF Distal Radius Fractures
David Ring, Boston, MA (a – AO Foundation)

HUMERAL DAIPHYSEAL TREATED WITH IM NAIL

Norbert Sudkamp, MD

I. Introduction
- •Golden standard of humeral shaft fracture treatment is conservative (Sarmiento Brace)

II.`Management depends on
- •Patient related factors
- •Fracture severity (degree of instability, number and dislocation of fragments, possible impairment of fragment vascularity)
- •Severity of trauma
- •Concomitant injuries (Monotrauma vs Polytrauma)

III. Diagnostic steps
- •X-rays in two planes with adjadent joints

IV.`Classification
- •AO / OTA fracture classification

V.`Conservative treatment for
- •Golden Standard except for surgical indications (listed below)
- •Enforced Arm Sling for one to two weeks
- •Sarmiento Brace after one or two weeks
- •Functional use of arm
- •Increase of phsysical therapy according to callus formation

VI. Operative stabilization for
- •Polytrauma patient with humeral shaft fracture
- •Muscle interposition
- •Open fractures Gustilo Type II and higher
- •Transverse fractures
- •Adipositas
- •Pathologic fracutres
- •Additional ipsilateral fractures
- •Progressive radial nerve palsy requiring radial nerve revision
- •Patient's wish

VII. Implant choice
- •IM interlocked nail (antegrade or retrograde insertion)
- •Plate (LC-DCP or LCP)

VII. Surgical Technique
- •Nail: supine, prone or beach chair position possible (surgeon's preference)
- •Plate: anterolateral, posterior approach (depending on fracture location)
- •Indirect reduction technique to preserve fragment vacularity
- •Knowlegde of radial nerve position

VIII. Advantages of Operative Fixation
- •Early functional aftertreatment
- •No immoblisation

IX. Problems of Operative Fixation
- •Stiffness and impairment of function both shoulder and elbow
- •Implant related scaring (titanium implants)
- •Secondary dislocation and failure of fixation (necessary revisions)
- •Implant failure
- •Infection and Non-unions

X. Outcome
- •Shoulder function
- •Constant score

XI. Implant removal
- •In case of implant related impingement
- •Intraarticular protrusion of implants
- •Shoulder stiffness related to scar tissue (titanium)

REFERENCES

1. Amillo S, Barrios RH, Martinez-Peric R, Losada JI: Surgical Treatment of the Radial Nerve Lesions Associated with with Fractures of the Humerus. J.Orthop.Trauma 7:211-215, 1993.
2. Balfour GW, Marrero CE: Fracture brace for the treatment of humerus shaft fractures caused by gunshot wounds. Orthop.Clin.North Am 26:55-63, 1995.
3. Habernek H, Orthner E: A Locking Nail For Fractures Of The Humerus. J.Bone Joint Surg. 73-B:651-653, 1991.
4. Jensen CH, Hansen D, Jorgensen U: Humeral shaft fractures treated by interlocking nailing: a preliminary report on 16 patients. Injury 23:234-236, 1992.
5. Rush LV, Rush HL: The Classic - Evolution of Medullary Fixation of Fractures by the Longitudinal Pin. Clin.Orthop. 212:4-9, 1986.
6. Sarmiento A, Kinman PB, Galvin EG, Schmitt RH, Phillips JG: Functional Bracing of Fractures of the Shaft of the Humerus. J.Bone Joint Surg. 58-A:596-600, 1977.
7. Sarmiento A, Horowitch A, Aboulafia A, Vangsness CT: Functional Bracing For Comminuted Extra-Articular Fractures Of The Distal Third Of The Humerus. J.Bone Joint Surg. 72-B:283-287, 1990.
8. Seligson D, Ostermann PA, Henry SL, Wolley T: The management of open fractures associated with arterial injury requiring vascular repair. J.Trauma. 37:938-940, 1994.
9. Slauterbeck JR, Britton C, Moneim MS, Clevenger FW: Mangled extremity severity score: an accurate guide to treatment of the severely injured upper extremity. J.Orthop Trauma 8:282-285, 1994.

FRACTURES OF THE PROXIMAL HUMERUS: FIXATION USING PERCUTANEOUS PINS AND IM NAILS

Ralph Hertel, MD

The purpose is to discuss alternatives to sutures and/or plating.

Percutaneous pinning is the historical workhorse, which offers the advantages of minimal invasiveness, quasi non-violation of the sub-deltoid space, and easy hardware removal.

On the other hand it has been associated with a large number of complications. These include pin migration to distant regions or organs, secondary loss of reduction, pin tract infection, damage of the glenoid due to protruding pins, damage of the axillary nerve while inserting the pins, damage to the biceps tendon, and others.

To avoid migration of the pins blocking devices were developed. They provide angular stability of the pins and therefore allow controlled impaction of the head guided by the pins, in analogy to the Dynamic Hip Screw. There is a tendency for perforation of the head, thus requiring removal of the implant.

In case of a complicated fracture patterns, the main difficulty is reduction. The following technical tricks and hints are useful:

- Reduction using percutaneous reduction hooks, joy stick K-wires, a small raspatorium, and Böhler's manoeuvre.
- To stabilize the tuberosities the use of canulated screws combined with the wiring of the collum chirurgicum component is increasingly popular.
- Alternatively, intramedullary devices can be used. The most useful are small-diameter rods that can be introduced at the supracondylar ridge. The advantage is easier positioning and reduced risk of migration. Preforation of the brittle subchondral bone is nevertheless a frequent observation. This obviously requires metal removal.
- The use of large-bore nails is being advocated especially by general traumatologists. These authors do not consider violation of the supraspinatus tendon and of the supraspinatus footprint and/or of the articular surface to be of major concern. One argument in favor of the nail is its relative ease of implantation. Arguments against are difficulties of reduction, stiffness of the large implant which does not fit the often osteoporotic bone, and impaired removability.

REFERENCES

1. Jaberg H, Warner JJ, Jakob RP. Percutaneous stabilization of unstable fractures of the humerus. J Bone Joint Surg Am 1992;74(4):508-15.
2. Gautier E, Slongo T, Jakob RP. [Treatment of subcapital humerus fracture with the Prevot nail]. Z Unfallchir Versicherungsmed 1992;85(3):145-55.
3. Jakob RP, Miniaci A, Anson PS, Jaberg H, Osterwalder A, Ganz R. Four-part valgus impacted fractures of the proximal humerus. J Bone Joint Surg Br 1991;73(2):295-8.
4. Resch H, Povacz P, Frohlich R, Wambacher M. Percutaneous fixation of three- and four-part fractures of the proximal humerus. J Bone Joint Surg Br 1997;79(2):295-300.
5. Resch H, Hubner C, Schwaiger R. Minimally invasive reduction and osteosynthesis of articular fractures of the humeral head. Injury 2001;32 Suppl 1:SA25-32.
6. Loitz D, Konnecker H, Illgner A, Reilmann H. [Retrograde intramedullary nailing of humeral fractures with new implants. Analysis of 120 consecutive cases]. Unfallchirurg 1998;101(7):543-50.

FRACTURE OF THE PROXIMAL HUMERUS: RECONSTRUCTION USING HEMIARTHROPLASTY

Ralph Hertel, MD

The purpose is to discuss indication, technique and results of hemiarthroplasty for irreparable fractures.

The indication for hemiarthroplasty is derived from an equation containing the perfusion of the cephalic fragment and the feasibility of an adequate osteosynthesis. When considering osteosynthesis important elements are bone quality and degree of comminution. If the head is ischemic hemiarthroplasty is indicated when fixation is considered too risky or frankly impossible.

Technical aspects are of great importance to obtain best possible results. Preoperative planning can be helpful in order to gain a rough idea on the sizing of the components.

After extraction of the head the first step is to **determine the size of the prosthetic** head. The surgeon's eye, comparing the resected head to trial heads, is the most accurate instrument for sizing. Considering the fact that the natural head is not a sphere but an elliptical structure a mean value between antero-posterior and lateral diameter should be selected.

The next step is the **instrumentation of the tuberosities.** It is essential to prepare the re-fixation of the tuberosities before the prosthesis is implanted. Maximum care should be taken to avoid additional devascularization of the tuberosities (cave periosteal sleeve!).

Firstly, stay sutures are passed through the dorso-cranial cuff. Then two 1mm steel wires are passed through the greater tuberosity approximately corresponding to the perforations of the prosthetic stem. The trial prosthesis can be used to check the appropriate position. Using a drill bit and a canula to pass the wires is helpful. Comminution of the tuberosities and bone quality – degree of osteopenia – are of little concern when the periosteal sleeve is kept intact.

Determination of prosthetic height
Height is best measured medially rather than laterally. To do so the humeral head can be temporarily reduced to the shaft. The medial fracture line can be anatomically reduced in most cases. The distance between the transition zone (end of cartilage) and the most medial fracture line determines prosthetic height and can be measured with precision (in millimeters). Reporting this distance to the trial prosthesis restores anatomic height. The medial reference affords high precision and does not require awesome instrumentation!

Adjustment of retrotorsion
Since retrotorsion is highly variable a customized approach is required. Adaptation is best obtained following a three-step approach:

1. Gross approximation can be obtained by using the mean normal value, which is approximately 25°, measured against the forearm axis.
2. Patients with a larger external rotation (contralateral side!) tend to require more retrotorsion.

Adjustment can best be obtained using a long retrotorsion stylus applied to the raspatorium and/or to the trial prosthesis. The angle can be measured using a goniometer. For cross-check and fine tuning, retrotorsion can be adjusted to the distal bicipital groove. The distance between the deepest point of the bicipital groove and the lateral marking on the prosthesis is approximately 8 mm (adjustable by +/- 1-2 mm according to the size of the patient!) (1, 2).

Adjustment of the medial and posterior offsets
This is only possible with third-generation prostheses featuring an eccentric head. The trial head is mounted on the double excenter platform if available. The head and the excenter are rotated in opposing directions until a harmonic calcar line (yellow line) is obtained. The posterior offset is adjusted to the particular patient. The mean normal value is 1.5 mm.

Implantation of the prosthesis
The definitive prosthesis is implanted using the presented landmarks considering height, retrotorsion and medial offset. The proposed landmarks allow for precise reconstruction of the patient's anatomy and do not require complicated instrumentation! Choosing between cemented and uncemented shafts depends on the obtainable press fit. It is our opinion that uncemented implantation preserves better blood supply to the shaft and therefore might enhance healing of the tuberosities. The shaft funnel (or any exposed cement) is topped with autogenous cancellous bone graft.

Definitive osteosynthesis of the tuberosities
Sutures or wires are passed through the two perforations of the implant,the head is reduced to the glenoid, the sutures or wires are then passed through the freely accessible lesser tuberosity, bone graft derived from the head is fitted under the hollow tuberosities, fine tuning of the reduction is achieved by placing no. 2 sutures in the inter-tubercular fracture region.

Consider that there is a tendency to overreduce the greater tuberosity. The aim is to have the tuberosity flush with the rim of the prosthetic head. The best landmark is the most medial insertion line of the supraspinatus. The sutures or wires are cautiously tensioned.

Rehabilitation
Rehabilitation aims at obtaining adequate range of motion (avoiding capsular and periarticular adhesions and contracture) while preventing the tuberosities from dislocating or non-consolidating. Immediately after surgery the arm is placed in neutral rotation on a moldable pillow.

Starting on the 2nd day after surgery and until the 6th week:

- The arm rests in a sling during the day and in an orthogilet at night.
- Instructed exercises are performed four times daily, generally by the patient him or herself.
- The best and generally available training tool is the patient's contralateral extremity, which is used to guide the affected arm. Exercises are basically passive, but the patient is allowed

to slightly innervate the muscles to follow the imposed motion.

The following assisted exercises are instructed:

- internal rotation: we expect the patient to reach their abdomen;
- external rotation: we expect the patient to reach 5°-10° less than the contralateral side;
- elevation: we expect the patient to touch the top of their head with the palm of their hand.

This exercise is best performed in supine position. The patient should reach this range of motion not later than by the 4th week. Failing this, rehabilitation needs to be intensified.

Radiological check-ups are best performed in biweekly intervals in order to monitor the healing of the tuberosities.

From the 7th week: continue with gentle stretching and start with gentle strengthening exercises. From the 10th week: intensification of stretching and strengthening exercises, which should be continued for several months.

Results

The results depend on the ability to obtain healing of the tuberosities and on the ability to obtain sufficient gleno-humeral range of motion. The quality of anatomic reconstruction seems to play an important role for both aspects.

Conclusion

Anatomic restoration of the outer shape of the proximal humerus combined with stable but not devascularizing fixation of the tuberosities offers best possible premises for adequate results.

REFERENCES

1. Hertel R, Knothe U, Ballmer FT. Geometry of the proximal humerus and implications for prosthetic design. J Shoulder Elbow Surg 2002;11(4):331-8.
2. Hempfing A, Leunig M, Ballmer FT, Hertel R. Surgical landmarks to determine humeral head retrotorsion for hemiarthroplasty in fractures. J Shoulder Elbow Surg 2001;10(5):460-3.

COMMINUTED RADIAL HEAD FRACTURE: ORIF

Ralph Hertel, MD

The purpose is to discuss indication, technical difficulties and results of open reduction and internal fixation of comminuted fractures of the radial head.

ORIF is indicated when forearm rotation remains impaired even after aspiration of the intraarticular hematoma and injection of a local anesthetic agent. A multislice CT scan can be very useful in order to appreciate the full extent of the fracture.

In complex fractures, indications for ORIF are frequent while need for replacement is relatively rare.

Fractures of the radial head are often associated with ligamentous lesions including the interosseous membrane and with cartilagineous lesions. Both lesions must be considered and, if required treated.

Artificial replacement is considered if the head cannot be reconstructed and the when the fracture is associated with a relevant lesion of the medial collateral ligament. This constellation is rare.

ORIF can be pursued with different aims. In the extreme case it is possible to consider ORIF as a temporary spacer, i.e. while the medial collateral ligament is healing.

The approach to the radial head and neck can be selected according to the specific needs. Although most frequently the lateral approach (Kocher) is adequate, the dorso-lateral approach can be very useful in fractures involving the proximal ulna.

ORIF can be performed using low profile plates or by using screws alone. Mini blade plates or plates with angular screw stability may be required in rare instances in which trans-cortical buttress cannot be obtained. Appropriate implants are small and low profile (2.0 and 1.5 mm systems). It is important not to jeopardize the proximal radio-ulnar joint. Therefore only only a limited sector for placement of plates and/or screws is available, the so-called safe zone. Specific tricks and hints to avoid injury to the radial nerve, and to reduce the fracture will be presented.

Results are jeopardized by stiffness, particularly reduced forearm rotation, by insufficiently addressed associated pathology and – in rare cases --– by an iatrogenic lesion of the radial nerve. Therefore attention to surgical detail and early passive motion is mandatory.

REFERENCES

1. O'Driscoll SW, Jupiter JB, Cohen MS, Ring D, McKee MD. Difficult elbow fractures: pearls and pitfalls. Instr Course Lect 2003;52:113-34.
2. Ring D, Quintero J, Jupiter JB. Open reduction and internal fixation of fractures of the radial head. J Bone Joint Surg Am 2002;84-A(10):1811-5.
3. Hotchkiss RN. Fractures of the radial head and related instability and contracture of the forearm. Instr Course Lect 1998;47:173-7.
4. Heim U. [Combined fractures of the radius and the ulna at the elbow level in the adult. Analysis of 120 cases after more than 1 year]. Rev Chir Orthop Reparatrice Appar Mot 1998;84(2):142-53.
5. Caputo AE, Mazzocca AD, Santoro VM. The nonarticulating portion of the radial head: anatomic and clinical correlations for internal fixation. J Hand Surg [Am] 1998;23(6):1082-90.

EXTERNAL FIXATION FOR INTRA-ARTICULAR FRACTURES OF THE DISTAL RADIUS

Margaret McQueen, MD

Although open reduction and internal fixation of intra-articular fractures of the distal radius can be effective there has been a recent move towards less invasive forms of treatment, in particular spanning or non-spanning external fixation with or without augmentation with metalwork, graft or bone substitutes.

In making a decision on the most suitable treatment for these injuries several factors should be considered. These include the age and premorbid health of the patient, the bone quality, the severity of the intra-articular displacement and the stability of the metaphyseal component of the fracture.

Spanning external fixation

Spanning external fixation employs pins in the second metacarpal and pins in the radius proximal to the extent of the fracture. The metaphyseal alignment is then reduced by closed means and maintained by the fixator. This may be sufficient to maintain the articular alignment if the articular extension is undisplaced. However it is recommended that the metaphyseal alignment is augmented with screws or Kwires as late collapse can occur with the use of spanning fixators (Seitz et al 1991, McQueen et al 1996, McQueen 1998).

If the articular surface was initially displaced and reduces by indirect means then it is recommended that fixation be used to maintain the reduced articular surface. This is generally by percutaneous methods using image intensification (Seitz et al 1991). In cases of persistent articular malalignment percutaneous reduction methods can be used followed by augmentation with percutaneous fixation. Bone grafting or bone substitutes should be used where there is a lack of support in the metaphysis for the reduced articular fragments. Open reduction is used only if closed techniques fail.

Outcome

Studies reporting outcome can be difficult to interpret as there is a lot of heterogeneity in the cases reported. The outcome is dependent on the amount of initial articular damage (Marsh et al 2002) and the metaphyseal and articular alignment after fracture healing (Knirk and Jupiter 1986, McQueen et al 1996, Rogachefsky et al 2001). Satisfactory results are reported in the majority of patients by most authors (Seitz et al 1991, Rogachefsky et al 2001). There has only been one randomised study comparing the outcome of closed reduction, percutaneous fixation and external fixation with open reduction and internal fixation for displaced intraarticular fractures of the distal radius (Kreder et al 2002). The authors concluded that the former approach resulted in more rapid return to function and superior functional outcome two years after injury.

Non-spanning external fixation

Non-spanning external fixation employs pins in the distal fragment and pins in the radius proximal to the fracture. This technique has been shown in a randomised study to give superior radiological and functional results in extra-articular and simple articular fractures of the distal radius because of improved reduction (McQueen 1998). It would not be unreasonable to extrapolate these results to the more severe articular fractures although this has not been tested. Clearly however the articular surface would have to be reduced and fixed prior to application of the fixator and in practice the presence of this fixation may preclude placement of pins in the distal fragment. However it is recommended that non-spanning fixation be used in those cases in which there is space for the pins in the distal fragment.

REFERENCES

1. Knirk JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. J Bone Joint Surg (Am) 68-A: 647-659, 1986.
2. Kreder HJ, Hanel DP, Agel J, McKee MD, Trumble TE. A randomised controlled trial of indirect reduction and percutaneous fixation versus open reduction and internal fixation for displaced intraarticular distal radius fractures. OTA Annual meeting abstracts, Toronto 2002, p201.
3. McQueen M.M.. Redisplaced unstable fractures of the distal radius. A randomised prospective study of bridging versus non-bridging external fixation. J Bone Joint Surg (Br) 80(4): 665-9, 1998.
4. McQueen MM, Hajducka C, Court-Brown CM. Unstable fractures of the distal radius. A randomised prospective study of four treatment methods. J Bone Joint Surg Br 78:404-9, 1996
5. Marsh JL, Buckwalter J, Gelberman R, Dirschl D, Olson S, Brown T, Llinias A. Articular fractures: Does an anatomic reduction really change the result? J Bone Joint Surg (Am); 84: 1259-71, 2002
6. Rogachefsky RA, Lipson SR, Applegate B, Ouellette EA, Savenor AM, McAuliffe JA. Treatment of severely comminuted intra-articular fractures of the distal end of the radius by open reduction and combined internal and external fixation. J Bone Joint Surg (Am); 83: 509-19, 2001
7. Seitz WH, Froimson AJ, Leb R, Shapiro JD. Augmented external fixation of unstable distal radius fractures. J Hand Surg (Am) 1991; 16: 1010-6

THE FIXATION TREATMENT OF CHOICE FOR DIAPHYSEAL HUMERAL FRACTURES IS A PLATE

Michael D. McKee, MD, FRCS(C)

Humeral Shaft Fractures- General

- Most humeral shaft fractures can be treated conservatively, with nonunion rates less than 10%
- Indications for operative treatment of humeral shaft fractures:
  - "floating elbow"
  - "floating shoulder"
  - pathological fractures
  - bilateral humeral fractures
  - polytrauma patients
  - failure of closed Rx
  - open fractures
  - vascular injury
  - neurological (is isolated radial nerve palsy an indication for ORIF?)
- Implants available for stable internal fixation:
  - flexible, small diameter nails
  - locking humeral nails
  - plates
- "Modern" interlocking humeral nails are designed to overcome the disadvantages of small flexible nails (axial instability, poor rotational control, requirement for supplemental fixation). Their locking capability depends on:
  - interlocking screws
  - expansion bolts
  -ridged fins / caps
- (Theoretical) advantages include:
  - decreased blood loss
  - less soft-tissue dissection
  - reaming = local bone graft
  - "load-sharing" device
  - proven record in L / E
- Although many early series reported very favourable outcome, other authors have detailed practical disadvantages of locked humeral nails including:
  - shoulder pain
  - nonunion
  - difficulty of reconstruction
  - fracture at the tip of the implant
  - high complication rate in narrow diameter canals
- Humeral plates (DCP, LCDCP etc.) have a well-established role in the treatment of humeral shaft fractures
- The obvious need for comparative data between these two types of implants has prompted a number of randomized clinical trials, which do not show any significant advantages in patients treated with humeral nails. In fact, a meta-analysis revealed that delayed and non-union rates, the incidence of shoulder pain, and re-operation rates are all higher in the nail group when compared to plates.
- Recent evidence has also suggested that it is safe to let patients with plated humeral fractures and associated lower extremity injuries use upper extremity weight bearing devices (high walker, elbow crutches) without loss of fixation
- Rather than being mutually exclusive these two techniques (humeral plates versus locking nails) may be complimentary and each may have specific indications

Technique - Plating

- semi-sitting, free-drape limb
- anterolateral approach
- identify nerve if fracture extends distally
- broad 4.5mm DCP / LCDCP
- lag screw + 6 cortices (minimum) proximal and distal
- early motion post-op
- no routine plate removal
- posterior approach for more distal fractures, especially with extension into joint

Results - Plating

- 95%union rate
- low (2-6%) re-operation rate
- low risk of permanent nerve injury
- minimal shoulder/elbow morbidity
- immediate stability, U/E wt-bearing immediately
- low re-fracture rate

REFERENCES

1. Bell MJ, Beauchamp CG, Kellam JK, McMurtry RY: The results of plating humeral shaft fractures in patients with multiple injuries: the Sunnybrook experience. J Bone Joint Surg [Br] 67: 293-296, 1985.
2. Bolano LE, Iaquinto JA Vasicek V: Operative Treatment of Humerus Shaft Fractures: A Prospective Randomized Study Comparing Intramedullary Nailing with Dynamic Compression Plating. Presented at the Annual Meeting of the AAOS, Orlando Fla, 1995.
3. Brumback RJ, Bosse MJ, Poka A: Intramedullary fixation of humeral shaft fractures in patients with multiple trauma. J Bone Joint Surg (Am) 68: 960-969, 1986.
4. Chapman J, Weber TG, Henley MB, Benca PJ: Randomized Prospective Study of Humerus Fixation: Nails versus Plates. Journal Orthop Trauma
5. McCormack R, Brien D, Buckley R, McKee MD, Powell JN, Schemitsch EH: A Randomized Prospective Trial of Humeral Shaft Fracture Fixation: Compression Plate versus Intramedullary Nail. Journal Bone Joint Surg(B) 2000: 83(B): p336-339.
6. McKee MD, Pedlow FX, Cheney PJ, Schemitsch EH: Fracture Below the End of Locking Humeral Nails: A Report of Three Cases. J Orthop Trauma 10(7): 500-513, 1996.
7. McKee MD, Miranda MA, Reimer BL, Blaiser RB, Redmond BI, Sims SH, Waddell JP, Jupiter JB: Management of Humeral Nonunion After Failure of Locking Intramedullary Nails. J Orthop Trauma 10(7): 492-499, 1996.
8. Sarmiento A, Kinman PB, Calvin EG et. al. Functional Bracing for Fractures of the Shaft of the Humerus. J Bone Joint Surg 59(A): 596-601, 1997.
9. Tingstead EM, Wolinsky PR, Shyr Y, Johnson KD. Effect of Immediate weight-bearing on Plated Fractures of the Humeral Shaft. Journal of Trauma, 2000:49;278-280.
10. Bhandari M, McKee MD, Schemitsch EH. A meta-analysis of prospective trials comparing plating versus nailing of humeral shaft fractures, Canadian Orthopaedic Association Annual Meeting, 2002.

DISTAL RADIUS FRACTURE—ARGUMENT IN FAVOR OF ORIF

David Ring, MD

1. Patients hate external fixators
- a. Cumbersome
- b. Ugly/frightening
- c. Provoke anxiety and can hinder rehabilitation

2. External fixators get infected
- a. Pin site infections routine1
- b. Occasional deep infection
  - i. Can compromise treatment—early fixator removal
  - ii. Occasional osteomyelitis

3. Problems associated with internal fixation are all manageable.
- a. Majority with dorsal2-4 rather than volar5 plates.
  - i. Tendon injury2
  - ii. Tendon irritation requiring plate removal3, 4
  - iii. Stiffness
- b. Volar internal fixation
  - i. Middle ground between Ex-fix and dorsal plate
    1. Fewer tendon problems6-8
    2. Less stiffness
    3. Can nearly always leave the plate in.
- c. Dorsal and radial implants can be reserved for the most complex fractures in which case a second operation for plate removal is justified.

4. Advantages to open reduction
- a. Direct manipulation of fragments
  - i. Many fractures cannot be reduced with closed means.
  - ii. Reduction of volar metaphyseal fracture lines can assure restoration of length, translational deformity, and ulnar inclination8.
- b. Volar cortex is stout and can be locked into place8.
- c. Direct visualization of fragments
  - i. Dorsal capsulotomy
  - ii. Through the fracture itself8.
- d. More secure fixation—particulary with locking bolts3, 8, 9
- e. NOT early motion—early motion does not appear to influence final motion1

REFERENCES

1. McQueen MM. Redisplaced unstable fractures of the distal radius: a randomized, prospective study of bridging versus non-bridging external fixation. J Bone Joint Surg 1998;80B:665-669.
2. Kambouroglou GK, Axelrod TS. Complications of the AO/ASIF titanium distal radius plate system (pi plate) in internal fixation of the distal radius: a brief report. J Hand Surg 1998;23A:737-741.
3. Ring D, Jupiter JB, Brennwald J, Buchler U, Hastings H. Prospective multicenter trial of a plate for dorsal fixation of distal radius fractures. J Hand Surg 1997;22A:777-784.
4. Carter PR, Frederick HA, Laseter GF. Open reduction and internal fixation of unstable distal radius fractures with a low-profile plate: A multicenter study of 73 fractures. J Hand Surg 1998;23A:300-307.
5. Nunley JA, Rowan PR. Delayed rupture of the flexor pollicis longus tendon after inappropriate placement of the pi plate on the volar surface of the distal radius. J Hand Surg 1999;24A:1279-1280.
6. Jupiter JB, Fernandez DL, Toh CL, Fellman T, Ring D. The operative management of volar articular fractures of the distal end of the radius. J Bone Joint Surg 1996; 78A:1817-1828.
7. Keating JF, Court-Brown CM, McQueen MM. Internal fixation of volar displaced distal radius fractures. J Bone Joint Surg 1994;76B:401-405.
8. Orbay JL. The treatment of unstable distal radius fractures with volar fixation. Hand Surgery 2000;5:103-112.
9. Gesensway D, Putnam MD, Mente PL, Lewis JL. Design and biomechanics of a plate for the distal radius. J Hand Surg 1995;20A:1021-1027.

COMPLEX FRACTURE OF THE RADIAL HEAD—ARGUMENT IN FAVOR OF PROSTHETIC REPLACEMENT

David Ring, MD

1. Data in support of ORIF radial head1-7
- a. Few small case series
- b. Mostly simple, partial radial head fractures (Mason 2)
  - i. These likely would have done well without surgery
  - ii. A controlled study would be needed to demonstrate an advantage.
- c. Complex fractures involving the entire head (Mason 3) do worse

2. The complex fractures do worse. (Mason 3)
- a. Unpredictable results in published series
- b. Dismal results in our series8
  - i. Early loss of fixation
  - ii. Nonunion/ avascular necrosis
- c. Similar findings from Heim4.

3. ORIF radial head is difficult
- a. Tedious and time consuming.
- b. Fragments too small to repair—partial resection
- c. Central impaction—often unrecognized, difficult to address.
- d. Fragments with little or no subchondral bone—no reliable fixation techniques
- e. Osteoporosis
- f. Exposure

4. ORIF radial head is often tenuous--tenuous fixation can be risky
- a. Essex-Lopresti
  - i. Loss of fixation can be disastrous
  - ii. Only possibility for a good result is the initial operation.
  - iii. A common cause of a chronic Essex-Lopresti is failed internal fixaiton
- b. Elbow fracture-dislocation
  - i. Relying on the radial head for stability

5. Prosthetic replacement with a metallic radial head
- a. Straightforward and rapid
- b. Provides stability (silastic didn't9, 10)
- c. Long term problems uncommon11, 12
  - i. Can be addressed with radial head resection once ligaments are healed if no Essex-Lopresti
- d. Prosthetic loosening does not matter11
  - i. Spacer only
  - ii. No evidence that this causes pain over an above expected post-traumatic pain.
  - iii. is not an issue—it's put in loose and intended as a spacer only.

6. Caveats
- a. Older prosthesis poorly sized—can fracture radial neck13
- b. Beware of overstuffing the joint

REFERENCES

1. Bunker TD, Newman LH. The Herbert differential pitch bone screw in displaced radial head fractures. Injury 1987;16:621-624.
2. Esser RD, Davis S, Taavao T. Fractures of the radial head treated by internal fixation: late results in 26 cases. J Orthop Trauma 1995;9:318-323.
3. Geel CW, Palmer AK, Rüedi T, Leutenegger AF. Internal fixation of proximal radial head fractures. J Orthop Trauma 1990;4:270-274.
4. Heim U. Surgical treatment of radial head fracture. Z Unfallchir Versicherungsmed 1992;85:3-11.
5. Kelberine F, Basseres B, Curvale G, Groulier P. Fractures of the radial head: an analysis of 62 surgically treated cases. Rev Chir Orthop 1991;77:322-328.
6. Khalfayan EE, Culp RW, Alexander AH. Mason Type II radial head fractures: operative versus nonoperative treatment. J Orthop Trauma 1992;6:283-289.
7. King GJW, Evans DC, Kellam JF. Open reduction and internal fixation of radial head fractures. J Orthop Trauma 1991;5:21-28.
8. Ring D, Quintero J, Jupiter JB. Open reduction and internal fixation of fractures of the radial head. J Bone Joint Surg 2002;84A:1811-5.
9. Carn RM, Medige J, Curtain D, Koenig A. Silicone rubber replacement of the severely fractured radial head. Clin Orthop 1986;209:259-269.
10. Gupta GG, Lucas G, Hahn DL. Biomechanical and computer analysis of radial head prostheses. J Shoulder Elbow Surg 1997;6:37-48.
11. Moro JK, Werier J, MacDermid JC, Patterson SD, King GJW. Arthroplasty with a metal radial head for unreconstructable fractures of the radial head. J Bone Joint Surg 2001;83A:1201-12011.
12. Knight DJ, Rymaszewski LA, Amis AA, Miller JH. Primary replacement of the fractured radial head with a metal prosthesis. J Bone Joint Surg 1993;75B:572-576.
13. PK, Hotchkiss RN. Problems with radial head prostheses. In: Poster presented at the 53rd annual meeting of the American Society for Surgery of the Hand; 1998 September 10 to 12; Minneapolis, Minnesota; 1998.

OPTIMIZING OPERATIVE TREATMENT OF INTERTROCHANTERIC HIP FRACTURES: HOW TO MAXIMIZE SUCCESS AND AVOID FAILURE IN 2004 (Z)

Moderator: George J. Haidukewych, MD, Tampa, FL (n)

Operative management of intertrochanteric hip fractures continues to evolve rapidly. Surgeons are confronted with an array of new surgical techniques and devices to treat these fractures. This symposium will update surgeons on the pros, cons, indications and contraindications of new surgical techniques and will highlight present controversies in the treatment of these fractures.

I. Cases with Panel and Audience Discussion
George Haidukewych, MD, Tampa, FL (n)

II. Sliding Hip Screw: What We Learned After a Few Decades
Richard F. Kyle, MD, Minneapolis, MN (a, e – DePuy, e – Zimmer)

III. Sliding Hip Screw: New Devices, New Decisions
Kenneth J. Koval, MD, New York, NY (e – Smith & Nephew, EBI-Biomet)

IV. Intramedullary Rods: Indications/Contraindications/Device Selection
Roy W. Sanders, MD, Tampa, FL (a – Smith & Nephew, c, e – S/A)

V. Primary Arthroplasty for Intertrochanteric Fractures: Is There a Role?
Rajit Saluja, MD, New Berlin, WI (n)

VI. Salvage of the Failed Intertrochanteric Fracture: What To Do If It All Goes Bad
George Haidukewych, MD, Tampa, FL (n)

SLIDING HIP SCREW: WHAT HAVE WE LEARNED AFTER A FEW DECADES

Richard F. Kyle, MD

I. Classification
- A. Stable versus unstable
  1. Stable - posteromedial buttress remains intact
  2. Unstable - large segment of posteromedial wall is fracture free and the posteromedial buttress is lost
- B. Orthopaedic Trauma Association Classification
  1. A1 Simple
  2. A2 Comminuted
  3. A3 Subtrochanteric component
- C. Kyle and Gustilo's modification of Boyd's Classification
  1. Type I - stable, nondisplaced fractures without comminution
  2. Type II - stable, displaced fractures with minimal comminution - can be reduced to a stable construct
  3. Type III - unstable fractures with a large area of posteromedial comminution
  4. Type IV - unstable intertrochanteric fracture with subtrochanteric extension

II. Clinical Examination
- A. Affected leg externally rotated and shortened
- B. Range of motion causes severe pain and should not be attempted

III. Imaging
- A. AP view - fracture line between greater and lesser trochanter seen
- B. Lateral view - amount of posterior comminution seen

IV. Treatment
- A. Basic Principles
  1. The fixation device must obtain good purchase in both proximal and distal fragments. This is dependent on three variables.
     a. Degree of osteoporosis of the bone
     b. Fracture pattern
     c. Correct use of fixation device
- B. Internal Fixation - Sliding Hip Screw
  1. Mechanics of sliding devices.
  a. Forces acting on the hip while standing on one leg amount to approximately three times the body weight applied at an angle of 159 degrees to the vertical plane
  b. The same forces act on hip fixation devices
  c. Devices of lower angles are subject to lower forces parallel to the sliding axis and higher forces perpendicular to the sliding axis. Perpendicular forces act to jam or bend the device preventing impaction
  d. Accurate center head placement of the lag screw is essential for proper fixation of the proximal fragment
  e. The best mechanical advantage is achieved by placing the sliding device in as high an angle as clinically possible while maintaining center head placement
  f. Most important step is proper placement of the guide pin in the femoral head. This must be checked on both AP and lateral radiographs.
- C. OrthoBiologics
  1. Important enhancer for intertrochanteric fracture fixation
  2. Delivery systems - placement of orthobiologics

V. Postoperative Care
- A. Type I, II, and III intertrochanteric fractures - weight bearing as tolerated
- B. Delayed weight bearing for Type 4 fractures

VI. Complications
- A. Avascular necrosis - less than 1%
- B. Nonunion - less than 1% in stable fractures. 5% in Type III and Type IV fractures. If nonunion does occur, valgus osteotomy is recommended
- C. Infection - less than 1% with use of prophylactic antibiotics
- D. Implant failure - occur most frequently after full collapse of the hip screw

REFERENCES

1. Alffram, PA: An epidemiologic study of cervical and trochanteric fractures of the femur in an urban population. Analysis of 1664 cases with special reference to etiologic factors. Acta Orthop Scand. Suppl 65, 1964.
2. Boyd HB, Anderson LD: Management of unstable trochanteric fractures. Surg. Gynec and Obstet. 112:633-638, 1961.
3. Chang WS, Zuckerman JD, Kummer FJ, Frankel VH: Biomechanical evaluation of anatomic reduction versus medial displacement osteotomy in unstable intertrochanteric fractures. Clin Orthop 225:141-146, 1987.
4. Clawson DK: Trochanteric fractures treted by the sliding screw plate fixation method. J Trauma 4:737-752, 1964.
5. Kenzora JE, McCarthy RE, Lowell JD, Sledge CB: Hip fracture mortality. Relation to age, treatment, preoperative illness, time of surgery, and complications. Clin Orthop 186: 45-56, 1984.
6. Kyle RF: Intertrochanteric fractures. Operative Orthopaedics. Michael W. Chapman, Ed Vol 1:353-359. Philadelphia, J.D. Lippincott, 1988.
7. Kyle RF, Gustilo RB, Premer RF: Analysis of six hundred twenty-two intertrochanteric hip fractures. A retrospective and prospective study. J Bone and Joint Surg 61A: 216-222, March 1979.
8. Massie WK: Extracapsular fractures of the hip treated by impaction using a sliding nail-plate fixation. Clin Orthop 22:180-202, 1962.
9. Norden M, Frankel VH: Biomechanics of the hip. Basic biomechanics of the the musculoskeletal system. Ed. 2:135-151. Philadelphia, Lea and Febiger, 1989.
10. Pauwel F: Der schenkenholsbruck em mechanisches problem. Grundlagen des heilungsvorganges prognose und kausale therapie. Stuttgart, Ferdinand Enke, 1935.
11. Sarmiento A, Williams EM: The unstable intertrochanteric fracture: treatment with a valgus osteomty and I-beam nail plate. A preliminary report of one hundred cases. J Bone Joint Surg 52A: 1309-1318, Oct 1970.
12. Tronzo RG: Surgery of the Hip Joint. Lea and Febiger, Philadelphia, 1973.

SLIDING HIP SCREWS: NEW DEVICES, NEW DECISIONS

Kenneth J Koval, MD

The sliding hip screw has been the implant of choice for the treatment of both stable and unstable intertrochanteric fractures. Sliding hip screw sideplate angles are available in 5o increments from 130° to 150°. The 135° plate is most commonly utilized; this angle is easier to insert in the desired central position of the femoral head and neck than higher angle devices and creates less of a stress riser in the subtrochanteric region.

Variations on the sliding hip screw's basic design include the Variable Angle Hip Screw, greater trochanteric stabilizing plates, the Medoff Plate, and the Percutaneous Compression Plate. The Variable Angle Hip Screw (VHS) is a sliding hip device that allows angular adjustment of the sideplate barrel to conform to different neck-shaft angles and has the advantage of reduced hospital inventory. The remaining three devices utilize the principles of controlled impaction but attempt to limit the amount of sliding of the lag screw within the sideplate barrel since excessive screw/barrel slide results in limb shortening, medialization of the distal segment and resultant fracture deformity.

VARIABLE ANGLE HIP SCREW (VHS)

The Variable Angle Hip Screw (VHS) (EBI, Parsippany, NJ) is a sliding hip device that allows angular adjustment of the sideplate barrel to conform to different neck-shaft angles. It also allows for compression and valgus reduction of fractures after fixation is achieved by permitting changes in the sideplate-barrel angle. The adjustable nature of the implant accommodates for variability of screw placement within the femoral head. Therefore, operating room inventory can be decreased since it is unnecessary to stock sideplates of different angles.

GREATER TROCHANTERIC STABILIZING PLATES

The Trochanteric Stabilizing Plate (Synthes, Paoli, PA) and the Lateral Buttress Plate (Smith and Nephew, Memphis, TN) are modular components that buttress the greater trochanter. These plates are placed over a four-hole sideplate and are used to prevent excessive slide (and resulting deformity) in unstable fracture patterns. These devices originally gained popularity in Europe and have been available in the United States for approximately 2 years. Clinical studies suggest that these lateral support plates are most useful with unstable peritrochanteric fractures with a deficient lateral cortical buttress. It prevents excessive telescoping and limb shortening.

MEDOFF PLATE

The Medoff Plate (Medpac, Culver City, California) is a biaxial sliding hip screw. It has a standard lag screw/barrel component for compression along the femoral neck. Additionally, there is a coupled pair of sliding components for the sideplate that allow fracture impaction longitudinally. If only uniaxial dynamization is desired, a locking set-screw can be applied, solely allowing sliding along the femoral shaft. However, for most intertrochanteric fractures, biaxial dynamization is recommended. Currently the system is only offered with a 135-degree angle sliding compression screw component. The indications for use of the Medoff plate are uncertain. Use of this device may be most appropriate for intertrochamteric fractures with subtrochanteric extension.

PERCUTANEOUS COMPRESSION PLATING (PCCP)

The Percutaneous Compression Plate (ie. Gotfried plate) (Orthofix, McKinney, TX), has two smaller diameter lag screw/barrel components which stabilize the femoral head and neck. This device was designed to be inserted through a minimally invasive surgical technique. Theoretically, these two lag screw components (9.3mm and 7.0 mm diameters), provide greater rotational stability of the proximal fracture fragment than the single large diameter lag screw of a standard sliding hip screw.

Other theoretical advantages provided by the use of two smaller diameter screws are preservation of the remaining lateral wall of the distal fragment. In unstable fracture patterns, it is the remaining lateral wall of the distal fragment which prevents excessive fracture collapse and subsequent fracture deformity. Placement of a large diameter single lag screw creates a larger defect in the lateral wall of the distal fragment which increases the risk of lateral wall fracture.

Due to its recent introduction, only three clinical trials from Europe and Israel have been completed. Decreased intra-operative blood loss and post-operative transfusion requirements were reported, compared to a standard sliding hip screw. However, due to its percutaneous insertion, a learning curve exists with large variations in operative time compared to a standard sliding hip screw.

REFERENCES:

1. Babst R, Renner N, Biedermann M, Rosso R, Herberer M, Harder F, Regazzoni P. Clinical results using the trochanter stabilizing plate (TSP): the modular extension of the dynamic hip screw (DHS) for internal fixation of selected unstable intertrochanteric fractures. J Orthop Trauma 1998; 12:392-9.
2. Chaim SH, Mukherjee DP, Ogden AL. A Biomechanical Study of Femoral Neck Fracture Fixation with the VHS Vari-Angle Hip fixation system. Am J of Orthopedics 2002; 31:22-4.
3. Gotfried Y. Percutaneous compression plating of intertrochanteric hip fractures. J Orthop Trauma 2000; 14:490-5.
4. Janzing HM, Houben BJ, Brandt SE, Chhoeum V, Lefever S, Broos P, Reynders P, et al. The Gotfried PerCutaneous Compression Plate versus the Dynamic Hip Screw in the treatment of pertrochanteric hip fractures: minimal invasive treatment reduces operative time and postoperative pain. J Trauma 2002; 52:293-8.
5. Kosygan KP, Mohan R, Newman RJ. The Gotfried percutaneous compression plate compared with the conventional classic hip screw for the fixation of intertrochanteric fractures of the hip. J Bone Joint Surg Br 2002; 84:19-22.
6. Madsen JE, Naess L, Aune AK, Alho A, Ekeland A, Stromsoe K. Dynamic hip screw with trochanteric stabilizing plate in the treatment of unstable proximal femoral fractures: a comparative study with the Gamma nail and compression hip screw. J Orthop Trauma 1998; 12:241-8.
7. Medoff RJ, Maes K. A new device for the fixation of unstable peritrochanteric fractures of the hip. J Bone Joint Surg Am 1991; 73A(8):1192-9.
8. Olson O, Ceder L, Lunsjo K, Hauggaard A. Biaxial dynamization in unstable intertrochanteric fractures. Good experience with a simplified Medoff sliding plate in 94 patients. Acta Orthop Scand 1997; 68:327-31.
9. Watson JT, Moed BR, Cramer KE, Karges DE. Comparison of the compression hip screw with the Medoff sliding plate for intertrochanteric fractures. Clin Orthop. 1998; 348:79-86.

CALCAR-REPLACEMENT HEMIARTHROPLASTY FOR UNSTABLE INTERTROCHANTERIC FRACTURES OF THE HIP

Rajit Saluja, MD

I. Numerous Classification Systems
- a. Evans-Jensen
- b. Sensheimer

II. Most Widely Used Method for Assessing Hip Fractures
- a. Simple Anatomic Identification of Fracture
- b. Most Classification: Stable (A) or Unstable (B)

III. Unstable Intertrochanteric Hip Fractures
- a. Loss of medial Column of support in proximal femur.

IV. Conventional Methods of Internal Fixation

V. Complications with Conventional Methods

VI. Hemiarthroplasty using a Calcar-Replacement Prosthesis
- a. Pho et al. J. Trauma 21: 792 – 797, 1981.
- b. Stern et al. Clin. Orthop. 218: 75-80, 1987.
- c. Haentjens et al. JBJS Vol. 71-A No. 8: 1214 – 1224, 1989 et al. Acta Orthop. Belg. 60: 274-279, 1994.
- d. Chan et al. Clin. Orthop. 371: 206-215, 2000.

VII. Indications for Hemiarthroplasty
- a. Unstable fracture configuration.
- b. Osteoporotic bone.
- c. Physiologic age greater than 75 years old.

VIII. Algorithm for Intertrochanteric Hip Fractures.
- a. At each step of decision making, psychosocial factors are also considered.

IX. Surgical Technique.
- a. Implant Choice
- b. Supplemental use of cables or wires
  - i. Greater Trochanteric Fixation
  - ii. In the Calcar Region to minimize hoop stresses and prevent fracture propagation

X. Post-operative Course.
- a. Immediate weight-bearing as tolerated.
- b. Anticoagulation
- c. Medical management -Hip Fracture pathway
- d. Follow-up: Same as for pts. Undergoing elective Total Hip Arthroplasty and Radiographic follow-up same as THA.

XI. Our Review
- a. 40 patients with unstable intertrochanteric hip fractures
- b. 34 Females, 6 Males.
- c. Average Age: 84.2 years old (60 – 100 y.o.)

XII. Materials & Methods - Outcome Analysis
- a. Hip Fracture Recovery Score (Zuckerman, Hospital for Joint Diseases).
- b. Score based on patient's function after surgery.
  - i. Basic Activities of daily living (44%).
  - ii. Indep. Activities of Daily Liv. (23%)
  - iii. Mobility - (33%).
- c. Loss of func. in first 3 months post-op.
- d. Signific.recovery in score between 3 – 6 mos

XIII. Results.
- a. Avg. L.O.S. -entire admission: 7.5 days (Range: 5 – 11 days)
- b. Avg. L.O.S. -post-operatively: 5.8 days (Range: 3 – 9 days)

XIV. Results.
- a. Average Follow-up: 33 months (15 – 50)
- b. 10 patients expired by the time of review.
- c. 4 patients expired within the first 6 months
- d. Average Hip Fracture Recovery Outcome Score: 71 out of 100 points. (16 – 99).
- e. 92% of pts could ambulate at least indoors with assistive devices.

XV. Complications

XVI. Discussion.
- a. Our Review
  - i. Older population with extremely unstable fracture configuration.
  - ii. Avg. outcome score 71 points is comparable to the avg. outcome score of entire group of hip fractures in Zuckerman's comprehensive review at 1 year follow-up (72.3 points)
  - iii. 92% of patients were mobile either with or without assistive devices.

XVII Conclusion
- a. Calcar replacement hemiarthroplasty
  - i. Stable reconstruction with supplemental cables or wires.
  - ii. Allows immediate weight bearing.
  - iii. Minimizes need for sequential radiographs for follow-up.
  - iv. Successful outcome in treating severely unstable IT fx's.

SALVAGE OF FAILED TREATMENT OF INTERTROCHANTERIC HIP FRACTURES: WHAT TO DO WHEN IT ALL GOES BAD

George J. Haidukewych, MD

Introduction

The number of patients with hip fractures in the United States continues to increase.1 The majority intertrochanteric hip fractures treated with contemporary techniques of open reduction and internal fixation heal. However, the huge and increasing number of hip fractures in the population means that even a small percentage1,2 of patients with nonunion or early fixation failure will lead many surgeons to encounter problems. Unfavorable fracture patterns, poor implant placement, and poor bone quality all increase the likelihood of fracture fixation failure.1,3,4 Effective strategies for salvage of this difficult problem are important because patients typically are severely disabled. The main management options are revision internal fixation, with or without bone grafting, or prosthetic replacement. The treatment is then individualized according to physiologic age, activity, remaining bone quality, the viability of the femoral head, and the status of the hip joint articular surface. The purpose of this section is to review the evaluation, surgical options, and results of salvage of failed treatment of intertrochanteric fractures.

Preoperative Evaluation

When evaluating a patient with failed internal fixation of a hip fracture, the surgeon should consider occult infection as a potential etiology of fixation failure. The author currently obtains preoperative complete blood counts with manual differentials, sedimentation rates, and C-reactive protein serologies. Aspiration of the nonunion site is not routinely performed, since it would be technically difficult to obtain an adequate specimen and the reliability of the results of such an aspirate has not been documented. Intraoperative tissue from the nonunion site is obtained for frozen section histology. If there is evidence of infection, all hardware is removed, deep cultures are obtained, necrotic tissue is debrided, and antibiotic impregnated methacrylate beads or spacers are placed. If staged arthroplasty is contemplated, then a Girdlestone resection with placement of an antibiotic impregnated spacer may be considered if the femoral head is thought to be infected. The definitive reconstruction is then performed after a period of organism specific intravenous antibiotics. The author favors a staged approach when infection is present, whether arthroplasty or an attempt to salvage the femoral head is planned.

Although most nonunions with failed fixation devices and persistent fracture instability do not pose a diagnostic dilemma, occasionally nonunion can be more subtle and difficult to diagnose. Patients may present with persistent pain and difficulty with ambulation several months after internal fixation. Radiographs may demonstrate settling of the fracture, a "halo" around the internal fixation device, or backing out of the hardware. If plain radiographs are equivocal, conventional or computed tomography can be useful in this setting to determine whether bony union has occurred.

Symptomatic malunion is uncommonly reported after hip fracture. However, shortening through the intertrochanteric area, and malunion of the greater trochanter all can occur after hip fractures, and can lead to limb length discrepancy or adverse hip biomechanics leading to limp or pain. In most cases moderately suboptimal hip biomechanics are accepted as the trade-off to gain good bone apposition in a stable position and fracture union. Very little has been written about the options for salvage of a severe malunion, with most data gathered from the treatment of neglected intertrochanteric hip fractures. In one small series5, corrective osteotomy was recommended for symptomatic intertrochanteric malunions in younger patients, while older patients were typically treated with hip arthroplasty. More studies are needed to be able to determine the ideal way to prevent and salvage malunions after hip fracture.

When evaluating the patient with the failed hip fracture, certain patient specific issues should also be addressed. When osteosynthesis is attempted, tobacco use, in any form, should be discontinued if possible. Medical and nutritional optimization, especially in elderly, debilitated patients also is desirable.

Salvage of Failed Intertrochanteric Hip Fractures: Young Patients

For younger patients with proximal bone quality adequate for internal fixation, the most common treatment for intertrochanteric hip fracture nonunion is revision internal fixation with selected bone grafting.6 Typically a fixed angle device such as the angled blade plate or dynamic condylar screw is the preferred fixation device, and usually autogenous bone grafting is performed as well. These devices can target the bone in the inferior region of the femoral head which has usually not been violated by prior implants. Nonunion of the intertrochanteric hip fracture in the young patient fortunately is uncommon.

Few studies of intertrochanteric nonunions have been published.7,8 Mariani and Rand9 reported on eleven patients with intertrochanteric nonunion with a mean age of fifty-three treated with repeat open reduction and internal fixation. Nine of eleven (82 per cent) achieved union at a mean of six months. A variety of implants were used successfully based on the location of remaining bone stock in the femoral head. Wu et al.10 reported on fourteen intertrochanteric fractures with cut-out of a lag screw of a dynamic hip screw. Patients were treated with re-insertion of a lag screw inferiorly in the femoral head, cement augmentation, and valgus producing subtrochanteric osteotomy. All nonunions healed at a mean of five months. Sarathy et al.11 reported on seven patients with intertrochanteric nonunions treated with valgus osteotomy, medial displacement, and 130 degree blade plate fixation. Six of seven healed. Haidukewych and Berry6 reported a series of twenty intertrochanteric nonunions treated with revision open reduction and internal fixation and selected bone grafting. Fixed angle devices were used in 75 per cent of cases. Nineteen of twenty nonunions healed. Therefore, the available literature suggests that a variety of different implants can be used successfully to salvage the intertochanteric nonunion, as long as stable proximal fragment fixation is obtained. It is desirable to restore as normal a neck shaft angle as possible.

Salvage of Failed Intertrochanteric Hip Fractures: Older Patients

Most intertrochanteric hip fracture nonunions occur in older patients with poor proximal bone quality and most fail by implant cut-out from the femoral head.1 The decision to perform revision internal fixation versus prosthetic replacement is based on patient characteristics, fracture pattern, remaining bone quality, and the status of the hip joint. In older patients, arthroplasty has some advantages, because it allows patients to be mobilized quickly.

When hip arthroplasty is performed for salvage of failed intertrochanteric fractures there are some specific technical considerations. The surgeon must decide whether to perform a total

hip arthroplasty or a hemiarthroplasty. It is not uncommon to have cut-out of previous internal fixation causing secondary damage to the hip joint. In this circumstance, or in patients with markedly severe pre-existing arthritis, a total hip arthroplasty usually is performed. With well-preserved articular cartilage, hemiarthroplasty can be considered. Hemiarthroplasty may provide better stability and "less surgery" for the frail patient. Total hip arthroplasty, however, probably provides more predictable pain relief.

Defects from previous internal fixation devices on the lateral femoral shaft create stress risers that can lead to intraoperative fracture of the femur, particularly with torsion. Preliminary dislocation of the hip before hardware removal may reduce femur fracture risk in these hips which are often quite stiff and can require much force to dislocate. Broken screws frequently are present. Having special broken screw removal instruments including trephines and grasping tools is helpful. Fluoroscopy may be necessary to safely remove broken screws.

Most patients with failed intertrochanteric fracture fixation have bone loss below the standard resection level for a routine primary total hip arthroplasty. Therefore, many need a calcar replacing implant to restore leg length and hip stability. It is wise to consider bypassing screw holes in the femur by two cortical diameters with longer stems to prevent subsequent fracture.12 Successful femoral component fixation can be obtained with either cemented or uncemented implants. For many older patients cemented fixation is advantageous, particularly if bone quality is poor, and the canal diameter is large. Cemented fixation also allows rapid mobilization in this patient population. If a cemented stem is chosen, the surgeon needs to be aware that cement can extrude from the empty screw holes.13 Bone graft from the resected femoral head can be used to graft large lateral defects, such as those created by the barrel of a sliding hip screw. If an uncemented implant is used, extensively porous coated stems have the advantage of providing fixation in the diaphysis of the femur bypassing the damaged, deformed, or deficient proximal bone. Fracture is possible with insertion of uncemented implants, especially in poor bone with multiple previous bicortical screw holes. Intraoperative radiographs after implant placement are strongly recommended, regardless of the type of femoral fixation chosen.

The management of the greater trochanter has been problematic and warrants special discussion. The greater trochanter can be a separate ununited piece of bone or it can be malunited preventing entrance into the femoral canal for femoral preparation. In these circumstances, the trochanteric slide technique, keeping the vastus lateralis, greater trochanter, and abductors as a single sleeve of soft tissue, is preferred. Patients should be counseled in advance that trochanteric problems relating to either persistent nonunion or painful trochanteric fixation devices are not infrequent after such reconstructions.14

Finally, bone deformity of the proximal femur related to fracture callus, fracture translation, or malunion frequently is present which increases the risk of femoral fracture during canal preparation. Shaping of the proximal bone with a high speed burr is safer than performing the same procedure with a rasp. The tracts of previously placed fixation devices often are sclerotic and can deflect reamers or broaches leading to proximal fracture or femoral perforation.

There are few published series on the results of hip arthroplasty for intertrochanteric nonunions. Mariani and Rand9 reported on nine patients with intertrochanteric nonunions treated with hip arthroplasty. At a mean of six years all patients had functional improvement. Stoffelen et al.15 reported on seven hip arthroplasties for intertrochanteric nonunion. Seventy-two per cent had good to excellent results. In 1991, Mehlhoff et al.16 reported on thirteen patients followed a mean of thirty-four months. Only 37 per cent had good to excellent results. Three patients dislocated, two of whom required reoperation for instability.

More recently, Haidukewych and Berry14 reported on 60 patients with a mean age of 78 years treated between 1985 and 1997 with hip arthroplasty for failed treatment of intertrochanteric hip fractures. Thirty-two total hip arthroplasties and 27 bipolar hemiarthroplasties were performed. Forty-four were followed for a mean of 5 years. Two hips were revised for aseptic loosening at 8 and 10 years respectively. There was only one dislocation. The seven year survivorship free of revision for any reason was 100 per cent, and 10 year survivorship was 88 per cent. Importantly, a calcar replacing stem or extra long neck length stem was needed in 65 per cent of cases and long stemmed implant was used in a high percentage of patients as well. A standard prosthesis was only suitable in 15 per cent of cases. Serious orthopedic complications were uncommon and most patient's ambulatory status and pain were markedly improved. The most common persistent complaint was discomfort over the greater trochanter, which was present in 11 per cent of hips.

Conclusions

In younger patients salvage of the failed intertrochanteric hip fracture typically involves efforts to preserve the hip joint with revision internal fixation, while in the majority of older patients prosthetic replacement is a reliable salvage option. The physiologic age of the patient, quality of the remaining proximal bone, presence of deformity, status of the hip joint, all influence decision making. Regardless of the salvage method chosen, attention to specific technical details can improve the success rate and reduce the complications of treating these challenging problems.

REFERENCES

1. Kyle RF, Cabanela ME, Russell TA, et al.: Fractures of the proximal part of the femur. Instruct Course Lect 1995;44:227-253.
2. Kyle RF, Gustilo RB, Premer RF: Analysis of 622 intertrochanteric hip fractures. J Bone Joint Surg 1979;61A:216-221.
3. Baumgaertner MR, Solberg BD: Awareness of tip-apex distance reduces failure of fixation of trochanteric fractures of the hip. J Bone Joint Surg 1997;79B:969-971.
4. Haidukewych GJ, Israel TA, Berry DJ: Reverse obliquity of fractures of the intertrochanteric region of the femur. J Bone Joint Surg 2001;83A:643-650.
5. Lifeso R, Younge D: The neglected hip fracture. J Orthop Trauma 1990;4:287-292.
6. Haidukewych GJ, Berry DJ: Revision internal fixation and bone grafting for intertrochanteric nonunion. Clin Orthop 2003;412:184-188.
7. Haentjens P, Casteleyn PP, Opdecan P: Hip arthroplasty for failed internal fixation of intertrochanteric and subtrochanteric fractures in the elderly patient. Arch Orthop Trauma Surg 1994;113:222-227.
8. Kim Y-H, Oh J-H, Koh Y-G: Salvage of neglected unstable intertrochanteric fractures with cementless porous-coated hemiarthroplasty. Clin Orthop 1992;277:182-187.
9. Mariani EM, Rand JA: Nonunion of intertrochanteric fractures of the femur following open reduction and internal fixation: Results of second attempts to gain union. Clin Orthop 1987;218:81-89.
10. Wu CC, Shih CH, Chen WJ, Tai CL: Treatment of cutout of a lag screw of a dynamic hip screw in an intertrochanteric fracture. Arch Orthop Trauma Surg 1998;117:193-196.
11. Sarathy MP, Madhavan P, Ravichandran KM: Nonunion of intertrochanteric fractures of the femur. J Bone Joint Surg 1994;77B:90-92.
12. Patterson BM, Salvati EA, Huo MH: Total hip arthroplasty for complications of intertrochanteric fracture. A technical note. J Bone Joint Surg 1990;72A:776-777.
13. Eschenroeder HC Jr, Krackow KA: Late onset femoral stress fracture associated with extruded cement following hip arthroplasty. Clin Orthop 1988;236:210-213.
14. Haidukewych GJ, Berry DJ: Hip arthroplasty for salvage of failed treatment of intertrochanteric hip fractures. J Bone Joint Surg 2003;85A:899-905.
15. Stoffelen D, Haentjens P, Reynders P, et al.: Hip arthroplasty for failed internal fixation of intertrochanteric and subtrochanteric fractures in the elderly patient. Acta Orthop Belg 1994;60:135-139.
16. Mehlhoff T, Landon GC, Tullos HS: Total hip arthroplasty following failed internal fixation of hip fractures. Clin Orthop 1991;269:32-37.

COMMONLY USED ENHANCERS OF BONE HEALING – DO WE REALLY HAVE EVIDENCE OF EFFICACY: LIVE MINI – DEBATES (K)

Moderator: Scott D. Boden MD, Decatur, GA (a – Medtronic, Centerpulse, Wright, DePuy, Osteotech, e – Medtronic, Centerpulse)

JMany approaches to enhancement of bone healing are in wide clinical use; yet the confidence in their efficacy is highly variable. Experts have been assembled to debate evidence for or against the use of electrical stimulation, ultrasound, platelet gels, demineralized bone matrix, and recombinant BMPs.

I. Introduction
Scott D. Boden, MD, Decatur, GA (a – Medtronic, Centerpulse, Wright, DePuy, Osteotech, e – Medtronic, Centerpulse)

II. Electrical Stimulation – PRO Position
Thomas A. Einhorn, MD, Boston, MA (a, b – OrthoLogic)

III. Electrical Stimulation – CON Position
Randy N. Rosier, MD, Rochester, NY (*)

IV. Ultrasound: PRO Position
Cato T. Laurencin, MD, Charlottesville, VA (n)

V. Ultrasound: CON Position
Joseph Benevenia, MD, Newark, NJ (n)

VI. Platelet Gels: PRO Position
J. Tracy Watson, MD, St. Louis, MO (a, b – Johnson & Johnson)

VII. Platelet Gels – CON Position
Joseph M. Lane, MD, New York, NY (a – Osteotech)

VIII. Demineralized Bone Matrix – PRO Position
William M. Parrish, MD, Hershey, PA (b – Osteotech)

IX. Demineralized Bone Matrix – CON Position
Jeffrey C. Wang, MD, Los Angeles, CA (n)

X. Recombinant BMPs – PRO Position
Harvinder S. Sandhu, MD, New York, NY (*)

XI. Recombinant BMPs – CON Position
Jay R. Lieberman, MD, Los Angeles, CA (a – National Institute of Health)

COMMONLY USED ENHANCERS OF BONE HEALING – DO WE REALLY HAVE EVIDENCE OF EFFICACY: A SERIES OF LIVE MINI-DEBATES

Moderator: Scott D. Boden, MD

Speakers: Debate 1: Electrical Stimulation
PRO -Thomas A. Einhorn, MD
CON – Randy N. Rosier, MD

Debate 2: Ultrasound Stimulation
PRO – Cato Laurencin, MD, PhD
CON – Joseph Benevenia, MD

Debate 3: Platelet Gels
PRO – J. Tracy Watson, MD
CON – Joseph Lane, MD

Debate 4: Demineralized Bone Matrix
PRO – William Parrish, MD
CON – Jeff Wang, MD

Debate 5: Recombinant Bone Morphogenetic Proteins
PRO – Harvinder Sandhu, MD
CON – Jay Lieberman, MD

Introduction: Many strategies are available to clinicians for biologically enhancing bone healing in a variety of clinical settings. In some cases, the most popular treatments have little or no credible evidence of clinical efficacy. The purpose of this symposium is to take a critical look at some of these strategies and determine if they satisfy the burden of proof for clinical efficacy and justify their relative cost based on the effect size of their healing enhancement. In general, many believe that metaphyseal defects, bone cysts, and long bone fractures are less demanding healing environments compared to spine fusion. As such, we will try to address evidence in both the spine and "non-spine" healing applications for each technology.

Debate 1: Electrical Stimulation

Pro Position

Thomas A. Einhorn, MD

Electric and electromagnetic fields have been used to promote healing in delayed unions and nonunions of bone for nearly forty years. Based on the discovery of electrical properties in bone in the 1950's and 60's, a series of pre-clinical investigations established the bone –promoting effects of electrical stimulation on cells 1-12. Those studies led to the development of several devices used to induce electrical effects in musculoskeletal tissues and, consequently, an innovative technology for the treatment of fractures. As this presentation will show, electric and electromagnetic stimulation is a successful strategy for the enhancement of fracture repair.

Bone as well as cartilage are mechanically sensitive tissues. As such, mechanical loading induces direct mechanical and associated electrical effects. When loaded, these tissues experience streaming potentials that are produced because of fluid flow through the charged extracellular matrix. The effects of fluid flow and streaming (or bioelectric) potentials have been shown to impart important information to cells and these biophysical signals are presumably responsible for the alterations in skeletal remodeling which result from altered loading13. The "PRO" position, that electric and electromagnetic fields do indeed enhance bone healing, is based on a series of preclinical studies, clinical studies, and, impressively, double-blind randomized control trials. The following is the evidence to support the PRO position:

I. Preclinical Studies

a. Fitzsimmons and coworkers5, 6 and Ryaby and coworkers14 showed that magnetic stimulation of cell cultures increases secretion of IGF-2 and the effects of electromagnetic stimulation on bone are growth factor-dependent. Subsequent studies by Aaron et al 15 showed stimulation of TGF-b mRNA when cultured chondrocytes were exposed to electromagnetic fields, and Nguy and Ota8 and Sahinoglu et al. 16 used electromagnetic fields to demonstrate up-regulation of mRNA for BMP-2 and BMP-4, respectively. Most recently, Zhuang et al.12 showed that capacitively coupled electric fields increased TGF-b1 mRNA in osteoblast cultures. These studies support the concept that electromagnetic fields mitigate their anabolic effects on bone tissue by direct stimulation of intracellular pathways leading to the expression of genes which are known to up-regulate bone formation.

b. Another approach in support of the proof of concept that electric and electromagnetic fields enhance bone formation is the use of these fields in the treatment of bone loss syndromes. Brighton et al.3,4 showed that low voltage, high frequency, capacitively coupled electrical signals can prevent osteopenia in a sciatic denervation model. McLeod and Rubin7 and Rubin et al.10 used an avian disuse osteopenia model to demonstrate that electromagnetic fields enhance bone formation. Skerry et al.11 achieved inhibition of bone loss with pulsed electromagnetic fields (PEMFS) in an ovariectomized canine model.

II. Clinical Studies

Electric and electromagnetic fields have been formulated into three clinically-available treatment modalities:

1. Direct current stimulation using percutaneous or implanted electrodes (invasive);
2. Electromagnetic stimulation using inductive coupling with time-varying magnetic fields (non-invasive);
3. Capacitive coupling stimulation using transdermal electrodes (non-invasive).

Initial studies involved clinical series now known as "Level 4" studies and retrospective reviews ("Level 3 and Level 4 studies") to document results in patients with nonunions who were treated with electric and electromagnetic fields. In most studies, fractures were not considered to be nonunions unless there had been no evidence toward healing for the three months before enrollment. In addition, no surgical intervention was to have been performed in the patients three months before enrollment. Blinded radiographic assessment was used to provide some level of objectivity in the evaluation of data. The following data are provided for these three modes of stimulation:

a. Direct Current – Brighton et al.17 reported an overall success rate of 62.5% based on 24 patients with nonunions who were enrolled in their study. This was then followed- up in a multi-center nonunion trial in

which 78% (total number, 258 patients) were shown to be healed. Patterson18 reported an overall success rate of 86% in patients with delayed union and nonunion.

b. Bassett et al.19,20 used PEMFs to demonstrate an 87% healing rate, with a median time to healing of 5.2 months, in 127 patients with nonunions. Heckman et al.21 also used pulsed electromagnetic fields and showed a 64% union rate in 149 patients but followed these patients for only up to 2.5 years.

c. The most recent technology is the use of non-invasive capacitive coupling. Brighton and Pollack22 showed healing rates of 77% in 22 nonunions at 23 weeks and this included 17 recalcitrant nonunions which had failed to heal with bone graft prior to electrical stimulation.

III. Randomized Control Trials

The most rigorous scientific study to address a clinical question is a randomized, controlled, double-blind trial. This type of investigation will fulfill Level-1 criteria and provides the best information upon which to base clinical decisions.

In 1998, Borsalino23, completed a randomized controlled trial in 51 femoral intertrochanteric osteotomies which were internally fixed with a blade plate. Patients were randomized to active treatment with PEMF or placebo. Three independent orthopedic surgeons used a 4-point scale to evaluate radiographs taken 40 and 90 days after osteotomy and each was blinded in the process. Patient compliance was excellent as 31 of 32 patients completed the protocol. Statistically significant improvements in healing were seen in the active group as manifest by a 41% increase in bone density, 64% rate of trabecular bridging and evidence of maturation of the callus. The only limitation of the study was the lack of an intent-to-treat analysis.

In 1990, Sharrard24 studied a PEMF in delayed unions of the tibiaes in 51 patients. Again, radiographic assessment was blinded and provided by both an orthopaedic surgeon and radiologist. Treatment was for 12 hours over 12 weeks. 45 of 51 patients completed this study. Nine of 20 patients who had active devices showed union. Only 3 of 22 patients in the placebo group showed union. Fisher's exact test showed these results to be highly significant ($p<.02$). Limitations of this study included lack of monitored radiographic evidence of healing for three months prior to enrollment and lack of an intent-to-treat analysis.

Mammi et al.25 evaluated PEMF in 40 tibial osteotomies treated with a staple. Radiographic assessment was blinded, a 4-point assessment scale was used, compliance was excellent (37 out of 34 patients completed the protocol) and 72.2% of patients in the active treatment group showed healing while only 6.3% of the placebo group healed ($p<.006$).

Finally, Scott and King26 performed the only randomized, controlled trial on capacitive coupling. Treatment was administered 24 hours per day for six months in 23 long bone nonunions. Twenty of 23 patients completed the protocol and 60% of the active group showed healing at 21 weeks. In contrast, none of the 11 placebo-treated patients showed healing. Fisher's exact test was statistically significant at $p<.004$.

The cumulative evidence from pre-clinical reports, case series, and randomized, controlled trials clearly support the concept that electric and electromagnetic fields stimulate bone formation and healing. Several classic studies performed as retrospective analyses on the use of autologous bone in the treatment of nonunions have only shown healing rates of between 62 and 85%. Thus, if autologous bone grafting is the so-called "gold standard" for the treatment of fractures and nonunions, enhancement of healing with electric and electromagnetic fields clearly meets that standard.

REFERENCES

1. Aaron RK, Ciombor D, Jolly G: Stimulation of experimental endochondral ossification by low-energy pulsing electromagnetic fields. J Bone Miner Res 4:227-233, 1989.
2. Bassett CAS: Fundamental and practical aspects of therapeutic uses of pulsed electromagnetic fields (PEMFS). Crit Rev Biomed Eng 17:451-529, 1089.
3. Brighton CT, Katz MJ, Goll SR, et al: Prevention and treatment of sciatic denervation disuse osteoporosis in the rat tibia with capacitively coupled electrical stimulation. Bone 6:87-97, 1985.
4. Brighton CT, Luessenhop CP, Pollack Sr, et al: Treatment of castration induced osteoporosis by a capacitively coupled electrical signal in rat vertebrae. J Bone Joint Surg 71A:228-236, 1989.
5. Fitzsimmons RJ, Ryaby JT, Magee FP, Baylink DJ: IGF-II receptor number is increased in TE-85 cells by low amplitude, low frequency electromagnetic field exposure. J Bone Miner Res 10:812-819,1995.
6. Fitzsimmons RJ, Ryaby JT, Magee FP, et al: Combined magnetic fields increase IGF-11 secretion of osteoblast cultures. Endocrinology 136:3100-3106, 1995.
7. McLeod KJ, Rubin CT: The effect of low-frequency electrical fields on osteogenesis. J Bone Joint Surg 74A:920-929, 1992.
8. Nagai M, Ota M: Pulsating electromagnetic field stimulate mRNA expression of bone morphogenetic protein-2 and -4. J Dent Res. 73:1601-1605, 1994.
9. Rosson JW, Simonis RB: Locked nailing for nonunion of the tibia. J Bone Joint Sug 74B:358-361, 1992
10. Rubin CT, McLeod KJ, Lanyon LE: Prevention of osteoporosis by pulsed electromagnetic fields. J Bone Joint Surg 71A:411-417, 1989.
11. Skerry TM, Pead MJ, Lanyon LE: Modulation of bone loss during disuse by pulsed electromagnetic fields. J Orthop Res 9:600-608, 1991.
12. ZhuangBrunnen JL, Brindley HH: Nonunion of the shafts of long bones: A review and analysis of 140 cases. JAMA 203:637-640,1968.
13. Pollack SR: Bioelectrical properties of bone. Orthop Clin North Am 15:47-59, 1984.
14. Ryaby JT, Fitzsimmons RJ, Khin NA, et al: The role of insulin-like growth factor in magnetic field regulation of bone formation. Bioelectrochem Bioeng 35:87-91. 1994.
15. Aaron RK, Ciombor D, Jones AR: Bone induction by decalcified bone matrix and mRNA of TGFb and IGF-1 are increased by ELF field stimulation. Trans Orthop Res Soc 22:548, 1997.
16. Sahinoglu T, Bhatt B, Gullet L, et al: Pulsed electromagnetic fields induce osteogenesis and upregulate bone morphogenetic protein-2 and -4 mRNA in rat osteoblasts in vitro. Trans Orthop Res Soc 21:204, 1996.
17. Brighton CT, Griedenberg ZB, Mitchell EI, Booth RE: Treatment of nonunion with constant direct current. Clin Orthop 124:106-123, 1977.
18. Patterson D: Treatment of nonunion with a constant direct current: A totally implantable system. Orthop Clin North Am 15:47-59, 1984.
19. Bassett CAL, Mitchell SN, Norton L, Pilla AA: A nonoperative salvage of surgically resistant pseudarthroses and nonunions by pulsing electromagnetic field: A preliminary report. Clin Orthop 1245:128-143,1977.
20. Bassett CAL, Pawluk RJ, Pilla AA: Augmentation of bone repair by inductively coupled electromagnetic fields. Science 184:575-577, 1974.
21. Heckman JD, Ingram AJ, Loyd RD, et al: Nonunion treatment with pulsed electromagnetic fields. Clin Orthop 161:58-66, 1981.
22. Brighton CT, Pollack SR: Treatment of recalcitrant nonunion with a capacitively coupled electric field. J Bone Joint Surg 67A:577-585, 1985.
23. Borsalino G, Banacani M, Bettati E. et al: Electrical stimulation of human femoral intertrochanteric osteotomies: Double blind study. Clin Orthop 237:256-263, 1988.
24. Sharrard WJW: A double-blind trial of pulsed electromagnetic field for delayed union of tibial fractures. J Bone Joint Surg 72B:347-355, 1990.
25. Mammi GI, Rocchi R, Cadossi R, Traina GC: Effect of PEMF on the healing of human tibial osteotomies: A double blind study. Clin Orthop 288:246-253, 1993.
26. Scott G, King JB: A prospective double blind trial of electrical capacitive coupling in the treatment of non-union o long bones. J Bone Joint Surg 76A:820-826, 1994.

Debate 1: Electrical Stimulation

Con Position

Randy Rosier, MD, PhD

I. Rationale for use of electrical stimulation

a. Original idea based on piezoelectric properties of bone (Fukada)
b. Mechanical deformation could alter electrical signals and account for the ability of bone to remodel in response to mechanical load (i.e., Wolff's law)
c. Initial studies with direct current application in bone -> stimulation of healing
d. Pulsed electromagnetic field and capacitively coupled electrical field followed as noninvasive methods

II. Mechanism of action

a. Electrical stimulation is an empiric method, and despite 30 years of research and clinical use the mechanism of action remains unknown (not very scientific!)
b. Many effects in vitro have been demonstrated; Putative targets of action include:
   i. Stimulation of osteoblastic calcium signaling
   ii. Stimulation of growth factor production
   iii. Stimulation of osteoblast and chondrocyte proliferation/matrix synthesis
c. Empiric nature of approach places clinical trials and clinical use in category of other non-mechanistic treatments which may have efficacy; examples would include herbal remedies, acupuncture, and magnet therapies
d. Empiricism fuels skepticism by patients and clinicians
e. Although trials show statistically significant efficacy over placebo, some patients heal with placebo, and a significant number don't heal with the treatment
f. Clinical protocols have also been largely empiric, and issues such as duration of use, weight-bearing status, immobilization, etc. have for the most part not been derived by rigorous evidence-based methodologies.

III. Efficacy of electromagnetic stimulation

a. Applications include both long bone fracture and spinal arthrodesis
b. Difficulties in determining endpoint for healing or progress toward healing
c. Numerous animal and human studies supporting use
d. Success rates in literature vary
e. Meta-analyses suggest efficacy of treatment
f. However, important to recognize that again, many patients with placebo heal and a substantial number with devices do not

IV. Benefits/disadvantages of electrical stimulation as a treatment

a. Positives
   i. No need for surgery – i.e., avoids surgical risks of infection, nerve injury, blood loss, scarring, thromboembolic disease, etc.
   ii. Avoids risks of anesthesia
   iii. Avoids need for hospitalization
   iv. Painless form of treatment; minimally inconvenient
   v. Avoids costs associated with surgery and hospitalization
b. Negatives
   i. Devices expensive
   ii. Protracted treatment time, especially in proportion of patients where treatment fails
   iii. May result in increased "down time" compared to surgery
   iv. Potentially longer time to full weight-bearing and activity
   v. Long term consequences of muscle atrophy/disuse uncertain, but likely related to length of treatment time and time to return to function.
   vi. Limited data in spinal applications and more variability; indications less well developed.

V. Cost-effectiveness issues

a. Cost of devices, follow-up studies, ancillary services
   i. Fractures that would have healed anyway
   ii. Patients whose fractures fail to heal despite the treatment
b. Work-related costs
   i. Time out of work – both lost worker productivity plus the cost of compensation
   ii. Slower rehab because of more protracted treatment
c. Social costs
   i. Family/psychological stress due to prolonged time of unemployment or activity limitations
   ii. Long term social effects unquantified
d. There has been no rigorous evaluation of the cost/benefit (cost/QUALY, comparison with other treatment methods, etc), so overall cost-effectiveness uncertain

REFERENCES

1. Sharrard WJW: A double-blind trial of pulsed electromagnetic field for delayed union of tibial fractures. J Bone Joint Surg 72B:347-355, 1990.
2. Simonis RB, Parnell EJ, Ray PS, Peacock JL: Electrical treatment of tibial nonunion: a prospective, randomized, double-blind trial. Injury 34:357-62, 2003.
3. Hannouche D, Petite H, Sedel L: Current trends in the enhancement of fracture healing. J Bone Joint Surg 83BL157-64, 2001.
4. Oishi M, Onesti ST: Electrical bone graft stimulation for spinal fusion: a review. Neurosurg 47:1041, 2000.
5. Jenis LG, An HS, Stein R, Young B: Prospective comparison of the effect of direct current electrical stimulation and pulsed electromagnetic fields on instrumented posterolateral lumbar arthrodesis. J Spinal Disorders 13:290-6, 2000.
6. Ryaby JT: Clinical effects of electromagnetic and electric fields on fracture healing. Clin Orthop 355(Suppl):S205-15, 1998.
7. Heckman JD, Sarasohn-Kahn J: The economics of treating tibia fractures: the cost of delayed union. Bull Hosp Jt Dis 56:63-72, 1997.

Debate 2: Ultrasound Stimulation

Pro Position

Cato T. Laurencin, MD, PhD

A. Does Ultrasound Work as an Enhancer of Bone Healing: Yes

1. Clinical Study: Heckman et al. Journal of Bone and Joint Surgery, 1994 "Acceleration of Tibial Fracture-Healing by Non-Invasive, Low Intensity Pulsed Ultrasound":
   a. Randomized, double blind, placebo controlled multicenter study
   b. Sixty-seven Closed or Grade I Open Tibial Shaft Fractures
   c. Thirty-three treated with closed reduction, long leg casting and Ultrasound Device with results compared to control.
   d. End-point: Healed Fracture

   Results: Statistically significant decrease in the time to clinical healing (86 + 5.8 days in the active-treatment group compared to 114 + 10.4 days in the control group (p= 0.01))

   Results: Statistically significant decrease in the time to "overall" healing (clinical and radiographic) (96 + 4.9 days in active treatment group compared to 154 + 13.7 days in the control group (p=0.0001))

   Definitive Study Demonstrating Efficacy of Low Intensity Ultrasound in Healing Fresh Fractures.
2. Clinical Study: Kristiansen et al. Journal of Bone and Joint Surgery 1997 "Accelerated Healing of Distal Radial Fractures with the Use of Specific, Low Intensity Ultrasound"
   a. Randomized, double blind, placebo controlled multicenter study
   b. Sixty-one distal radius fractures treated with closed reduction, below elbow casting
   c. Thirty fractures treated with active Ultrasound Device compared to Thirty fractures treated with control (Ultrasound Device with unplugged transducer)
   d. End-point: Healed Fracture

   Results: Statistically significant decrease in the time to union (61 + 3 days compared with 98 +5 days (p< 0.0001))

   Results: Statistically significant decrease in loss of reduction (20 + 6 percent compared with 43 + 8 percent (p<01)

   Results: Statistically significant decrease in mean time until loss of reduction ceased. (12 + 4 days compared with 25 + 4 days)

   Definitive Study Demonstrating Efficacy of Low-Intensity Ultrasound in Healing Fresh Fractures.

B. Are the Human Data on Ultrasound Efficacy Surprising: No, They are supported by Animal Studies

1. Duarte: Acceleration of normal fracture-repair process in rabbits using Ultrasound.
2. Pilla: (Fibular osteotomy model), Low Intensity Ultrasound accelerates fracture repair in the rabbit.
3. Klug: Scintigraphic technique, Demonstrated faster callus maturation in rabbit close fracture model.

C. Why does Ultrasound Work So Well: Evidence that its effects are multifactorial

1. Stimulation of Bone Cell Growth (Sun et al.)
2. Stimulation of Bone Cell Metabolism via PGE-2 (Kokubu et al.)
3. Causes direct changes to local vascularity at fracture sites leading to accelerated bone repair.
   a. Rawool et al. suggests this results in increased micromechanical fluid pressure leading to increased cellular calcium intake and subsequent protein synthesis and repair
4. Stimulation of fibroblasts through increased protein synthesis (Doan et al., Enwemeka et al.)
5. Stimulation of synthesis of vascular endothelial growth factor, basic fibroblast growth factor, and interleukin-8. (Reher et al.)
6. Nitric Oxide as a mediator of mechanical stress events facilitating bone repair. (Reher et al.)

Ultrasound most probably has multiple factors contributing to its efficacy.

REFERENCES

1. Heckman, J.D., Ryaby, J.P., McCabe, J., Frey, J.J., Kilcoyne, R.F.: Accelaration of tibial fracture healing by non-invasive, low intensity pulsed ultrasound. Journal of Bone and Joint Surgery 76-A, 26-34, 1994
2. Kristiansen, T.K., Ryaby, J.P., McCAbe, J., Frey, J.J., Roe, L.R.: Acceleration of healing of distal radial fractures with the use of specific low-intensity ultrasound. Journal of Bone and Joint Surgery 79-A, 961-973, 1997
3. Duarte, L.R.: The stimulation of bone growth by ultrasound. Arch. Orthop. And Trauma Surg. 101, 153-159, 1983
4. Pilla, A.A., Mont, M.A., Nasser, P.R., Khan, S.A., Figueiredo, M., Kaufman, J.J., and Siffert, R.S. Non invasive low-intensity pulsed ultrasound accelerates bone healing in the rabbit. J. Orthop. Trauma 4, 246-253, 1990
5. Klug, W., Franke, W.G., and Knoch, H.G.: Scintigraphic control of bone-fracture healing under ultrasonic stimulation: an animal experimental study. European J. Nucl. Med. 11, 494-497, 1986
6. Sun, J.S., Hong, R.C., Chang, W. H.S., Chen, L.T., Lin, F.H., Liu, H.C.: In vitro effects of low-intensity ultrasound stimulation on the bone cells. J. Biomed. Mater. Res. 57, 449-456, 2001.
7. Kokubu, R., Matsui, N., Fujoka, H., Tsunoda, M., Mizuno, T. Low intensity pulsed ultrasound exposure increases prostaglandin E2 production via the induction of cyclooxygenase-2 mRNA in mouse osteoblasts. Biochem. Biophys. Res. Commun. 256, 284-287, 1999
8. Rawool, N.M., Goldber, B.R., Forsberg, F., Winder, A.A., Hume, E.: Power Doppler assessment of vascular changes during fracture treatment with low-intensity ultrasound. J. Ultrasound Med. 22, 145-153, 2003
9. Doan, N., Reher, P., Meghji, S., and Harris, M. In vitro effects of therapeutic ultrasound on cell proliferation, protein synthesis, and cytokine production by human fibroblasts, osteoblasts and monocytes, J. Oral Maxillofac Surg. 57, 409-419, 1999
10. Enwemeka, C.S., Rodriguez, O., Mendosa, S.: The biomechanical effects of low-intensity ultrasound on healing tendons. Ultrasound Med Biol. 16, 801-807, 1990
11. Reher, P., Doan, N., Bradnock, B., Meghji, S., Harris, M.: Effect of ultrasound on the production of IL-8, basic FGF, and VEGF. Cytokine 11, 416-423, 1999
12. Reher, P., Harris, M., Whiteman, M., Hi, H.K., Meghji, S.: Ultrasound stimulates nitric oxide and prostaglandin E2 production by human osteoblasts. Bone 31, 236-241, 2002

Debate 2: Ultrasound Stimulation

Con Position

Joseph Benevenia, MD

Current Evidence
- History
- Basic Science
- Clinical Science

Background

Low intensity (30 mW/cm_) pulsed ultrasound signal promotes accelerated healing. Controlled animal trials have reinforced these findings showing shorter time to fracture healing. While there has been some evidence for altered gene expression, the exact mechanism is unknown.

Recently several clinical studies have shown that therapeutic ultrasound may be useful in the treatment of fractures. Three of these studies were randomized, double-blind, placebo-controlled. These studies analyzed fresh uncomplicated tibia, distal radius and scaphoid fractures.

Results of Studies

The results of these individual studies showed that in fresh closed scaphoid and radius, and closed and grade I open tibia fractures time to healing was decreased significantly [$p<0.01$, $p<0.0001$, and $p=0.0001$ respectively].

These studies have also been subject to a meta-analysis and pooled data has shown similar results (n=158) with a 95% confidence interval.

Other studies have shown equivocal results in fractures treated with open methods (i.e. reamed nails).

Problems
- Fracture gap/patterns
- Co-mormidities
- Outcome Studies
- Compliance
- Overuse

Con Issues

Studies that have looked at ultrasound and its use in surgically treated fractures have been equivocal.

This has led researchers to propose several criticisms:
- There is no evidence that ultrasound works in anything other than fresh, simple fractures in humans.
- The effect of reaming may negate the positive influence due to its osteoblastic effect.
- The influence of ultrasound in the presence of measurable fracture – gaps has not been substantiated. There is no evidence that it is useful in patients with complex injuries and bone loss.
- Studies need to be performed identifying specific outcome parameters.
- Compliance remains an issue despite the fact that it is adequate in these few prospective studies.

REFERENCES

1. Wang SJ, Lewallen DG, Bolander ME, Chao EYS, Ilstrup DM, Greenleaf JF. Low intensity ultrasound treatment increases strength in a rat femoral fracture model. J Orthop Res 1994;12:40-7.
2. Pilla AA, Mont MA, Nasser PR, Khan SA, Figueiredo M, Kaufman JJ, et al. Non-invasive low-intensity pulsed ultrasound accelerates bone healing in the rabbit. J Orthop Trauma 1990;4:246-53.
3. Yang KH, Parvizi J, Wang SJ, Lewallen DG, Kinnick RR, Greenleaf JF, et al. Exposure to low-intensity ultrasound increases aggrecan gene expression in a rat femur fracture model. J Orthop Res 1996;14:802-9.
4. Emami A, Petrén-Mallmin M, Larsson S. No effect of low-intensity ultrasound on healing time of intramedullary fixed tibial fractures. J Orthop Trauma 1999;13:252-7.
5. Emami A, Larsson A, Petrén-Mallmin M, Larsson S. Serum bone markers after intramedullary fixed tibial fractures. Clin Orthop 1999;368:220-9.
6. Heckman JD, Ryaby JP, McCabe J, Frey JJ, Kilcoyne RF. Acceleration of tibial fracture-healing by non-invasive, low-intensity pulsed ultrasound. J Bone Joint Surg Am 1994;76:26-34.
7. Kristiansen TK, Ryaby JP, McCabe J, Frey JJ, Roe LR. Accelerated healing of distal radial fractures with the use of specific, low-intensity ultrasound. J Bone Joint Surg Am 1997;79:961-73.
8. Mayr E, Rudzki MM, Rudzki M, Borchardt B, Haüsser H, Rüter A. Beschleunigt niedrig intensiver, gepulster Ultraschall die Heilung von Skaphoidfrakturen? Handchir Mikrochir Plast Chir 2000;32:115-22.

Debate 3: Platelet Gels

Pro Position

J. Tracy Watson, MD

INTRODUCTION:

Following acute fracture or operative interventions, platelets are activated by thrombin and subendothelial collagen with the subsequent release of their granules into the wound environment. This fracture or wound hematoma contains a pool of platelet-derived factors released from the platelets (TGF-_-1, PDGF-AB, IGF-1, EGF, VEGF) which can stimulate the formation of blood vessels, the invasion of pluripotential mesencymal stem cells (MSC), monocytes, macrophages, and the further aggregation of platelets……Additionally, these platelet released factors are thought to be "osteo-PROMOTIVE" as evidenced by their ability to enhance the mitogenic activity of fibroblasts, osteoblasts, smooth muscle cells and endothelial cells setting the appropriate conditions necessary for the further progression of fracture healing. The ability to deliver a concentrated amount of platelets would intuitively help to contribute to these early stages of bone repair and thus "jump start" the entire fracture healing cascade.

BASIC SCIENCE:

1) Involvement of Platelets in Stimulating Osteogenic Activity Slater et al. J Orthop Res 1995;13:655-63. "The very large biological effect of a small volume of platelet supplement may have been a reflection of the interactive and possibly synergistic effects of the multiple platelet- derived growth factors." Authors conclusions: That platelets may play an important role in early healing of fractures and may be useful as a CHEAP autologous source of multiple growth factors to enhance osteoblast proliferation in vivo.
2) Large volume of additional Initial work was performed in maxillofacial research evaluating effectiveness of augmenting bone formation around titanium dental implants documenting increased bone deposition with APG (autogenous platlet gel).
3) Evaluation of larger alveolar, sinus and cranial defects treated with PRP alone demonstrated NO significant improvement radiographically or histomorphometrically in terms of bone formation and healing of these defects. Improved results were seen when APG was combined with various materials....autograft, allograft, CaSO4, HA, and TCP,.... in terms of defect healing. Results better than with the graft material alone without addition of APG. Concept of Composite grafting utilizing APG as carrier for other materials. Ip, TH. Dent Imlantol Update 2003;14(2):9-14
4) Exogenous TGF-_, and PDGF studied in several critical size defect models of bone regeneration, fracture healing, and distraction osteogenesis, with most studies showing increased bone or callus formation and increased mechanical stability. Additionally PDGF has been shown to be a potent mitogen stimulating periosteal derived cells. However the factors appear to be much less potent in terms of the dramatic direct bone formation that occurs with the true BMP'S (BMP-2,BMP-4, BMP-7)
5) Positive wound healing effect secondary to mitogenic potency of PDGF on keratinocytes and endothelial cells. PDGF found to be a major proliferative and migratory stimulus for connective tissue cells during the initiation of wound repair processes. (Plastic surgery literature) Platelet derived factors appear to act as a mitogenic and proliferative stimulus on the particular tissue at hand, and these target tissues respond by undergoing a generalized histogenesis of that particular type. These factors noted to have a global application and effect..i.e.will stimulate a whole variety of tissue types dependent on the location where the stimulus occurs...LOCATION SPECIFIC EFFECT....True BMP'S by contrast will form bone irregardless of the stimulus site...TISSUE SPECIFIC EFFECT

CLINICAL STUDIES: published

1) Six human studies using APG found in dental literature documenting increased bone deposition, bone regeneration, and augmentation of dental implant replacement and dental defects.
2) Orthopaedic spine surgery, 2 human clinical studies demonstrating statistical increase in fusion rates with PRP augmentation of graft composites.
3) Orthopaedic traumatology, (multiple case reports/ abstracts) documenting effectiveness of use of APG as carrier for various alloplastic graft substitutes and achieving enhanced graft incorporation.

CONCLUSIONS:

Basic science literature strongly supports the positive effects and cellular stimulation by APG as a mechanism for bone repair as well as generalized stimulation of host tissue contacts.

Considered an Osteopromotive factor vs. true Bone Morphogenes which are Osteoinductive. Therefore is NOT indicated as a sole adjuvant to fracture healing and should be utilized in combination with various auto/alloplastic composites.

Safety and cost concerns of APG vs other adjuvant therapies
Published prospective comparative studies currently lacking…
Current Evidence comparable to other adjuvants at the initiation of THEIR initial generalized use,

REFERENCES

1. Rasubala L, Yoshikawa H, Nagata K, Iijima T, Ohishi M. Platelet-derived growth factor and bone morphogenetic protein in the healing of mandibular fractures in rats.Br J Oral Maxillofac Surg. 2003 Jun;41(3):173-8.
2. Ip TH. Using platelet-rich plasma to enhance a composite graft in the maxillary sinus. Dent Implantol Update. 2003 Feb;14(2):9-14.
3. Danesh-Meyer MJ, Filstein MR, Shanaman R. Histological evaluation of sinus augmentation using platelet rich plasma (PRP): a case series. J Int Acad Periodontol. 2001 Apr;3(2):48-56.
4. Sanchez AR, Sheridan PJ, Kupp LI. Is platelet-rich plasma the perfect enhancement factor? A current review.Int J Oral Maxillofac Implants. 2003 Jan-Feb;18(1):93-103.
5. Schilephake H. Bone growth factors in maxillofacial skeletal reconstruction. Int J Oral Maxillofac Surg. 2002 Oct;31(5):469-84. Review.
7. Lieberman JR, Daluiski A, Einhorn TA. The role of growth factors in the repair of bone. Biology and clinical applications. J Bone Joint Surg Am. 2002 Jun;84-A(6):1032-44. Review.
8. Tischler M. Platelet rich plasma. The use of autologous growth factors to enhance bone and soft tissue grafts.N Y State Dent J. 2002 Mar;68(3):22-4.
9. Kim SG, Chung CH, Kim YK, Park JC, Lim SC. Use of particulate dentin-plaster of Paris combination with/without platelet-rich plasma in the treatment of bone defects around implants. Int J Oral Maxillofac Implants. 2002 Jan-Feb;17(1):86-94.
10. Bhanot S, Alex JC. Current applications of platelet gels in facial plastic surgery. Facial Plast Surg. 2002 Feb;18(1):27-33.
11. Anitua E. The use of plasma-rich growth factors (PRGF) in oral surgery. Pract Proced Aesthet Dent. 2001 Aug;13(6):487-93; 93.
12. Schmitz JP, Hollinger JO. The biology of platelet-rich plasma. J Oral Maxillofac Surg. 2001 Sep;59(9):1119-21.

13. Stefani CM, Machado MA, Sallum EA, Sallum AW, Toledo S, Nociti FH Jr. Platelet-derived growth factor/insulin-like growth factor-1 combination and bone regeneration around implants placed into extraction sockets: a histometric study in dogs. Implant Dent. 2000;9(2):126-31.

14. Lee YM, Park YJ, Lee SJ, Ku Y, Han SB, Klokkevold PR, Chung CP. The bone regenerative effect of platelet-derived growth factor-BB delivered with a chitosan/tricalcium phosphate sponge carrier. J Periodontol. 2000 Mar;71(3):418-24.

15. Lane JM, Tomin E, Bostrom MP. Biosynthetic bone grafting. Clin Orthop. 1999 Oct;(367 Suppl):S107-17.

16. Lowery GL, Kulkarni S, Pennisi AE. Use of autologous growth factors in lumbar spinal fusion. Bone. 1999 Aug;25(2 Suppl):47S-50S.

17. Anitua E. Plasma rich in growth factors: preliminary results of use in the preparation of future sites for implants. Int J Oral Maxillofac Implants. 1999 Jul-Aug;14(4):529-35.

18. Kim WJ, Mohan RR, Mohan RR, Wilson SE. Effect of PDGF, IL-1alpha, and BMP2/4 on corneal fibroblast chemotaxis: expression of the platelet-derived growth factor system in the cornea. Invest Ophthalmol Vis Sci. 1999 Jun;40(7):1364-72.

19. Arm DM, Tencer AF, Bain SD, Celino D. Effect of controlled release of platelet-derived growth factor from a porous hydroxyapatite implant on bone ingrowth. Biomaterials. 1996 Apr;17(7):703-9.

20. Andrew JG, Hoyland JA, Freemont AJ, Marsh DR. Platelet-derived growth factor expression in normally healing human fractures. Bone. 1995 Apr;16(4):455-60.

21. Nash TJ, Howlett CR, Martin C, Steele J, Johnson KA, Hicklin DJ. Effect of platelet-derived growth factor on tibial osteotomies in rabbits. Bone. 1994 Mar-Apr;15(2):203-8.

22. Canalis E, Varghese S, McCarthy TL, Centrella M. Role of platelet derived growth factor in bone cell function. Growth Regul. 1992 Dec;2(4):151-5. Review.

23. SA. Growth factor impact on wound healing. Clin Podiatr Med Surg. 1991 Oct;8(4):937-53. Review.

24. Mustoe TA, Purdy J, Gramates P, Deuel TF, Thomason A, Pierce GF. Reversal of impaired wound healing in irradiated rats by platelet-derived growth factor-BB. Am J Surg. 1989 Oct;158(4):345-50.

25. Ross R, Raines EW, Bowen-Pope DF. The biology of platelet-derived growth factor. Cell. 1986 Jul 18;46(2):155-69. Review. No abstract available.

26 .de Obarrio JJ, Arausz-Dutari JI, Chamberlain TM, The use of autologous growth factors in periodontal surgical therapy: platelet gel biotechnology – case reports. Int J Periodontics Restorative Dent. 2000 Oct;20(5)486-97.

27. Aghaloo TL, Moy PK, Freymiller EG. Investigation of platelet-rich plasma in rabbit cranial defects: A pilot study. J Oral Maxillofac Surg. 2002 Oct;60(10):1176-81

28. Kassolis JD, Rosen PS, Reynolds MA. Alveolar ridge and sinus augmentation utilizing platelet-rich plasma in combination with freeze-dried bone allograft: case series. J Periodontol. 2000 Oct;71(10):1654-61.

29. Slater M, et al. Involvement of Platelets in Stimulating Osteogenic Activity J Ortho Research 13:655-663, 1995.

30. Lariviere B, Rouleau M, Picard S, Beaulieu AD. Human plasma fibronectin potentiates the mitogenic activity of platelet-derived growth factor and complements its wound healing affects. Wound Repair Regen. 2003 Jan-Feb;11(1):79-89.

31. Marx RE, Carlson ER, Eichstaedt RM, et.al Platelet Rich Plasma, Growth Factor Enhancement for Bone Grafts Oral Surg and Enodontics June 1998,85(6)

32. Rosier RN, O'Keefe RJ, Hicks DG. The potential role of transforming growth factor beta in fracture healing. Clin Orthop. 1998 oct;(355 Suppl):S294-300.

33. Lammens J, Liu Z, Aerssens J, Dequeker J, Fabry G. Distraction bone healing versus osteotomy healing: a comparative biochemical analysis. J Bone Miner Res. 1998 Feb;13(2):279-86.

34. Yazawa M, Ogata H, Nakajima T, Mori T, Wantanabe N, Handa M. Basic studies on the clinical applications of platelet-rich plasma. Cell Transplant. 2003;12(5):509-18.

35. Uhl E, Rosken F, Sirsjo A, Messmer K. Influence of platelet-derived growth factor on microcirculation during normal and impaired wound healing. Wound Repair Regen. 2003 Sep-Oct;1195):361-7.

36. Gruber R, Karreth F, Frommlet F, Fischer MB, Watzek G. Platelets are mitogenic for periosteum-derived cells. J Orthop Res. 2003 Sep;21(5):941-8.

37. Cross KJ, Mustoe TA. Growth factors in wound healing. Surg Clin North Am. 2003 Jun;83(3):531-45, vi.

38. Gope R. The effect of epidermal growth factor & platelet-derived growth factors on wound healing process. Indian J Med Res. 2002 Nov;116:201-6.

39. Lowery GL, Kulkarni S, Pennisi AE, Use of Autologous Growth Factores in Lumbar Spinal Fusion. Bone 25(2): 47-50, 1999.

Debate 3: Platelet Gels

Con Position

Joseph Lane, MD

A) Bone Graft Adjuvants:
Purpose → Cell access
Distribute healing response
Deliver active protein
Required components for bone regeneration:
Osteoinduction factor
Osteoconductive matrix
Osteoprogenitor cells
But mitogens are not necessary

B) Bone Marrow has 1/50,000 active stem cells
Aged 1/2,000,000
Bone Marrow and Blood lead to a platelet enriched clot

C) *Why Give Up the Cells?
Platelet gel contains
PDGF
TGF-_ → not shown to be osteoinductive?? How good is TGF-_ for osteoinduction
1) These lead to cell proliferation but no cell differentiation
2) PDGF make calvarial bone cells increase in number
But these cell do not increase alkaline phosphatase
3) PDGF decreases adult osteoblast function
4) PDGF increases bone degredation

***PDGF/TGF-_ do not enhance bone performance and are not osteoinductive**

D) Platelet Gel Concentration →
6 – 10 fold (in-vivo) increase in platelet and factors (PDGF/TGF-_)
However changes in cellular activity in tissue culture (ex-vivo) require 100-1000 fold (ex-vivo) augmentation

IS A 6-10 FOLD INCREASE RELEVANT?

E) PDGF and Osteogenin (BMP-like product) →
decreases bone formation compared to osteogenin alone in a rat calvarial defect
*PDGF inhibits BMP-like factors

F) Clinical Trial with platelet gel cohort studies
Posters/Presentations
No evidenced based randomized trial in print
Anterior fusion with platelet gel
No enhancement over ABG
Posterior fusion decreases from 91% ‡68%

***NO ENHANCEMENT – MAY BE PROBLEMATIC CLINICALLY**

G) Platelet Gels
No standardized methodologies for preparation
Patients differ
The blood volume necessary for enhancement are 5 fold between
AGF (Interpore-Cross) and Symphony (DePuy)

***PRODUCT VARIABLE**

CONCLUSION:
PLATELETS GEL
NEED EVIDENCE BASED TRIALS TO PROVE TRUE EFFICACY AND SAFETY

REFERENCES

Boden SD: Overview of the biology of lumbar spine fusion and principles for selecting a bone graft substitute. Spine, 2002; 27:S26-S31.

Canalis E, McCarthy TL and Centrella M: Effects of platelet-derived growth factor on bone formation in vitro. J Cell Physiol. 1989:140:530-537.

Centrella M: Human platelet derived TGF-_ stimulates parameters of bone growth in fetal rat calvariae. Endocrinology. 1986;119:2306-2312.

Harris SE, Bonewald LF, Harris MA, et al: Effects of transforming growth factor _ on bone nodule formation and expression of bone morphogenetic protein 2, osteocalcin, osteopontin, alkaline phosphatase, and Type 1 collagen mRNA in long-term cultures of fetal rat calvarial osteoblasts. J Bone Miner Res. 1994 9:955-863.

Hee TH, Majd ME, Holt RT, Myers L; Do autologous growth factors enhance transforaminal lumbar interbody fusion? Eur Spine J 2003;12:400-407.

Howes R, Bowness GR, Grotendorst GR, et al. Platelet-derived growth factor enhances demineralized bone matrix induced cartilage and bone formation. Calcif Tissue Int. 1988;42:34-38.

Kasperk CG: Interactions of growth factors present in bone matrix with bone cells effects on DNA synthesis and alkaline phosphatase. Growth Factors. 1990;3:147-158.

Marden LJ, Fan RSP, Peirce GF, et al: Platelet derived growth factors inhibit bone regeneration induced by ostogenin, a BMP, in rat craniotomy defects. J Clin Invest. 1993;92:2897-2905.

Noda M: In vivo stimulation of bone foration by TGF-_. Endocrinology. 1998;124:2991-2994.

Pfeilschifter J: Stimulation of bone matrix apposition in vitro by local growth factors. Endocrinology. 1990;127:69-75.

Slater M: Involvement of platelets in stimulating osteogenic activity. J Orthop Res. 1995;13:655-663.

Weiner BK and Walker M: Perspectives on "Efficacy of autologous growth factors in lumbar intertransverse fusions" Spine. 2003; 28(17):1968-1971.

Debate 4: Demineralized Bone Matrix

Pro Position

William Parrish, MD

I. Introduction
- A. History
- B. Preparation of Demineralized Bone Graft Material
- C. Safety Issues
- D. Product Options

II. Evidence of Efficacy
- A. Animal Models
- B. Human Clinical Results

III. Clinical Use of Demineralized Bone Matrix Materials

IV. Case Studies
- A. Tumor
- B. Trauma
- C. Joint Reconstruction

Demineralized bone matrix materials have been commercially available in the U.S. for approximately ten years. Demineralized bone is available in many forms and may be manufactured to meet specific grafting needs. These materials are used to extend volumes of autograft or allograft, enhance performance of autograft or allograft (osteoinduction) or as a stand alone substitute for autograft or allograft.

During the past ten years, the use of these materials has expanded significantly. This has occurred in spite of questions concerning the efficacy and safety of demineralized bone matrix graft. The surgeon/ consumer must address these issues and be confident that demineralized bone matrix grafts will enhance healing or fusion rates while not compromising patient safety. Demineralized bone matrix is manufactured from processed demineralized bone powder. Tens of thousands of processed grafts have been implanted in the U.S. without a single case of HIV or Hepatitis transmission reported. This includes DBM products and other forms of processed grafts such as cancellous cubes and structural grafts..

Athymic nude rat models have been utilized to demonstrate the ability of DBM to induce bone formation in a subcutaneous pouch. Larger animal models including studies with rabbits, horses and rhesus monkeys have also demonstrated this ability. Prospective studies on humans are limited but those available do support the position that demineralized bone matrix grafts do possess osteoinductive properties.

The injection of demineralized bone matrix gel with bone marrow has been demonstrated to be effective in treating simple bone cysts. Demineralized bone matrix has also been shown to form bone in fibular defects created in conjunction with high tibial osteotomies. In addition, unpublished case reports and the experience of many surgeons have demonstrated highly successful surgical results using DBM.

All demineralized bone products are not alike. There can be variation in processing of final products and differences in carriers and composition of the graft material. It is incumbent on the practicing surgeon to closely examine any available research supporting the use of any DBM product. Close scrutinization of the data and histologic confirmation that the material has the ability to induce new bone formation should be demanded before a graft product is implanted.

REFERENCES

1. Bauer, TW. Muschler, GF. Bone Graft Materials. An Overview of the Basic Science. CORR. (371): 10-27, 2000 Feb.
2. Boden, S. Louis-Ugbo, J. Murakami, H. Kanazawa, H. Sun Kim, H. Minamide, A. Evidence of Osteoinduction y Grafton DBMin Non-Human Primate Spine Fusion. North American Spine Society, November 2001
3. Edwards, JT. Diegmann, MH. Scarborough, NL. Osteoinduction of Human Demineralized Bone: Characterization of a Rat Model. CORR. (357): 219-28, 1998 Dec.
4. Goldberg, VM. Stevenson, S. The Biology of Bone Grafts. Seminars in Arthroplasty. 4(2): 58. 1993
5. Rosenthal, RK. Folkman, J. Glowacke, J. Demineralized Bone Implants for Nonunion of Fractures, Bone Cysts and Fibrous Lesions. CORR. (364): 61-9. 1999 Jul.
6. Rougraff, BT. Kling, TJ. Treatment of Active Unicameral Bone Cysts with Percutaneous Injection of Demineralized Bone Matrix and Autogenous Bone Marrow. JBJS. (84A): 921-29, 2002 June.
7. Russell, JL. Block, JE. Clinical Utility of Demineraliqed Bone Matrix for Osseous Defects, Arthrodesis and Reconsturction: Impact of Processing Techniques and Study Methodology. Orthopedics. 22(5): 524-31, 1999 May.
8. Scarbourough, N. White, EM. Hughes, JV. Manrique, AJ. Poser, JW. Allograft Safely: Viral Inactivation with Bone Demineralization. Contemporary Orthopedics. 31(4): 257, 1995
9. Zang, M. Powers, RM Jr. Wolfinbarger, L Jr. Effect of Demineralization Process on the Osteoconductivity of Demineralized Bone Matrix. Journal of Periodontology. 68(11): 1085-92, 1997 Nov.

Debate 4: Demineralized Bone Matrix

Con Position

Jeffrey Wang, MD

Introduction

- DBM – derived from human tissue and contains osteoinductive proteins
- Components/process of production – different preparations have different processing methods and different methods of sterilization which can add variability of various products and effectiveness
- Amount of BMPs available in each product are much less than the dose that is typically thought to be enough for the stimulation of a spinal fusion to complete healing in humans.

DBM – do we know what we are getting?

- Commercially available products have different carriers
- Different amounts of DBM contained in each
- Different methods of processing
- Different methods of sterilization which include avenues for sterilization or Processing - Chemical treatments, Radiation treatments
- There also exist donor inconsistencies due to the fact that the tissue comes from donors of different ages, varying amounts of biological potential, different numbers of osteoprogenitor cells with age.
- Some donors may have osteoporotic bone which may influence biological potential of the product
- There exists no way of standardardizing the biological potential of the donors
- There is no way to measure the dosage of standards of the DBM products

Testing

- Validation of each processing method is not standard/consistent between products
- Preclinical data in animal models may not be relevant to human spine fusion

Preclinical data

- Urist model
  - Not relevant to human clinical use
  - Small osteoinductive potential needed to form bone in muscle hindlimb
  - Different behaviors of different products as studies have demonstrated
- Rodent spinal fusion
  - Different fusion rates for different commercially available products
  - Some products do not induce bone formation
- Rabbit spinal fusion
  - Some evidence of increase bone formation in preclinical studies
  - Different forms of product specifically made for rabbit may not mimic the actual product used in humans
- Canine and other larger animal data have similar criticisms as lower animal models
- Non-human primate studies
  - Some evidence of increase bone formation in presented studies
  - Question applicability to human spinal fusions

Human data

- Human spinal fusion data demonstrates use of DBM as extender
- No studies utilizing DBM as sole biological graft material in lumbar spine
- Cervical studies demonstrate use as stand alone product, but this environment more conducive to healing
- Lumbar fusion model is more stringent and DBM is not used as stand-alone product
- Overall data is weak for use of DBM in human spinal fusion
- More data is needed and future study is needed with randomized controlled prospective studies looking at human spinal fusions

REFERENCES

1. An HS, Simpson JM, Glover JM, Stephany J. Comparison between allograft plus demineralized bone matrix versus autograft in anterior cervical fusion. A prospective multicenter study. Spine. 1995 Oct 15;20(20):2211-6.

   Frenkel SR, Moskovich R, Spivak J, Zhang ZH, Prewett AB.Demineralized bone matrix. Enhancement of spinal fusion. Spine. 1993 Sep 15;18(12):1634-9.
2. Girardi FP, Cammisa FP Jr. The effect of bone graft extenders to enhance the performance of iliac crest bone grafts in instrumented lumbar spine fusion. Orthopedics. 2003 May;26(5 Suppl):s545-8.
3. Guizzardi S, Di Silvestre M, Scandroglio R, Ruggeri A, Savini R. Implants of heterologous demineralized bone matrix for induction of posterior spinal fusion in rats. Spine. 1992 Jun;17(6):701-7.
4. Martin GJ Jr, Boden SD, Titus L, Scarborough NL. New formulations of demineralized bone matrix as a more effective graft alternative in experimental posterolateral lumbar spine arthrodesis. Spine. 1999 Apr 1;24(7):637-45.
5. Morone MA, Boden SD. Experimental posterolateral lumbar spinal fusion with a demineralized bone matrix gel. Spine. 1998 Jan 15;23(2):159-67. Interaction of allogeneic demineralized bone matrix and porous hydroxyapatite bioceramics in lumbar interbody fusion in rabbits.
6. Ragni P, Lindholm TS. Interaction of allogeneic demineralized bone matrix and porous hydroxyapatite bioceramics in lumbar interbody fusion in rabbits. Clin Orthop. 1991 Nov;(272):292-9.
7. Sassard WR, Eidman DK, Gray PM, Block JE, Russo R, Russell JL, Taboada EM. Augmenting local bone with Grafton demineralized bone matrix for posterolateral lumbar spine fusion: avoiding second site autologous bone harvest. Orthopedics. 2000 Oct;23(10):1059-64; discussion 1064-5.

Debate 5: Recombinant BMPs

Pro Position

Harvinder Sandhu, MD

A biologic agent or technique that intends to enhance bone healing or regeneration must satisfy two critical hurdles prior to widespread clinical use:

1. There must be credible evidence of reliable and reproducible efficacy for use in the intended application.
2. There must be substantial assurance of safety for use in the intended application.

Recombinant bone morphogenetic proteins (rhBMPs) have been among the most extensively studied osteoinductive agents in musculoskeletal science. They are the only products discussed in this symposium that have overwhelmingly fulfilled the above requirements.

Satisfying the "Burden of Proof"

A successful response to an osteoinductive agent in a lower order mammalian animal model is essential in demonstrating "proof of concept" of use of such an agent. However, this success does not imply a similar outcome in higher animals. Subsequent studies in more challenging environments are essential in demonstrating "feasibility" of use. Finally, success in highest order primate models is necessary to prove clinically relevant "efficacy" prior to experimentation in humans. Most agents currently available for clinical use as bone healing enhancers have failed to pass each of the steps in this cascading burden of proof. Many have not even been subjected to this degree of examination.

The osteoinductive potency of rhBMPs was first revealed 15 years ago in studies on critical long bone defects in lower animal models. This established a proof of concept for the use of rhBMPs for skeletal repair. Subsequently, beginning in 1994, numerous studies from varied centers showed feasibility of use of rhBMP-2 and rhBMP-7 for repair of long bone defects and for spinal fusion. Experiments with these recombinant molecules in sheep, dogs, and rabbits demonstrated 100% efficacy for achieving either anterior or posterior spinal fusion. The chronology of the bone generation in each of these studies was remarkably predictable. Finally, prior to any use in humans, rhBMP-2 was shown to achieve a similar degree of efficacy for both anterior and posterior spinal fusion in non-human primates. No other class of products in the published literature has reproducibly shown such extraordinary efficacy in this environment. Table I is a sampling of the experiments examining the use of rhBMP-2 in various animal spinal fusion models.

As a consequence of the overwhelming data derived from animal studies, rhBMPs have been used in several clinical trials examining use in spinal fusion as well as tibial nonunions. In several studies, the results have demonstrated an unprecedented superiority of rhBMPs over "gold standard" autograft for bone repair and generation.

A pivotal investigational device exempted (IDE) and randomized study of anterior lumbar intervertebral fusion using titanium cages with rhBMP-2 carried by a collagen sponge showed that all 143 patients implanted with the molecule had achieved a successful radiographic fusion by one year following surgery. Fusion "success", incorporating factors in addition to radiographic findings, was noted in 94.5% of rhBMP-2 implanted patients compared to 88.7% of autograft-implanted patients.

Subsequently, a prospective and randomized pilot IDE study examining the use of rhBMP-2 with collagen combined with allograft for anterior lumbar fusion also showed that all 24 patients implanted with the molecule achieved radiographic fusion in one year. In contrast, only 90% of patients implanted with allograft combined with iliac autograft in this prospective randomized study achieved fusion at the same time point. The improvement in back pain and Oswestry pain and disability scores were significantly better in the rhBMP-2 implanted patients. A pilot IDE study of posterolateral lumbar fusion also showed that all 20 patients implanted with rhBMP-2 carried by a tricalcium phosphate / hydroxyapatite composite carrier achieved successful radiographic fusion by two years while only 2 of 5 patients in the autograft control arm had successfully fused. Ten of the 20 patients had achieved their posterolateral fusion without the use of internal fixation.

Burkus et al have reported on an integrated analysis of 679 patients undergoing anterior lumbar interbody fusion using Titanium cages with either rhBMP-2 or autograft. The patients treated with rhBMP-2 had statistically superior outcomes with regard to length of surgery, blood loss, hospital stay, re-operation rate, median time to return to work, and fusion rates at 6, 12, and 24 months. Oswestry Disability Index scores and the Physical Component Scores and Pain Index of the SF-36 scale at 3, 6, 12, and 24 months showed statistically superior outcomes in the rhBMP-2 group.

Csimma, et al have shown a 44% reduction in the risk of failure when rhBMP-2 on a collagen sponge was used in the treatment of established tibial nonunions. The treated patients had statistically fewer hardware failures, fewer infections, and faster wound healing. Most importantly, the rhBMP-2 treat patients had statistically earlier fracture healing compared to controls.

Table II is a partial list of clinical studies examining the use of rhBMPs in bone repair and regeneration.

Assurance of Safety:

The safety profile for rhBMP-2 has been extensively examined. The potential concerns include bony overgrowth, ectopic bone formation, interaction with dura mater, cancer risk, immunogenicity, systemic toxicity, reproductive toxicity, and local toxicity.

Bone overgrowth has not occurred beyond the immediate proximity of the carrier matrix for the osteoinductive molecule either in the extensive pre-clinical animal studies or among patients enrolled in the clinical trials. There have been no confirmed neurologic sequelae related to inadvertent bone growth in proximity to neural structures or the spinal canal. In fact, specific pre clinical studies were performed to evaluate the effect of rhBMP-2 on exposed dura and exposed CSF resulting from dural puncture. Again, no neurologic consequence was found related to this interaction. More recently, Sheehan et al have demonstrated in a non human primate model that rhBMP-2 carried by an absorbable collagen sponge could successfully repair bilateral critical sized calvarial defects. Safety examination revealed no epileptogenic activity in any of the animals. MR imaging revealed no evidence of adverse effects on the brain parenchyma.

Findings show that rhBMP-2 has an antiproliferative effect on human tumor colony–forming units taken from breast, ovarian, lung, and prostate cancers, and cerebellar neuroectodermal tumor cell lines. Deliberate preclinical safety studies mandated by the food and drug administration not only failed to demonstrate any proliferative effect of rhBMP-2 on human osteosarcoma, prostate, breast, tongue, and lung carcinoma cell lines but actually showed inhibition. The Ames in vitro mutagenicity test showed no mutagenic activity related two rhBMP-2.

The bone morphogenetic proteins are rapidly cleared from the systemic circulation. Furthermore, the typical carriers used to deliver these molecules enable a slow exposure of the molecule to the local environment. As a result, the local and systemic exposure of the molecule is extremely small. Not surprisingly, no end organ effect has been seen with the use of rhBMP-2 either in the pre clinical animal studies or in the clinical trials. Furthermore, although antibodies to bone morphogenetic proteins can traverse the placental barrier, the food and drug administration has determined that the molecule can be used safely in women of childbearing age. This is in part due to the relatively low antibody response rate to these molecules. Serology tests among clinically treated patients revealed antibody response rates of under 1% at three months following an exposure to the molecules. In contrast, positive antibody titers to the rhBMP-2 carrier (collagen sponge) were noted in nearly 20% of patients.

Conclusion:

More than 50% of the bone grafting procedures performed worldwide are for the purpose of spinal fusion. The most common forms of fusion include anterior and posterior lumbar arthrodesis. Prospective and controlled clinical trials have demonstrated the superiority of rhBMP-2 compared to autograft in these most common applications. Sequential pilot and pivotal clinical studies have reproducibly shown nearly perfect efficacy for achieving radiographic fusion. The larger studies have clearly demonstrated the statistical superiority of rhBMP-2 over autograft among perioperative measures, fusion criteria, and clinical outcome criteria. Integrated analysis of multiple clinical trials has also revealed a remarkably strong safety profile associated with the clinical use of recombinant bone morphogenetic proteins.

Some have argued that the clinical application of high doses of a singular osteoinductive molecule is non physiologic and thus inefficient. However, replication of physiology should not be construed as an implication of efficacy and safety. Clinical success and the relative absence of risk should be the ultimate determinants. In this regard, the bone morphogens proteins have surpassed all other osteoinductive agents studied to date. The achievement of virtually 100% efficacy in combination with a high level of safety leaves little room for alternative strategies for bone graft replacement. Whether these agents can achieve similar outcomes in the treatment of more challenging conditions such as multilevel fusion, repair of large segmental defects, or compromised healing environments remains to be seen. More elegant interventions such as local gene therapy or combination molecular therapies may be reserved for these less common circumstances. At this moment, however, the bone morphogenetic proteins represent the new gold standard in bone grafting surgery.

Table I

INVESTIGATOR	YEAR	SPECIES	FACTOR	LEVEL	RESULT	CONC.	DOSE
Cook *et al.*	1994	Canine	rhBMP-7	T13-L7	Radiographic and histologic studies revealed solid fusion for rhBMP-7 group 6 weeks after surgery. Autograft group attained fusion 26 weeks after fusion.		
Paramore *et al.*	1997	Canine	rhBMP-7	Not a fusion model	Safety study; subarachnoid bone formation; no neurologic deficit	1.0 mg/cc	2.8 mg
Cunningham *et al.*	1999	Sheep	rhBMP-7	T5-T10	Endoscopic interbody arthrodesis with a BAK cage either empty, + autograft, + rhBMP-7 or autograft alone. At 16 weeks there was biomechanical and histomorphometric equivalence (75%) to autograft (62%) in terms of fusion.	1.0 mg/cc	2.8 mg
Magin *et al.*	1999	Sheep	rhBMP-7	L4-L5	Posterior lumbar interbody fusion model. Groups were as follows: autograft alone, deproteinized bovine hydroxyl apatite alone and rhBMP-7 on a collagen carrier. rhBMP-7 group had 80% fusion at 4 months with 60% increase in bone formation compared to the other groups at 12 weeks.	1.0 mg/cc	3.0 mg
Sachs *et al.*	1999	Goat	rhBMP-7	C3-C5	Anterior cervical fusion model. Animals received either allograft alone or allograft with rhBMP-7 in varying doses. Results indicated increased bone formation qualitatively and quantitatively in all the rhBMP-7 groups compared to the control group at 24 weeks.	1.0 mg/cc	3.5 mg

Table I (cont.)

INVESTIGATOR	YEAR	SPECIES	FACTOR	LEVEL	RESULT	CONC.	DOSE
Cheung *et al.*	1999	Primate	rhBMP-7	L4-L5	No statistical difference in fusion rate histologically or biomechanically between rhBMP-7 + autograft group (66%) and autograft alone group(16%).	0.3-3.0 mg/cc	0.3-3.0 mg
Jeppsson *et al.*	1999	Human	rhBMP-7	C1-C2	rhBMP-7 on a collagen carrier used as an adjunct to wire fixation in 4 patients with atlanto-axial instability due to rheumatoid arthritis. Only 1 had new bone formation at 6 months	Proof of concept study	Not a clinical dose or formulation
Laursen *et al.*	1999	Human	rhBMP-7	T11-L2	rhBMP-7 + collagen implanted in unstable thoracolumbar burst fractures in 5 patients. Study discontinued as bone formation was inadequate	1.0 mg/cc	3.5mg
Patel et al.	2000	Rabbit	rhBMP-7	L5-L6	Single-level posterolateral intertransverse process fusions were performed at the L5-L6 level using either autograft or OP-1. Nicotine was administered via subcutaneous mini-osmotic pumps. Fusion rate was 25% for nicotine exposed + autograft, 100% for nicotine exposed + OP-1.	1.0 mg/cc	3.5 mg
Cunningham et al.	2000	Canine	rhBMP-7	L3-L4 or L5-L6	Posterolateral fusion in the lumbar spine using OP-1 Putty alone, OP-1 Putty with iliac crest autograft and iliac crest autograft alone. Superior bone formation and fusion was observed in both OP-1 groups	1.0 mg/cc	2.4 mg
Patel et al.	2000	Human	rhBMP-7	L3-S1	Safey and efficacy study using OP-1 as an adjunct to iliac crest autograft. At 6 months, 10/12 (83%) clinical success with OP-1 + autograft and (2/4) 50% clinical success with autograft alone patients.	1.0 mg/cc	3.5 - 7.0mg
Schimandle *et al.*	1995	Rabbit	rhBMP-2	L5-L6	rhBMP-2 + autograft versus autograft alone; 100% fusion achieved in the experimental group versus 42% in the control group	1.0 mg/cc	3.5 mg
Holliger *et al.*	1996	Rabbit	rhBMP-2	L5-L6	rhBMP-2 + collagen versus autograft alone; fusions with rhBMP-2 were biomechanically superior to the fusions with autograft alone	0.11 mg/ml 0.43 mg/ml	0.7 mg 2.7 mg
Sheehan *et al.*	1996	Canine	rhBMP-2	T13-L7	rhBMP-2 + autograft with collagen produced fusion mass radiographically, volumetrically and biomechanically superior to autograft alone or autograft + collagen alone.	0.64 mg/ml	2.7 mg
Muschler *et al.*	1994	Canine	rhBMP-2		rhBMP-2 was delivered in a PLGA carrier was compared to autograft alone and PLGA alone. No difference between rhBMP-2 + PLGA and autograft alone.	0.8 mg/ml	1.6 mg

Table I (cont.)

INVESTIGATOR	YEAR	SPECIES	FACTOR	LEVEL	RESULT	CONC.	DOSE
Sandhu *et al.*	1996	Canine	rhBMP-2	L4-L5	Dose response relationship of rhBMP-2 studied.	CONC	DOSE
Sandhu *et al.*	1996	Canine	rhBMP-2	L4-L5	No statistical difference in fusion rates between decorticated and undecorticated sites with the use of intermediate to high dose rhBMP-2	0.2 mg/ml	0.4 mg
Fischgrund *et al.*	1997	Canine	rhBMP-2	L1-L6	Evaluation of rhBMP-2 with a variety of carrier media.	0.03 mg/ml 0.05 mg/ml 0.10 mg/ml 0.21 mg/ml 0.42 mg/ml	0.058 mg 0.115 mg 0.230 mg 0.460 mg 0.920 mg
Meyer *et al.*	1999	Canine	rhBMP-2	Not a fusion model	Safety study; rhBMP-2 applied at experimental durotomy site resulted in no neurologic abnormalities.	0.03 mg/ml 0.10 mg/ml 0.42 mg/ml	0.058 mg 0.230 mg 0.920 mg
Sandhu *et al.*	1996	Sheep	rhBMP-2	L4-L5	100% anterior lumbar interbody fusion at 6 months with rhBMP-2 + collagen carrier in a threaded titanium cage.	0.43 mg/ml	0.43 mg
Sandhu *et al.*	1997	Sheep	rhBMP-2	L4-L5	rhBMP-2 added to porous tantalum cylindrical cages. Significantly greater bone ingrowth occurred in the porous macrostructure compared with cages that had not been combined with the rhBMP-2.	0.10 mg/ml	0.24 mg
Zdeblick *et al.*	1998	Goat	rhBMP-2	C2-C5	100% fusion in BAK cage + rhBMP-2 group.	0.43 mg/ml	0.69 mg
Boden *et al.*	1996	Rabbit/ Primate	rhBMP-2	L4-L5/ L4-L5	1) Video assisted lateral intertransverse process arthrodesis procedure optimized in rabbit and primate model.2) Rabbits underwent both standard and video assisted fusion + rhBMP-2. 3) Video assisted fusion + rhBMP-2 in primates. Video assisted fusion with rhBMP-2 successful in both models.	0.58 mg/ml	1.2 mg
Boden *et al.*	1998	Primate	rhBMP-2	L6-S1	Laparascopic anterior spinal fusion with threaded titanium interbody cage with collgen carrier + rhBMP-2; 100% fusion in experimental group.	0.4 mg/ml	0.2 mg
Boden *et al.*	1999	Primate	rhBMP-2	L4-L5	rhBMP-2 + hydroxyapatite-tricalcium phosphate; 100% fusion in experimental group	Rabbit 0.1 mg/ml Primate 2.25 mg/ml	Rabbit 0.24 mg Primate 32 mg

Table I (cont.)

INVESTIGATOR	YEAR	SPECIES	FACTOR	LEVEL	RESULT	CONC.	DOSE
Hecht *et al.*	1999	Primate	rhBMP-2	L7-S1	Anterior interbody fusion with cylindrical cortical allograft dowel with collagen sponge + rhBMP-2; 100% fusion at 8 weeks.	0.75 mg/ml 1.5 mg/ml	0.3 mg 0.6 mg
Martin Jr *et al.*	1999	Primate	rhBMP-2	L4-L5	Different combinations of doses of rhBMP-2 and carriers tested.	1.3 mg/ml 2.0 mg/ml 2.7 mg/ml	6 mg 9 mg 12mg
Boden *et al.*	2000	Human	rhBMP-2	L4-L5 or L5-S1	rhBMP-2 + threaded tapered cylindrical fusion cages; 100% patients fused with 2 year follow-up.	1.5 mg/ml	0.40 mg
Riew *et al.*	1998	Rabbit	Adv-BMP-2	L5-L6	Adenoviral vector carrying human BMP-2 gene used to transduce marrow derived mesenchymal stem cells. MSC's loaded on to collagen sponges and placed on transverse processes of experimental group. 20% fusion at 7 weeks.	0.43 to 2.2 mg/ml	2 to 32 mg
Wang *et al.*	1999	Rat	Adv-BMP-2	L4-L5	Bone marrow cells were transfected with adenoviral vector carrying human BMP-2 and loaded onto a demineralized bone matrix carrier. 100% fused at 4 weeks	1.5 mg/ml	4.2 mg 8.4 mg
Alden *et al.*	1999	Rat	Adv-BMP-2	L6-S1	Adenovirus-mediated gene transfer of hBMP-2 was performed paraspinally in athymic rats via percutaneous injection. All rats treated with Adv-BMP-2 formed ectopic bone at 12 weeks.	Proof of concept study.	
Alden *et al.*	2000	Rat	Adv-BMP-9	L6-S1	Adenovirus-mediated gene transfer of hBMP-9 was performed paraspinally at the lumbosacral junction. All rats treated with Adv-BMP-9 formed bone leading to a solid arthrodesis at 16 weeks.	Proof of concept study.	

Table II

TRIAL TYPE	COMPARISON	SITE	CARRIER	SAMPLE SIZE	DOSE	RESULT
Pilot IDE study	rhBMP-2 (INFUSE) vs autograft	ALIF	Absorbable collagen sponge in a lumbar tapered titanium interbody fusion device (LT-CAGE™)	n=14 (**Experimental**, n=7 open retroperitoneal approach; n=4 laparoscopic approach; **Control**, n=3)	1.5 mg/mL	100% fusion success in experimental group (11/11) vs 67% in control group (2/3)
Pivotal Clinical Trial	rhBMP-2 (INFUSE) vs autograft	ALIF	Absorbable collagen sponge in a lumbar tapered titanium interbody fusion device (LT-CAGE™)	n=279 (**Experimental**, n=143; **Control**, n= 136)	1.5 mg/mL	Blood loss and operative time significantly less in experimental group. Clinical success rate at 12 months was experimental 78.9% vs control 75.2%
Pivotal Clinical Trial	rhBMP-2 (INFUSE) vs autograft (historical control)	Laparoscopic ALIF	Absorbable collagen sponge in a lumbar tapered titanium interbody fusion device (LT-CAGE™)	**Experimental**, n=136 vs **Historical control**, n=266	1.5 mg/mL	Fusion success in both groups exceeded 90% 12 months after surgery
Pilot Clinical Trial	rhBMP-2 (INFUSE) vs autograft	ALIF	Absorbable collagen sponge in allograft bone dowels	n= 47 (**Experimental**, n=24; **Control**, n=23)	1.5 mg/mL	100% radiographic fusion in experimental group at 12 months vs 90% fusion in controls. At 2 years, 67% of INFUSE patients returned to work vs 35% of the control group
Pilot Clinical Trial	rhBMP-2 (INFUSE) vs autograft	PLIF	Absorbable collagen sponge in cylindrical hollow threaded cages (Interfix™)	n=67 (**Experimental**, n=34; **Control**, n=33)	1.5 mg/mL	Fusion success of 92.3% in experimental group vs 77.8% in control group at 24 months.
Pilot Clinical Trial	rhBMP-2 (INFUSE) vs autograft	ACDF	Absorbable collagen sponge in machined fibular ring grafts (Cornerstone™)	n=33 (**Experimental**, n=18; **Control**, n=15)	1.5 mg/mL	100% radiographic fusion at 6 months post surgery in both groups. Perioperative blood loss less in experimental cohort
Pilot Clinical Trial	rhBMP-2 (Dibotermin alfa) + intramedullary nail (IM) vs intramedullary nail fixation alone	Open tibial shaft fractures	Absorbable collagen sponge	n=450 (**Cohort 1**: Standard of care (IM nail), n=150; **Cohort 2**: IM nail + 0.75 mg/mL rhBMP-2, n=151; **Cohort 3**: IM nail + 1.5 mg/mL rhBMP-2, n=149		rhBMP-2 implant safe and at a dose of 1.5 mg/mL significantly superior in clinical success vs IM nail alone by accelerating wound healing and fracture repair
Pilot IDE Trial	rhBMP-7 (OP-1) + intramedullary nail (IM) vs intramedullary nail + autograft	Tibial nonunions	Type I collagen carrier	n=124 (**Experimental**: n=63; **Control**: n=61)	3.5 mg/mL	At 9 months postsurgery, 81% experimental were judged to be clinical success vs 85% control. Radiographically, 75% success in the OP_1 group vs 84% in the control group

Debate 5: Recombinant BMPs

Con Position

Jay Lieberman, MD

I. Biology of Bone Morphogenetic Proteins.

1. Members of the TGF-B superfamily.
2. At least 14 individual molecules have been identified but they have variable osteoinductive potential.
   a. Urist (1965) – coined the term the "bone induction principle" and was the first to recognize that a protein (BMP) was responsible for this effect.
   b. Wozney (1988) – identified the genetic sequence of bone morphogenetic protein, which led to the identification of various isoforms. Various BMPs can be produced by recombinant technology.
3. Osteoinductive BMPs
   a. BMPs 2,4,6 and 7 appear to have the most potent osteoinductive activity
   b. BMPs 2,6 and 9 may play a role in inducing osteoblast differentiation of mesenchymal stem cells.
   c. Most BMPs can stimulate osteogenesis in mature osteoblasts.

II. Pre-Clinical Evaluation

1. Both rhBMP 2 and 7 (OP-1) have demonstrated efficacy in healing of critical sized defects and osteotomies in rat, rabbit, sheep and dog models.
   a. A dose dependent effect was noted with respect to quality of bone formation via biomechanical testing.
   b. Scaldini and Johnson – canine model, the lowest dose of BMP was associated with a superior biomechanical performance than two higher doses.
2. BMP has been used successfully to enhance spine fusion in various animal models.
   a. Variety of carriers have been used in these studies including: collagen sponge, polylactic acid and copolymers (polylactic acid – polyglycolic acid).
   b. Voids in the fusion mass were noted in two studies in which polymers containing polylactic acid carriers were used.
3. Results of pre-clinical studies demonstrate osteoinductive potential of these proteins but also suggest that further study of the potential influence of the protein dose and the carrier on bone repair is necessary.

III. Clinical Studies – Orthopaedic Applications

1. Clinical Studies
   a. Boden et al – Anterior spinal fusion – 20 mg of rhBMP-2 in a metallic cage.
   b. Friedlander et al – OP-1 (3.5 mg of BMP-7 on bovine derived Type I collagen matrix) and IM rodding versus autograft and IM rodding for treatment tibial non-unions.
   c. BESST (BMP-2 Evaluation in Surgery for Tibial Trauma) Study Group – patients with open tibia fractures randomized to receive either the standard of care (IM nail and routine soft tissue management (control group) or standard of care and an implant containing 6 mg or 12 mg of rhBMP-2 on a collagen sponge.
2. Summary of Clinical Studies
   a. BMP on a collagen sponge has demonstrated osteoinductive activity in humans with respect to promoting spinal fusion, healing tibial non-unions and tibial fractures. However, overall the clinical results have been mixed.
3. Problems with clinical studies
   a. It is difficult to determine the extent of healing on plain radiographs especially with hardware.
   b. In the two trials treating tibial non-unions and tibial fractures it was difficult to obtain two homogenous patient populations.
   c. Large doses of BMP-2 or OP-1 were required to see an adequate osteoinductive effect.
4. Clinical Status
   a. FDA approval: Anterior Spinal Fusion – BMP-2 in a collagen sponge in a metallic cage
   b. Humanitarian Device Exemption – OP-1 in type I bovine derived collagen to treat recalcitrant tibial non-unions.

IV. BMPs – Unresolved Issues

1. Overall the clinical results have been somewhat disappointing and there are serious concerns about the large doses of BMP required to induce bone formation in humans. Safety and cost issues need further scrutiny.
   a. Supraphysiologic doses of protein (milligrams) are necessary to produce an adequate biologic response. There are only nanograms of BMP in the body.
2. Clealy the carriers must be optimized to maximize the ability of responding cells to to respond to the BMP signal.
   a. Different carriers may be required for different clinical applications.
3. Off – label use and dosage
   a. Approximately 70% of BMP being used today is off label use
   b. Surgeons need to be careful about altering carriers, doses and clinical applications. True informed consent must be obtained from patients.
   c. We must protect the safety of our patients.
4. Clearly define the indications for BMPs and other bone graft substitutes to enhance efficacy and maintain control on costs.

REFERENCES:

1. Lieberman, JR., Daluiski, A., Einhorn, TA. The role of growth factors in the repair of bone. Biology and clinical applications. J. Bone Joint Surg Am. 2002; 84:1032-1044.
2. Sciadini MF, Johnson KD. Evaluation of recombinant human bone morphogenetic protein-2 as a bone-graft substitute in a canine segmental defect model. J Orthop Res. 2000; 18:289-302.
3. Boden SD, Zdeblick TA, Sandhu HS, Helm SE. The use of rhBMP-2 interbody fusion cages. Definitive evidence of osteoinduction in humans: a preliminary report. Spine. 2000;25:376-81.
4. Winn SR, Uludag H, Hollinger JO. Carrier systems for bone morphogenetic proteins. Clin Orthop. 1999;367 Suppl:S95-106.
5. Friedlander GE, Perry CR, Cole JD, Cook SD, Cierny G, Muschler GF, Zych GA, Calhoun JH, LaForte AJ, Yin S. Osteogenic protein-1 (bone morphogenetic protein-7) in the treatment of tibial nonunions. J Bone Joint Surg Am. 2001;83 Suppl 1:S151-8.

ONCOLOGIC PITFALLS AND SOLUTIONS FOR THE GENERAL ORTHOPAEDIST (T)

Moderator: Scott D. Weiner, MD, Akron, OH (n)

Not every tumor-related problem needs to be referred. This symposium will assist the practicing orthopaedic surgeon in determining which situations can lead to problems. This symposium aims to teach improved patient care and help avoid potential medico-legal problems.

I. Common Technical Mistakes in the Surgical Management of Pathologic Fractures
Scott D. Weiner, MD, Akron, OH (n)

II. Cystic Lesions of Bone and Soft Tissue – "How Can You be Sure"
Patrick J. Getty, MD, Cleveland, OH (n)

III. Errors in the Diagnosis and Management of Soft Tissue Masses
Timothy A. Damron, MD, Syracuse, NY (n)

IV. Which Bone and Soft Tissue Tumors can be Treated by a General Orthopaedist?
Mark T. Scarborough, MD, Gainesville, FL (n)

V. Uses and Misuses of Tumor Prostheses for Tumorous and Non-Tumorous Conditions
Terrance D. Peabody, MD, Chicago, IL (e – Centerpulse/Zimmer)

VI. Documentation Risk Management in Orthopaedic Tumors – A Lawyer's Perspective
Eric Gibbs, Esq., Orlando, FL (n)

COMMON DECISION MAKING AND TECHNICAL MISTAKES IN THE SURGICAL MANAGEMENT OF PATHOLOGIC FRACTURES

Scott D Weiner, MD

I. Surgical Planning

a. Appropriate Pre-Operative Staging
   i. CT scanning of chest, abdomen, pelvis; mammography, PSA, bone scan, SPE… will identify most primary lesions. (remember a skeletal survey for potential myeloma)
   ii. identifying the origin of a metastatic lesion can be very helpful
      1. lesions with very poor survival (i.e. lung, multiple internal organ involvement) deserve more conservative surgery or non-operative treatment
      2. A renal cell carcinoma could be found, leading to a possible embolization prior to surgery to limit blood loss. Renal cell lesions also tend to be progressive and patients tend to survive longer than expected, therefore a more sturdy construct is desirable. A solitary renal cell met could be treated with a wide resection for cure, so referral should be considered.
      3. If no primary lesion is found, the lesion must be presumed to be a possible sarcoma and referral or biopsy should be performed prior to surgical stabilization. Biopsy of 'reamings' are inaccurate and impossible to freeze intra-operatively.

b. Avoid Missing A Primary Tumor
   i. Beware of an 'isolated' metastasis. Don't always assume that a new lesion in someone with cancer is a metastasis (second primary lesions and sarcomas do occur)
   ii. Stage an isolated lesion fully (MRI, bone scan etc) and consider biopsy… core biopsy may be preferred to limit contamination. Always discuss with your pathologist his/her comfort level with a core biopsy. They may want an open biopsy to prevent sampling error. Remember to always follow sarcoma biopsy principles (longitudinal incision along resection incision, minimal dissection, limit hemostasis)
   iii. Authors approach…I prefer to do an open biopsy if I am planning on surgical stabilization. I obtain an intraoperative frozen section and review it with my musculoskeletal pathologist. If it is a carcinoma, lymphoma or myeloma; I proceed with stabilization at the same setting. If the diagnosis is uncertain or a possible sarcoma, I perform the biopsy alone and defer treatment until the permanent section.
   iv. Authors approach…If non-operative treatment is planned; I prefer to do a core biopsy to make a diagnosis. Although a core is sometimes difficult for diagnosing sarcomas, it is very accurate for mets, myeloma and lymphoma. Beware of fracture callus (looks like sarcoma)

c. Radiograph the Entire Length of Involved Bones
   i. it is imperative that the entire bone be examined looking for other lesions or weakened areas that could compromise proposed fixation (may change fixation method)
   ii. allows assessment of joint integrity (i.e. structurally significant acetabular defects in a patient with a femoral neck fracture)

d. Assess Patient's Overall Condition and Functional Expectations
   i. Patients with limited life expectancy or serious medical co-morbidities should be considered for less-invasive procedures or non-operative treatment. This is often difficult to assess accurately, therefore long discussions with the patient and family regarding risks and complications is mandatory so they can understand potential adverse outcomes. REMEMBER THAT WE ARE TREATING PATIENTS, NOT X-RAYS. Our job is to teach the patients and let them make an informed decision as it pertains to their wishes and expectations.
   ii. The patient's level of independence and need for ambulatory aids affects treatment options. Find out what the patient expects to do after the reconstruction and make certain that it is obtainable.

e. Has the Patient Received Chemotherapy or Radiation?
   i. Patients receiving chemotherapy are prone to infections which make mega-prostheses and large allografts particularly risky. Beware of steroid use with some protocols. I tend to avoid exceedingly extensive surgeries in patients needing on-going chemo or steroids.
   ii. Radiation therapy weakens the bone and can compromise fixation. You may need to consider adding PMMA or a more sturdy device in radiated bone. Radiation is also recommended post-operative to limit tumor progression (note… renal cell responds poorly to XRT and often needs higher doses). Post-op radiation can also affect the reconstruction.

II. Peri-Operative Considerations

The goals of managing metastatic lesions are relief of pain and allowing early return to functional independence. Rarely, is surgery considered for cure in metastases. These goals are obtained by achieving "the three S's"

Stable …

   i. The planned reconstruction should allow early (unencumbered) range of motion and provide for early weight bearing. You should avoid the need for bracing or extended protected ambulation. Examples… endoprosthesis for femoral neck fractures, rotating hinge knee replacements for extensive distal femoral lesions.
   ii. Avoid the need for long rehab stay. The goal is to get the patient home to be with their loved ones, not to 'recover' away from their families.
   iii. Consider adding PMMA re-enforcement to add stability to a construct. Most lesions require post-op radiation. XRT has no effect on the PMMA but bone grafts or bone graft substitutes will 'melt away' with radiation. Bone grafts also fail to provide immediate stability that delays early weight bearing.
   iv. Remember to x-ray the entire bone involved!!! Nothing is worse than 'fixing a fracture' and having the same bone break somewhere else.

Sturdy…

i. The reconstruction should outlive the patient. Revision surgery in a patient with metastatic disease is defeating the original purpose. Choose a technique that will achieve this goal. N.B… do not go overboard with sturdiness in someone who has a limited survival (i.e. lung) since the surgery itself may be too extensive.

ii. I prefer intra-medullary fixation to plating. Besides the fact that other lesion may exist in the bone, metastatic lesions often progress (in spite of XRT) and can leave a plate 'swimming in cancer soup'. A rod may prevent this by obtaining fixation distant to the tumor and allowing load sharing. A rod also allows fixation of the 'entire' bone in case other lesions develop. Theoretically, less blood loss and less extensive exposures allow faster recovery.

Survivable…

i. Since the goal of treating metastatic disease is the relief of pain and improvement in function for the remaining life of the patient, we should not do procedures that carry an excessively high morbidity or mortality.

ii. Make certain that a patient will tolerate medically an extensive procedure, i.e. acetabular reconstructions, hinge knee replacements, spinal surgery. These procedures, except in rare instances, should be reserved for patients with prolonged survival (breast, renal, prostate, myeloma). Additional problems exist with the prolonged survival, i.e. need for revisions, so make the reconstruction as sturdy as possible, also.

iii. Excessive blood loss is common especially with renal cell carcinoma and myeloma. Pre-op embolization can be helpful but carries it's own set of complications. Authors approach…I use pre-op embolization (within 12 hr) for renal mets where I plan on opening the lesion or where the bone is circumferentially missing. For diaphyseal renal mets, I prefer IM rodding without embolization and do not open the lesion (they still bleed!). Renal cell lesions are also relatively radioresistent (needing higher dosage of XRT) and tend to progress whether they are embolized or cemented. Therefore, I prefer to span the defect with the rod and limit blood loss.

iv. Even though other lesions bleed, I reserve embolization only for renal mets. If significant bleeding is encountered, proceed quickly and try to curette the entire lesion. This often works for tumors other than renal. Sometimes procedures need to be aborted if bleeding persists… remember, do no harm.

v. Beware of tumor 'emboli' during reaming, rod insertion or insertion of a stem. Warn anesthesia during these times to hydrate the patient and watch for cardiac collapse. Include this in your informed consent as we all have experienced an unexpected death.

III. Technical Pitfalls

a. Beware of the impending fracture (consider non-op treatment first)
   i. If surgery is delayed, obtain an x-ray immediately prior to surgery to assess progression.
   ii. Be exceedingly careful when prepping and draping to prevent an impending fracture from completing. That simple procedure just got more difficult and may even change your proposed plan.
   iii. Patients rarely have a single met, so be careful moving the patient from the bed to the table and while positioning to avoid other fractures (I remember a case as a resident when a simple femoral rod became both femurs and a humerus)
   iv. Since rods have a bend and we try to fit them into intact bones, the bone often breaks on insertion. Make sure you use a proper entry hole and over-ream (2mm) the canal. Even doing this, non-displaced fractures are common. Explain this possibility to patients as the recovery tends to be slower with more immediate post-op pain.
   v. Bones with metastatic lesion are often osteopenic, so guide wire insertion may perforate the bone. Use fluoroscopy to confirm accurate placement!!

b. Juxta-articular lesions
   i. Most lesions can be stabilized with internal fixation (usually plates) with cement augmentation.
   ii. Preservation of intact joints lead to improved function, but if the lesion involves the joint or a path fracture extends into the joint, partial or total joint replacement is often needed. For fractures of the femoral neck, I prefer endoprosthesis but do a "thumb test" to assess acetabular integrity. If the thumb deforms the acetabulum, do a THA.
   iii. X-ray evaluation to assess arthrosis. Consider arthroplasty if the patient had symptomatic joint pain prior to pathologic fracture. I prefer to save the joint even with arthrosis to decrease morbidity. Make certain that adequate stability is possible when the joint is saved.
   iv. Post-op radiation is needed to limit further destruction.

c. Shaft lesions
   i. Rod preferred… fill entire bone (head fixation in femoral fixation), watch for extra-medullary penetration, hypotension during reaming/ insertion, early weight bearing. I typically do not cement the lesion if I can avoid it (decreased blood loss, surgical time) but watch tumor progression.
   ii. Plating should be avoided unless inadequate fixation with a rod is anticipated (humerus). Consider PMMA augmentation. I try to shorten the bone if possible to get some bony contact (avoid gaps). I occasionally add a thick Steinman pin to decrease a stress riser.

d. Blastic mets
   i. Fixation is difficult, esp. prostheses… common penetration of cortex along path of least resistance. Broaching instead of reaming can avoid this.

CYSTIC LESIONS OF BONE AND SOFT TISSUE – HOW CAN YOU BE SURE?

Patrick Getty, MD

I. Bone lesions

A. Simple bone cyst

1. X-rays
   - Central, geographic lytic lesion
   - Metaphyseal ‡ diaphyseal with time
   - </= width of epiphysis
   - Fallen leaf sign with Fx
2. CT / MRI
   - Thinned cortex
   - Cyst fluid with MR characteristics of water
     → Low on T1
     → High on T2
   - Single fluid-fluid level with Fx
3. Management
   - Observation
   - Steroids, percutaneous bone grafting, rods, curettage

B. Aneurysmal bone cyst

1. X-rays
   - Eccentric, lytic lesion with variable border
   - Expansile with periosteal new bone formation
   - Metaphyseal
2. CT / MRI
   - Thinned, expanded cortex
   - Multiple fluid-fluid levels
   - Septae +/- enhancement
   - No nodular enhancement
3. Management
   - Biopsy
   - Curettage and bone graft

C. Telangiectatic osteosarcoma

1. X-rays
   - Eccentric, lytic, permeative lesion
   - Cortical destruction
   - Metaphyseal
2. CT / MRI
   - Multiple fluid-fluid levels
   - Nodular enhancement
   - Soft tissue extension
3. Management
   - CTX / Wide resection / CTX

D. Intra-osseous ganglion

1. X-rays
   - Eccentric, juxta-articular
   - Classically in medial malleolus
   - Round to oval, geographic, lytic lesion
2. CT / MRI
   - Multilobular
   - Myxoid/ fluid MR characteristics
     → Low on T1
     → High on T2
   - Can be 'complex'
3. Management
   - Usually observe
   - Curettage and bone graft

II. Soft tissue lesions

A. Ganglion

1. MRI
   - Juxta-articular or along tenosynovium
   - Usually pure water signal
   - Rim enhancement
   - May be heterogeneous if 'complex'
2. Management
   - +/- excision
   - Treat underlying problem

B. Myxoid tumors

1. MRI
   - Myxoid characteristics (mimics water)
     → Low on T1
     → High on T2
   - Variable enhancement pattern (regardless of benign v. malignant)
   - Atypical site for ganglion
2. Management
   - Biopsy
   - Dx-specific Tx

C. Hematoma

1. CT / x-rays
   - May have mineralization
2. MRI
   - Protean manifestations
   - Time-dependent signal characteristics (T1 / T2)
     → Hyperacute phase: intermediate / high
     → Acute phase: intermediate / low
     → Subacute phase: high / high
     → Chronic: low / low rim with fluid centrally
   - Hemosiderin-laden macrophages produces rim if low / low
   - Often with inflammatory changes
3. Management
   - Biopsy
   - Serial observation

References

1. Bauer TW, Dorfman HD: Intraosseous ganglion: a clinicopathologic study of 11 cases. Am J Surg Pathol 6:207-213, 1982.
2. Dahlin DC, McLeod RA: Aneurysmal bone cyst and other non-neoplastic conditions. Skeletal Radiol 8:243-250, 1982.
3. Damron TA, Rock MG: Diagnostic strategies and biopsy. In Simon MA, Springfield D(eds.): Surgery for Bone and Soft-Tissue Tumors. Philadelphia, Lippincott-Raven Publishers, 1998, pp 509-523.
4. Huvos AG, et. al.: Telangiectatic osteogenic osteosarcoma: a clinicopathologic study of 124 patients. Cancer 49:1679-1689, 1976.
5. Kattapuram SV, Rosenthal DI: Diagnostic imaging. In Simon MA, Springfield D(eds.): Surgery for Bone and Soft-Tissue Tumors. Philadelphia, Lippincott-Raven Publishers, 1998, pp 31-45.
6. Schajowicz F, Sainz MC, Slullitel JA: Juxta-articular bone cysts (intra-osseous ganglia): a clinicopathological study of eighty-eight cases. J Bone Joint Surg 61B:107-116, 1979.

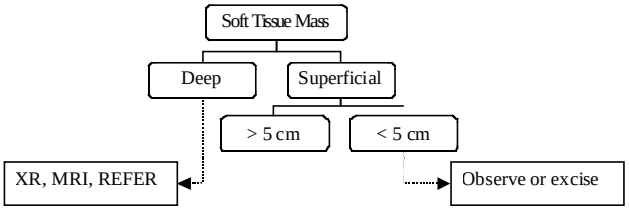
ERRORS IN THE DIAGNOSIS AND MANAGEMENT OF SOFT TISSUE MASSES

Timothy A. Damron, MD

THE PROBLEM: Benign soft-tissue tumors outnumber malignant ones 200:1. However, 2/3 to 4/5 of soft-tissue tumors at tertiary care centers are malignant. The vast majority of soft-tissue tumors seen by general orthopedists are benign. Hence, guidelines are needed to determine those tumors that need to be referred.

I. Diagnostic errors

A. History and physical
   1. Limited number of tumor types diagnosed on H & P
      a. MOST pediatric Baker's cysts
      b. MANY superficial lipomas
      c. SOME synovial cysts/ganglions
      d. SOME benign peripheral nerve sheath tumors
   2. If not exactly one of those, follow established guidelines
      a. Simon's algorithm



      b. Norwegian guidelines
      c. United Kingdom NHS guidelines
   3. Most common fallacies on H & P

B. Radiographic evaluation
   1. Imaging can only diagnosis a few specific soft-tissue tumors
   2. Vast majority of soft-tissue tumors are "non-specific" on MRI
   3. Common radiographic errors

C. Advanced staging
   1. Local imaging before tissue!
   2. Timing of distant staging less crucial

II. Biopsy dilemmas

A. When to biopsy? (eg. pre-referral in local community vs. post-referral in tertiary care center)
   1. Rule of thumb: Refer if deep or large, OR if any question !
   2. Caveat: Bad things can happen to those who biopsy (Mankin et al)

B. Where to biopsy? (eg. anatomically)
   1. Rule of thumb: In line with planned incision for tumor resection
   2. Caviat: Minimize contamination

C. What type of biopsy?
   1. Rule of thumb: Trucut if deep or large, excisional if small and superf.
   2. Caviats: Numerous

D. What to do with it? Deliver it like a gift!
   1. Card (completed path report)
   2. Wrapping (keep the tissue moist)
   3. Context (communicate hx and DDX with pathologist, review films)

III. Definitive management

A. Refer or resect? (Same question as with biopsy)
   1. Rule of thumb: Refer if deep or large
   2. Caviat: 1/3 of soft tissue sarcomas are small and superficial

B. Margins (Enneking)
   1. Intralesional (eg. synovectomy)… ok for synovial proliferation (PVNS)
   2. Marginal (eg. shell-out)… ok for lipomas
   3. Wide (eg. resection)… goal for sarcomas
   4. Radical (eg. compartmental resection)

C. Adjuvant therapy for sarcomas
   1. Radiotherapy
   2. Chemotherapy

D. Prognosis: Depends upon size, depth, and grade

REFERENCES

1. (2000). "Adjuvant chemotherapy for localised resectable soft tissue sarcoma in adults. Sarcoma Meta-analysis Collaboration (SMAC)." Cochrane Database Syst Rev(2): CD001419.
2. Akerman, M. (1997). "The cytology of soft tissue tumours." Acta Orthop Scand Suppl 273: 54-9.
3. Bauer, H. C. (1997). "Biopsy: complicated and risky." J Bone Joint Surg Am 79(10): 1591-3.
4. Bennert, K. W. and F. W. Abdul-Karim (1994). "Fine needle aspiration cytology vs. needle core biopsy of soft tissue tumors. A comparison." Acta Cytol 38(3): 381-4.
5. Hoeber, I., A. J. Spillane, et al. (2001). "Accuracy of biopsy techniques for limb and limb girdle soft tissue tumors." Ann Surg Oncol 8(1): 80-7.
6. Kilpatrick, S. E., J. O. Cappellari, et al. (2001). "Is fine-needle aspiration biopsy a practical alternative to open biopsy for the primary diagnosis of sarcoma? Experience with 140 patients." Am J Clin Pathol 115(1): 59-68.
7. Mankin, H. J., T. A. Lange, et al. (1982). "The hazards of biopsy in patients with malignant primary bone and soft- tissue tumors." J Bone Joint Surg Am 64(8): 1121-7.
8. Mankin, H. J., C. J. Mankin, et al. (1996). "The hazards of the biopsy, revisited. Members of the Musculoskeletal Tumor Society." J Bone Joint Surg Am 78(5): 656-63.
9. O'Sullivan, B., A. M. Davis, et al. (2002). "Preoperative versus postoperative radiotherapy in soft-tissue sarcoma of the limbs: a randomised trial." Lancet 359(9325): 2235-41.
10. Peabody, T. D., C. P. Gibbs, Jr., et al. (1998). "Evaluation and staging of musculoskeletal neoplasms." J Bone Joint Surg Am 80(8): 1204-18.
11. Schwartz, H. S. and D. M. Spengler (1997). "Needle tract recurrences after closed biopsy for sarcoma: three cases and review of the literature." Ann Surg Oncol 4(3): 228-36.
12. Simon, M. A. and J. S. Biermann (1993). "Biopsy of bone and soft-tissue lesions." J Bone Joint Surg Am 75(4): 616-21.
13. Skrzynski, M. C., J. S. Biermann, et al. (1996). "Diagnostic accuracy and charge-savings of outpatient core needle biopsy compared with open biopsy of musculoskeletal tumors." J Bone Joint Surg Am 78(5): 644-9.
14. Ward, W. G., P. Savage, et al. (2001). "Fine-needle aspiration biopsy of sarcomas and related tumors." Cancer Control 8(3): 232-8.

WHICH BONE AND SOFT TISSUE TUMORS CAN BE TREATED BY A GENERAL ORTHOPAEDIST?

Mark Scarborough, MD

Advantages and disadvantages of the general orthopedist treating selected bone and soft tissue tumors

ADVANTAGES	DISADVANTAGES
Local treatment	Complex diagnostic challenge
Continuity of care	May require extensive imaging and interpretation
Avoids referral	Pathologic support insufficient
Reimbursement	Potential for wrong diagnosis
	Unpredictable outcome
	Liability for diagnostic errors or poor outcome

Which Bone and Soft Tissue Tumors Can Be Treated by a General Orthopaedist?
None?

Selected Bone Tumors
Metastatic carcinoma
Myeloma
Unicameral bone cysts (UBC)
Non-ossifying fibromas (NOF)

Selected Soft Tissue Tumors
Ganglia
Focal Pigmented villonodular synovitis (PVNS)
Schwannomas
Superficial lipomas

Principles
Do a careful history and thorough physical exam
Treat only classic cases of "safe lesions"
Refer if:
- Primary bone neoplasm
- Potentially malignant bone or soft tissue tumor
- Not comfortable treating case
- Pathology and radiology support inadequate
- Any case where if treated and turns out to be malignant the ultimate treatment would be different

Case Examples

REFERENCES

1. Mankin, H. J., Lange, T. A., and Spanier, S. S.: The hazards of biopsy in patients with malignant primary bone and soft-tissue tumors. J. Bone Joint Surg. Am. 64:1121-1127, 1982.
2. Mankin, H. J., Mankin, C. J., and Simon, M. A.: The hazards of the biopsy, revisited. Members of the Musculoskeletal Tumor Society. J. Bone Joint Surg. Am. 78:656-663, 1996.

ONCOLOGY RECONSTRUCTIVE TECHNIQUES FOR NONONCOLOGIC CONDITIONS

Terry Peabody, MD

Tumor Reconstructions for Non-Tumorous Conditions

A. Etiology of Severe Bone and Soft-Tissue Loss
1. Trauma
2. Infection
3. Revision Surgery-Revisionoma

B. Lessons Learned in Oncology
1. Heroic Attempts to Salvage Diseased Bone Not in Patients Best Interest
2. Limitations of Bone Grafts
   a. Resorption
   b. Fracture
   c. Prolonged Limited Weight Bearing and Immobilization
3. Importance of Soft-Tissue Coverage
   a. Rotational Flaps
   b. Free Flaps
4. Prompt Recognition of Complications

C. Soft-Tissue Reconstruction
1. Gastrocnemius Rotation Flap
   a. Extensor Tendon Reconstruction
   b. Utilitarian about Proximal Tibia or Distal Femur
2. Free Flap
   a. Healthy Vascularized Tissue
   b. Static or Dynamic (innervated)
3. Hip Abductor Mechanism Reconstruction
4. Important Not to have Prosthesis only Covered by Skin
5. Drains Recommended

D. Skeletal Reconstruction
1. Endoprosthesis
   a. Advantages
      i. Available
      ii. Reliable
      iii. Immediate Weight Bearing
   b. Disadvantages
      i. Lack of familiarity
      ii. Expense
      iii. Long-term Durability
   c. Indications- Bone Loss about a Joint, 25-30 mm distal femur, tibia below collateral insertion, severe bone loss hip
2. Segmental Allografts
   a. Advantages
      i. Soft-tissue Attachments
      ii. Available
      iii. "Biologic"
   b. Disadvantages
      i. Prolonged Immobilization
      ii. Entensive Fixation
      iii. Resorption and Fracture
      iv. Viable Cartilage Preservation
   c. Indications –Intercalary bone loss, alloprosthetic composite
3. Vascularized Bone Grafts
   a. Advantages-Biologic
   b. Disadvantages-Technical difficulty, non-weight bearing
   c. Indications-Non-unions, supplement reconstruction, fusions, upper extremities

E. Outcomes
1. Prosthetic Survival 70% 10 Year survival, worse for proximal tibia, unknown cemented v uncemented results
2. Functional Loss-Worse in Upper extremity,rotator cuff and capsular absence, Hip-lack of functional abductor mechanism

F. Contraindications
1. Active Infection
2. Inability to provide soft-tissue coverage
3. Check FDA status of Implant-few for bone cancer only

REFERENCES

1. Horowitz S, Glasser D, Lane J and Healey J. Prosthetic and extremity survivorship in limb salvage: how long do the reconstructions last? Clin Orthop 1993; 293;280.
2. Kniesl J, Finn H and Simon, M. Mobile knee recostruction after resection of malignant tumors of the distal femur: musculoskeletal tumors. Orthop Clin North America 1991;22;105.
3. Malawer M and Chou L. Prosthetic survival and clinical results with use of large segment replacements in the treatment of high-grade bone sarcomas. J Bone Joint Surg 1995;1977;77;1154.
4. Jaurequito J, DuBois C, Smith S, Gottlieb L and Finn H. Medial gastrocnemius transposition flap for the treament of disruption of the extensor mechanism after total knee arthroplasty. J Bone Joint Surg 1997;79;866.

CHARTING: A LAWYER'S PERSPECTIVE

Eric P. Gibbs

I. Introduction: the Purpose of the Medical Record
- A. facilitate decision making: you and others
- B. record treatment
- C. basis for charges: you and hospital
- D. evidence
  1. medical malpractice
  2. other claims (auto, premises, social security…)
  3. administrative actions against physicians
  4. peer review

II. Technical Charting Points that Can Impact a Lawsuit
- A. date and time
- B. blue or black ink
- C. legibility
- D. corrections
- E. telephone contacts: consistent method
- F. abbreviations
- G. promptness
- H. consistency
- I. templates
- J. post-it notes

III. Broader Charting Concerns
- A. not charted, not done
- B. pertinent positives
- C. charting by those you employ
- D. office nurses and clerks understand your abbreviations, orders
- E. relationship between consulting and attending physicians
- F. late entries: suspicious, but better than silence, so think and think again
- G. poor outcomes
- H. disagreements among physicians
- I. discharge instructions
- J. informed consent

IV. Altering the Chart: LoseYour Case, Your Coverage, Your License and Your Freedom: Real Life Horror Stories

SCIENTIFIC EXHIBITS

SCIENTIFIC EXHIBIT NO. SE081

AAOS Complementary and Alternative Medicine (CAM) Committee

Acupuncture Uses in Pain and Musculoskeletal Disease

Harris Gellman, MD, *Coral Springs, FL (n)*
Andrew D. Hutter, MD, West Orange, NJ (n)

Purpose: To provide a basic description of acupuncture, its uses and non-uses. To provide scientific information including data and clinical studies of acupuncture as it relates to musculoskeletal disease (both pro and con), and the treatment of pain. To demonstrate some of the techniques, as well as the safety issues, of acupuncture. To show acupuncture can supplement a traditional orthopaedic practice. Content: Basic description of acupuncture techniques and equipment. Why is acupuncture relevant to the orthopaedic surgeon? Scientific studies, both pro and con. How to integrate acupuncture into your practice. Relationship of material presented to orthopaedics: Acupuncture has been recommended by the NIH as useful in the treatment of musculoskeletal pain. Accordingly, orthopaedic surgeons should have a basic understanding of the mechanism of action of acupuncture. Scientific data from the NIH Acupuncture Consensus Conference will be presented on musculoskeletal conditions where acupuncture may be useful as an adjunctive treatment or as part of a comprehensive treatment program.

SCIENTIFIC EXHIBIT NO. SE082

AAOS Committee on Biological Implants and Committee on Patient Safety

Safety of Musculoskeletal Allograft Tissue

Michael J. Joyce, MD, *Cleveland OH*
(e – Musculoskeletal Transplant Foundation)
Seth Greenwald, D Phil (Oxon), Cleveland, OH
Randy N. Rosier, MD, PhD, Rochester, NY (n)
David Wong, MD, Denver, CO (a, b, e – Stryker, a – Centerpulse, e Neurospine)

The orthopaedic surgeon has the responsibility to inform patients about the risks and benefits of using banked musculoskeletal allograft tissue in various surgical procedures. The surgeon must be aware of the current potential for transmitting blood borne diseases, e.g., hepatitis, HIV and bacterial infections, etc. Cultural, religious differences and conceptual limitations of recipients should also be taken into account. The exhibit provides an understanding of tissue bank practices in donor screening, serology testing, processing, and, when applicable, secondary sterilization or terminal sterilization. The historical record of disease transmission is presented and the outstanding safety record associated with the use of allograft tissue is outlined. Progressive governmental regulatory oversight, standards, and a national voluntary accreditation program are reviewed. The exhibit also demonstrates that the use of human allograft tissue is predicated on the gracious altruistic gift from the donor/donor family to the patient recipient.

SCIENTIFIC EXHIBIT NO. SE083

AAOS Committee on Biological Implants

Xenotransplantation: Potential Challenges and Choices in Orthopaedic Surgery

Cato T. Laurencin, MD, *PhD, Elkins Park, PA (n)*
William A. Jiranek, MD, Richmond, VA (*)

This exhibit serves to educate surgeons on the growing interest in the use of xenotransplantaton procedures for treatment of a wide variety of human diseases, current controversies involving xenotransplantation and efforts made to date to address safety issues surrounding their use. The exhibit will present definitions used for xenotransplantaton, xenotransplantation products and zoonoses, as well as provide background information on the growth of xenotransplantaton procedures in the United States. Guidelines for use of xenotransplanted materials as described by the FDA and other regulatory agencies will be summarized. Finally, a derscription of current and possible future xenotransplanted tissue products in orthopaedic surgery will be summarized. The use of xenotransplanted tissues for treatment of a wide variety of human diseases is increasing. In orthopaedic surgery, the first xeno-based products for treatment of musculoskeletal-conditions have been approved. Therefore it is important to begin discussion and education regarding issues of safety surrounding the use of xeno-based products.

SCIENTIFIC EXHIBIT NO. SE084

AAOS Biomedical Engineering Committee

◆The Basics of Surgical Navigation for Clinicians

Anthony M. DiGioia III, MD, *Pittsburgh, PA*
(a – Zimmer, National Science Foundation, National Institute of Health, d – CaSurgica, e – Zimmer)
Branislav Jaramaz, PhD, Pittsburgh, PA (d – CaSurgica)
Scott Delp, PhD, Stanford, CA (n)
S. David Stulberg, MD, Chicago, IL (n)
David Kahler, MD, Charlottesville, VA
(e – Smith & Nephew)

Surgical navigation systems provide real time intraoperation guidance. These smart guidance devices represent a new generation of intraoperative surgical tools. The steps for navigation include: 1) collection of anatomic information such as preop or intraop imaging, kinematic data or anatomic landmarks; 2) intraop tracking; 3) registration; 4) intraop guidance; 5) validation and assessment of accuracy. Examples are presented in this Exhibit for total hip replacement (THR), total knee replacement (TKR) and pelvic screw placement in trauma. Navigation systems were used to measure the orientation of bones, mechanical guides and implants or screw trajectories at all times during surgery. Soft-tissue balancing and ROM before and after the joint reconstruction are also measured and documented. Navigation and other computer assisted orthopaedic surgical (CAOS) tools are being introduced into the operating room in daily clinical practice. It is important for surgeons to understand the basic principles of navigation tools as well as the limitations. In addition, understanding issues related to clinical and technical accuracy and validation of these systems is critical to their clinical use.

SCIENTIFIC EXHIBIT NO. SE086

AAOS Orthopaedic Device Forum

◆Antibiotic Loaded Bone Cement in Aseptic Total Joint Replacement: Whys, Wherefores, and Caveats

William A. Jiranek, MD, *Richmond, VA (n)*
Arlen D. Hanssen, MD, Rochester, MN (a – Hawkins Chemical Corp)
A. Seth Greenwald, D Phil (Oxon), Cleveland, OH (n)

Bacterial infection of prosthetic implants remains one of the most common (incidence 1% in primary THR, and 3% in revision) and costliest (-US estimate-$250 million per year) complications of hip arthroplasty. This exhibit reviews the current literature on the efficacy of antibiotic loaded bone cement (ALBC) for prophylaxis in arthroplasty surgery. Global use patterns of ALBC, and the current FDA regulatory position are discussed in the light of the May 2003 approval of premixed Simplex P with Tobramycin. Based on this data, the exhibit presents indications and contraindications for the use of ALBC. The effect of dosage on strength and elution is discussed, as well as patient safety issues related to antibiotic resistance, and systemic toxicity.

SCIENTIFIC EXHIBIT NO. SE087

AAOS Women's Health Issues Committee

James Slauterbeck, MD, Lubbock, TX (n)
Laura L. Tosi, MD, *Washington, DC (n)*
Joseph A. Buckwalter, MD, Iowa City, IA (n)
Barbara J. Campbell, MD, Somerset, PA (b – Merck & Co)
John D. Kaufman, MD, Santa Clarita, CA (b – Aventis, Merck & Co, Proctor and Gamble)
Joseph M. Lane, MD, New York, NY (n)
Sally A. Rudicel, MD, Boston, MA (n)
Leigh Callahan, PhD, Chapel Hill, NC (*)
Barbara Boyan, PhD, Atlanta, GA (*)

Musculoskeletal conditions and injuries are a significant source of pain, disability, and economic burden for women. Studies have indicated that 1) women are disproportionately affected by musculoskeletal conditions and injuries; 2) musculoskeletal problems are under-recognized as to their effect on physical, emotional, and economic indicators; 3) osteoarthritis and osteoporosis, which overwhelmingly affect more women than men, are consistently associated with disability and diminished quality of life; and 4) the economic costs associated with musculoskeletal problems are estimated at $254 billion. This scientific exhibit highlights the work of the Women's Health Issues Committee and its mission to enhance awareness and understanding of the sex and gender-based differences in incidence, presentation, diagnosis, treatment, and prevention of musculoskeletal diseases. The exhibit will present the orthopaedic surgeon with information about education, research, and cultural/societal issues in women's musculoskeletal health and highlight materials available from AAOS and other sources. The materials will include handout copies of the AAOS Position Statement on Fragility Fractures, the Women's Musculoskeletal Health Section of the AAOS Research Agenda, and the AAOS Research Priorities on Osteoporosis and Bone Health. Complimentary copies of the National Osteoporosis Foundation's "Physician's Guide to Prevention and Treatment of Osteoporosis" and the "Health Professional's Rehabilitation Guide to Osteoporosis" will also be available. These materials demonstrate the important role that orthopaedists can play in women's musculoskeletal health.

SCIENTIFIC EXHIBIT NO. SE088

AAOS Committee on Aging

Increasing Your Knowledge in Geriatric Orthopaedics

Elton Strauss, MD, *New York, NY (n)*
Peter Z. Cohen, MD, Pittsburgh, PA (n)
Susan M. Day, MD, Grand Rapids, MI (n)
Richard C. Fisher, MD, Denver, CO (n)
Abbot Kagan II, MD, Fort Myers, FL (n)
Robert R. Karpman, MD, Sun City West, AZ (n)
Kenneth J. Koval, MD, New York, NY (n)
Charles Weiss, MD, Miami Beach, FL (c, d – Genzyme Biosurgery)
Kathleen C. Buckwalter, PhD, Iowa City, IA (*)

In the year 2000 there were 600 million people over the age of 60. By 2025 this number is expected to reach 1.6 billion and 75% of these people will live in developing countries. The average life expectancy does not reflect the percentage of elderly citizens in the population and thus underestimates the magnitude of the resources necessary for their health care. The annual per capita health care expenditure varies greatly from less than $50 in some African countries to a high of $3724 in the United States. Pressure from the aging population is already straining health care budgets and services around the globe. In the US about 12% of the population is greater than 65-years of age. This group uses 48% of the total annual inpatient hospital days and accounts for about 50% of the Orthopaedic surgical workload. By 2020 this group is expected to increase to 16.5% of the total population or about 54 million people. The Orthopaedic surgical workload is expected to concomitantly increase by 28%. Will there be enough of us with geriatric expertise to meet this demand? The AAOS is addressing this issue through the Committee on Aging and other initiatives. These include symposia and instructional courses, development of a resident curriculum in geriatric medicine, multidisciplinary collaboration with the National Association of Orthopaedic Nurses, the American Geriatric Society and others.

SCIENTIFIC EXHIBIT NO. SE089

AAOS Committee on Infections

Guidelines for the Use of Antibiotic Prophylaxis and Discussion of the AAOS Committee on Infections Advisory Statements

Jerome D. Wiedel, MD, *Aurora, CO (n)*
Jason H. Calhoun, MD, Galveston, TX (n)
Laura J. Prokuski, MD, Madison, WI (n)
L. Scott Levin, MD, Durham, NC (n)
Mark J. Triffon, MD, Columbus, OH (n)
Adelisa Panlilio, MD, Atlanta, GA
Paul D. Holtom, MD, Los Angeles, CA

This exhibit will highlight the committee's work that has generated advisory statements for the prevention of infections. The first statement relates to the prevention of the transmission of bloodborne pathogens with an overview of the strategies intended to reduce the risk of transmitting bloodborne pathogens in a variety of orthopaedic settings. Two advisory statements have been developed for antibiotic prophylaxis recommendations to prevent hematogenous prosthetic joint infections in dental and urologic patients. An advisory statement relating to the emergence of Vancomycin resistant bacteria and specific recommendations to reduce the nosocomial spread of

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

resistant Staphylococci and Enterococci microbes will be presented. A computer monitor with the AAOS web site will be available for demonstrating how to access advisory and position statements and patient educational materials. A presentation of the CDC slide show on the "Prevention of Antimicrobial Resistance in Hospitalized Adults" will also be shown in this exhibit.

SCIENTIFIC EXHIBIT NO. SE090

AAOS Occupational Health and Workers' Compensation Committee

Common Musculoskeletal Disorders and OSHA's Ergonomics Guidelines

Richard E. Strain, Jr, MD, *Davie, FL (n)*
Gunnar B. J. Andersson, MD, Chicago, IL (n)
James Aragona, MD, Clark, NJ (n)
Stanley James Bigos, MD, Seattle, WA (*)
Robert H. Haralson III, MD, MBA, Knoxville, TN (n)
George B. Holmes, Jr, MD, Chicago, IL (*)
Delores K. Kirkpatrick, MD, Atlanta, GA (n)
Randall David Lea, MD, Baton Rouge, LA (n)
D. Allan MacKenzie, MD, Foster City, CA (n)
J. Mark Melhorn, MD, Wichita, KS (n)
Norman Maskowitz, MD, Hallandale Beach, FL (n)
Barry P. Simmons, MD, Boston, MA (n)
Jon B. Tucker, MD, Pittsburgh, PA (n)

The AAOS Occupational Health and Workers' Compensation Committee is charged with identifying occupational hazards for orthopaedic surgeons; developing programs to increase workplace safety; acting as an informational resource to the AAOS Fellowship on occupational health issues; and monitoring and analyzing relevant trends and changes in the various workers' compensation systems and job safety requirements as they apply to orthopaedic surgeons and patients. Workers' compensation patients comprise a significant percentage of a typical orthopaedic surgeon's practice. As such, it is important to be knowledgeable about existing federal ergonomics initiatives as well as current evidence-based research on musculoskeletal disorders (MSDs) commonly seen in the workplace. A good understanding of these issues can help orthopods advise and treat patients who have been injured at work. The purpose of this exhibit is twofold. First, the exhibit will summarize the work of the Occupational Safety and Health Administration (OSHA) with respect to ergonomics. OSHA has developed a four-pronged comprehensive approach to ergonomics designed to quickly and effectively address MSDs in the workplace. The four segments of OSHA's strategy for reducing the occurrence of MSDs in the workplace are the development of industry-specific guidelines, outreach, enforcement, and research. Second, the exhibit will examine carpal tunnel syndrome and low back pain, since these conditions are common causes of disability in the U.S. The exhibit will examine these conditions from an evidence-based standpoint by reviewing the existing evidence and highlighting the risk factors and exposure-response relationship of these conditions to work activities.

SCIENTIFIC EXHIBIT NO. SE091

AAOS Patient Education Committee

An Educated Patient Is Your Best Outcome

Janet Sybil Biermann, MD, *Ann Arbor, MI (b – Oncology Journal)*
Charlotte B. Alexander, MD, Houston, TX (*)
Arnold T. Berman, MD, Philadelphia, PA (n)
Stephen E. Conrad, MD, Daly City, CA (n)
Thomas P. Sculco, MD, New York, NY (n)
Eleby R. Washington, MD, Los Angeles, CA (n)

Patient education is valuable throughout the continuum of musculoskeletal care -- for patients, orthopaedists, orthopaedic nurses and medical administrative staff. New AAOS evidence-based research shows favorable patient education outcomes, and the Academy is a partner to Member orthopaedists who want to build and enhance their own patient education programs. This exhibit presents: EVIDENCE-BASED RESEARCH: Learn conclusions and recommendations of focus group market research guiding new AAOS products and programs, and facts about value of patient education in improving culturally competent care, helping maintain professional competencies and addressing concerns for medical liabilities and patient informed consent. INTERNET-BASED PATIENT EDUCATION: Use live Internet connection to try out AAOS patient education Web site, Your Orthopaedic Connection (http://www.OrthoInfo.org), and sign up for free quarterly e-newsletter to stay informed as new patient education articles are added. PATIENT EDUCATION "HOW TO" KIT: Take home a free Patient Education "How To" Kit with tools and materials to strengthen your medical practice's patient education program. Kit includes sample "Rx for patient education" notepads printed with the Your Orthopaedic Connection Web site address and space for individualized notes and recommendations to patients, informative flyer, table of contents listing all articles on the Web site, and library of printouts of popular articles to copy and share. Also includes injury prevention posters, postcards, brochures, handouts and more materials. QUESTIONS AND ANSWERS: Meet with expert "Orthopaedists On Call" to discuss integrating patient education strategies into orthopaedic practice. Academy staff is also available to help Members locate patient education resources.

PAPERS

PAPER NO. 031

Comparison of Conventional versus Computer Assisted Acetabular Component Insertion

Rolf Georg Haaker, MD, *Brakel, Germany (b – Aesculup)*
James B Stiehl, MD, Milwaukee, WI (n)
Martin Stockheim, Bochum, Germany (n)
Andreas Ottersbach, MD, Brakel, Germany (*)
K Tiedjen, Bochum, Germany (*)
F Rubenthaler, Bochum, Germany (n)

Introduction: This study compared the efficacy of computer aided surgery to place acetabular component orientation in 45 degees abduction, 20 degrees operative anteversion as compared to conventional freehanded techniques. Methods: 73 patients underwent THA with freehand cup insertion were compared with 98 patients using a CT based computer navigation. A post-operative CT scan determined cup position with a validated computer algorithm. Results: Following CAS, cup position was 43∞ (95%CI: 0.97) abd, 22.2∞ (95% CI: 1.72) version. For free-hand, cup position was 45.7∞(95% CI: 9.1∞) abd, and 28.5∞(95% CI: 10.2∞) version. F ratio was 5.56 for abd and 3.67 for version (p<.001) F ratio for the last CAOS position compared to the CT control was 0.30 for abd and 1.55 for version (NSD). Discussion: CAS statistically improved accuracy over freehand methods.

PAPER NO. 032

Factors Influencing Wear Rates After Total Hip Arthroplasty

Robert Hopper, PhD, *Alexandria, VA (a - Inova Health Care Services)*
John M Iskander, III, Alexandria, VA (a – Inova Health Care Services)
Anthony M Young, Alexandria, VA (a - Inova Health Care Services)
C Anderson Engh Jr, MD, Alexandria, VA (a - Inova Health Care Services, e – DePuy, Johnson & Johnson)

Background: Understanding the factors that contribute to polyethylene wear after total hip arthroplasty can help optimize implant selection and post-operative management. Between 1990 and 1999, the Duraloc (DePuy) cup was used for most primary total hip arthroplasties performed at our institution. This study sought to evaluate the effect of implant and patient characteristics on polyethylene wear rates. Methods: We identified 572 Duraloc cups that had minimum 3-year radiographic follow-up and at least 3 follow-up x-rays. The mean follow-up was 6.2 years (range 3-12 years). Using computer-assisted radiographic measurements, two-dimensional head penetration data was used to calculate a linear wear rate for each hip. The effects of implant and patient factors were examined using multiple linear regression techniques. Results: Liners sterilized by gamma-irradiation wore 0.09 mm/yr less than those that were sterilized by non-crosslinking chemical surface treatments. For every additional year of age at the time of surgery, the wear rate decreased by 0.003 mm/yr. For each additional year that gamma-irradiated Hylamer liners were stored in air, the wear rate increased by 0.05 mm/yr. Other factors associated with an increased wear rate included a lateralized liner, male gender and a pre-operative diagnosis of osteoarthritis. Increased body mass index, a ceramic head and barrier packaging of gamma-irradiated liners decreased wear rates. Cup position, polyethylene thickness and femoral head diameter did not have a significant influence on linear wear rate. Discussion and Conclusion: Owing to the large number of hips, we were able to quantify the effect of implant and patient factors on polyethylene wear rates. The substantially decreased wear rate associated with gamma-irradiation was attributed to the sterilization-induced polyethylene crosslinking.

PAPER NO. 033

Early Failures of Elective Primary Total Hip Replacement: Effect of Surgeon Volume

Nizar Mahomed, MD, *Toronto, ON Canada (n)*
Elena Losina, MD, Boston, MA (*)
Jane Barrett, Lebanon, NH (n)
John A Baron, MD, MS, Lebanon, NH (n)
Jeffrey N Katz, MD, Boston, MA (n)

Introduction: Hospital and surgeon volume is inversely associated with perioperative mortality, dislocation and infection rates following total hip replacement (THR). This study evaluated the relationship between hospital/surgeon volume on early failures requiring revision in Medicare beneficiaries in 1995-1996. Methods: We analyzed claims data of 6826 Medicare beneficiaries, who underwent elective primary THR in 1995-1996 in OH, PA and CO. The primary outcome for the analysis was the time between the primary THR and the first revision, after adjustment for sociodemographic and clinical variables. Associations between rates of revisions/surgeon volume were determined by risk ratios after adjusting for hospital volume, patient age, poverty status, gender and comorbidities. We examined whether the effect of surgeon volume on revision rates differed across yearly time intervals. Results: Of patients who had primary THR in 1995-96, 271 (4%) had at least one revision by the end of 1999, 126 (46%) of those occurring within the first year after the surgery. Cumulative rates of revision ranged from 2.3% for primary THR in high volume centers, performed by high volume surgeons to 5.9% for patients who had primary THR performed by low volume surgeons in low volume centers. Further analysis revealed that the effect of surgeon volume was striking in the first year after the surgery (RR: 2.34; 95%CI: 1.47- 3.78) and was not evident in the subsequent years (RR: 1.08; 95%CI: 0.73-1.58). Discussion and Conclusion: Patients of low volume surgeons have considerably higher rates of early failure, especially within the first year following surgery. This study highlights the importance of including surgeon volume among factors that influence referrals for elective THR.

PAPER NO. 034

Iatrogenic Nerve Injury During Primary Total Hip Arthroplasty

Christopher Michael Farrell, MD, *Rochester, MN (n)*
Bryan Donald Springer, MD, Rochester, MN (n)
George John Haidukewych, MD, Rochester, MN (n)
Bernard F Morrey, MD, Rochester, MN (n)

IntroductionThe purpose of this study was to review a large consecutive series of iatrogenic nerve injuries sustained during primary total hip arthroplasty to learn more about the risk factors, outcomes, and prognosis. Methods Between 1970 and 2000, 27,004 consecutive primary total hip arthroplasties were performed at our institution. Forty-seven patients (0.17 percent) with iatrogenic nerve injuries were identified using the complications log of our total joint registry. The average age was forty-nine years (range, twenty-one to ninety years) and all patients were followed until neurologic recovery, death, or a minimum of two years. One patient was lost to follow-up, the remaining forty-six were followed a mean of 74 months (range, two to 246 months). Nerve injuries were classified as complete or incomplete, and only injuries with documented objective motor weakness were included. At follow-up, the extent of neurologic recovery, need for braces, gait aids, or medications for neurogenic pain was evaluated. ResultsThere were twenty-eight complete injuries (seventeen peroneal, ten sciatic, and one femoral) and nineteen incomplete injuries (fourteen peroneal, three sciatic, and two femoral). The preoperative diagnoses of developmental dysplasia of the hip (p=0.0007) or post-traumatic arthritis (p=0.02) were associated with a significantly increased relative risk of iatrogenic nerve injury. There was a strong trend for increased risk of injury for body mass index of greater than thirty (p=0.054) or the use of a posterior approach (p=0.054). At follow-up, nine of twenty-seven (33 per cent) complete palsies and seven of nineteen (37 percent) incomplete palsies fully recovered their preoperative strength. Twenty-one patients required gait aids, and fifteen required permanent use of an ankle-foot orthosis. Five patients required daily medication for chronic neurogenic pain. Discussion and ConclusionIatrogenic nerve injury during primary total hip arthroplasty is uncommon. The large consecutive number of patients studied allowed us to more accurately determine the incidence and specific risk factors for nerve injury. Preoperative diagnosis of developmental dysplasia of the hip or post-traumatic arthritis, the use of a posterior approach, or a body mass index over thirty increased the relative risk of sustaining iatrogenic nerve injury. In sharp contrast to prior literature, the majority of nerve injuries, whether complete or incomplete, did not fully recover.

PAPER NO. 035

Obesity and Perioperative Morbidity in Total Hip and Total Knee Replacement Patients

Robert S. Namba, MD, *Irvine, CA (a – DePuy, Johnson & Johnson, Smith & Nephew, Zimmer)*
Liz Paxton, MA, San Diego, CA (a – DePuy, Johnson & Johnson, Smith & Nephew, Zimmer)
Donald C Fithian, MD, El Cajon, CA (a – DePuy, Johnson & Johnson, Smith & Nephew, Zimmer)
Mary Lou Stone, PT, San Diego, CA (a – DePuy, Johnson & Johnson, Smith & Nephew, Zimmer)

This prospective study evaluated the prevalence of obesity and its impact on perioperative morbidity in primary total hip (THA) and total knee arthroplasty (TKA) patients. While a Body Mass Index (BMI) > 30 is an accepted definition of obese, BMI >35 allows for stratification of TJA patients. 1,071 THA and 1,813 TKA patients (2001-2002) at 18 different hospitals were classified into obese (BMI >35) and non-obese (BMI< 35) groups. We documented medical history and postoperative complication rates up to 1 year post-operatively. Hypothesis: Obesity is risk factor for perioperative morbidity. Mean BMI for obese and non-obese THA groups were 39 (N=126) and 27 (N=945). Mean BMI for obese and non-obese TKA groups were 41 (M=337) and 28 (n=1,476). Obese groups were younger (THA mean=61,TKA=64) than non-obese groups (THA=67; TKA=69) (p<.001). The obese TKA group had more females (75%) than the non-obese group (57%) (p<.001). Preoperative morbidity in the BMI >35 groups included higher rates of diabetes (THA=15% vs 8%, TKA=21% vs 12%) and hypertension (THA=53% vs. 36%;TKA=54% vs 44%) (p<.001). The obese groups had higher post-operative infection rates than the non-obese groups (TKA=1.3% vs. .2%, p=.01; THA=1.3% vs. .3%). Dislocation rates among obese and non-obese THA patients (.6%) were similar (.6% vs. .8%). Using the CDC definition (BMI > 30), the U.S. prevalence of obesity (27%) is similar to our THR patients (29%) and much lower than TKA patient rate (57%), suggesting a strong association between obesity and severe knee arthritis.

PAPER NO. 036

Arterial Injury Associated with Elective Orthopedic Joint Reconstruction

Thomas L Bernasek, MD, *Tampa, FL (n)*
B. Johnson, MD, Tampa, FL (*)
A Miranda, BSN, Tampa, FL (*)
D Bandyk, Tampa, FL (*)
Kenneth A Gustke, MD, Temple Terrace, FL (n)

Introduction: To review the diagnosis and management of arterial injury associated with elective orthopedic joint procedures since this adverse event is uncommon but has the potential for permanent limb injury and litigation. Methods: A retrospective review (1997-2002) identified 17 patients who sustained an arterial injury during an elective orthopedic (knee joint replacement-13, hip surgery-4,) procedure for degenerative osteoarthritis (n=17). Clinical records were reviewed for presenting signs, type of injury, management, and outcome (permanent injury, limb loss, litigation). Results: The incidence of artery injury associated with elective joint replacement/repair was 0.8% (17/2250), highest for knee joint replacement (1.3%). Fourteen patients (82%) had a prior orthopedic procedure at the arterial injury site. Presenting signs included acute ischemia with loss of limb Doppler arterial flow/pulses (13 patients, 76%), intraoperative arterial bleeding (4 patients, 24%), non-healing wound (3 patients, 18%), or limb edema (2 patients, 12%); the diagnosis was delayed (>24 hr) in 4 patients. Arterial thrombosis was the most common abnormality identified (73% of injuries) followed by laceration / avulsion (20%) and pseudoaneurysm development (13%), and involved the iliac-3, common femoral-2, deep femoral-1, superficial femoral-4, popliteal-12, or tibial-5. Concomitant popliteal venous injury was present in one patient. Arterial repair consisted of a vein bypass (n=15, 88%), primary repair (n=3, 18%), thrombectomy (N=2, 12%). One patient (6%) underwent primary above-knee amputation. Pre-existing atherosclerosis was identified in 9 injured arterial segments. Outcomes included death (n=1, septic shock), limb loss (n=3, 18%), and fasciotomies (14.3%). Conclusions: Arterial injury associated with elective orthopedic joint surgery is more common during redo-procedures and in patients with pre-

existing atherosclerosis. Despite arterial repair/bypass, limb morbidity is common and related to pre-existing occlusive disease or extent of arterial thrombosis.

PAPER NO. 037

The Effect of Body Mass Index And Surgical Approach on Post-Operative Limp in Total Hip Arthroplasty

Christopher J Vinton, MD, *Holden, MA (a – Aventis Pharmaceuticals)*
Kami White, MD, Worcester, MA (n)
John Wixted, MD, Somerville, MA (*)
Thomas E Varney, MD, Worcester, MA (*)
James P Waddell, MD, Toronto, ON Canada (n)
Brian F Kavanagh, MD, Greenwich, CT (*)

Introduction: Body mass index (BMI) and operative approach (anterolateral versus posterior) may affect post-operative limp in patients undergoing primary total hip arthroplasty (THA). Materials and Methods: Data was examined from a voluntary questionnaire-based registry. There was complete data (BMI, surgical approach, pre-operative limp and post-operative limp) for 1749 primary THA patients at 3 months and 1341 at 1 year. The operative approach trends from 1995 to 2001 were also examined. Results: The percentage of patients reporting limp was significantly higher in the anterolateral group (67.0 percent) compared to the posterior group (56.1 percent) at three months ($p<.0001$). As BMI increased, there was a significant increase in post-operative limp for all patients with a limp rate of 79.3 percent in the BMI greater than or equal to 40 group compared to 53.8 percent in the BMI less than 25 group ($p<.0001$). At one year, the same relationship was seen, although limp rates decreased in all groups. There was a significant change in operative approach with anterolateral approach accounting for 45 percent in 1995 and 26 percent in 2001. The posterior approach accounted for 52 percent and 67 percent in the respective time periods. Conclusions: Reports of post-operative limping increased with BMI. Obese patients had significantly higher rates of post-operative limping despite improvement from three months to one year in all BMI groups. Additionally, the anterolateral approach group had higher post-op limp rates than the posterior approach group. A significant shift towards the posterior approach can be seen between 1995 and 2001.

PAPER NO. 038

Are Dislocation Rates Higher in Posterior Appraoch to Primary Total Hips?

Wayne Gregory Paprosky, MD, *Winfield, IL (e – Zimmer, Inc.)*
Steven H Weeden, MD, Fort Worth, TX (*)

The dislocation rates after primary hip arthroplasty continue to diminish as improved soft tissue repairs are performed during surgery. Many series report that the dislocation rate after a primary hip arthroplasty utilizing the posterior approach is 2 to 3 times greater than that seen after an anterior approach. The aim of the current study is to present our mid-term results and dislocation rate after primary total hip arthroplasty utilizing the posterior approach and enhanced soft tissue repair of the posterior capsule and short external rotators. METHODS: Since 1994, the senior author has repaired the posterior capsule and the short external rotators to the greater trochanter with non-absorable suture. The repair does not include formal drill holes in the greater trochanter. A review of 945 primary total hips was performed. The average follow-up is 4.4 years (range 2 to 9). the average patient age was 62.3 years (range 36 to 82). RESULTS: The dislocation rate at 6.8 years average follow-up was 0.85 percent (8 patients). Three patients (0.32%) required revision surgery. Two patients dislocated after trauma and were treated non-operatively while the remaining three patients dislocated within the first post-operative year and show no signs of instability at the latest follow-up. No patients were lost to follow-up. DISCUSSION: Many factors affect hip stability after primary total hip arthroplasty. The surgical approach, femoral head size, femoral offset and component position all contribute. Numerous authors continue to report that the posterior approach carries a higher dislocation rate than the anterior approach. The best treatment for post-op dislocation is prevention by careful surgical technique and patient education. We feel that the correct orientation of the components and an enhanced soft tissue repair results in an extremely low dislocation rate following the posterior approach in primary total hip arthroplasty.

PAPER NO. 039

The Influence of Stem Size on the Outcome of Primary Total Hip Arthroplasty with Extensively Porous Coated Femoral Components

Vivek Mohan, MD, *Alexandria, VA (a- Inova Health Care Services, e – DePuy, Johnson & Johnson)*
Tim Walde, MD, Alexandria, VA (a- Inova Health Care Services, e – DePuy, Johnson& Johnson)
Jarrod Nagowski, Alexandria, VA (a- Inova Health Care Services, e – DePuy, Johnson& Johnson)
C Anderson Engh Jr, MD, Alexandria, VA (a- Inova Health Care Services, e – DePuy, Johnson & Johnson)
Charles A Engh Sr, MD, Arlington, VA (a- Inova Health Care Services, c, d, e – DePuy, Johnson & Johnson)

We identified 1545 hips that had a primary cementless total hip arthroplasty with an extensively porous coated femoral component, minimum two year follow-up, and had completed a patient questionnaire. 23.5% (363) femoral components were small diameter (9,10.5, or12 mm), 68.4% (1057) were standard size (13.5, 15, or 16.5mm), and 8.1% (125) were large diameter (18, 19.5, or 21mm) components. Our purpose was to evaluate the outcome based on stem size. The hypothesis was that patients with larger stems would have more failures either because of reoperation, loosening, or pain. 15 year survivorship free of femoral reoperation was 97.9 plus or minus 4.2%, 98.9 plus or minus 0.8%, and 96.5 plus or minus 3.1% for the large, standard and small stems respectively. 7.5% (116) either had a reoperation or a loose component. This included 4.8%(6), 5.1%(54), and 15.4%(56) of the hips in the large, standard and small stems sizes respectively.The questionnaire allowed patients to specify the severity and location of pain separately in the remaining 1429 hips. 5%(6), 2.2%(22), and 1.6%(5) of the hips with large, standard and small stems were dissatisfied with their hip and had activity limiting pain. The most common pain location was the greater trochanter. 2.4%(3), 4.5%(47), and 3%(11) of the hips with large, standard and small stems had activity limiting pain in the thigh.Patients with large diameter extensively porous-coated femoral components were no more likely to be revised, loose, or have activity limiting pain. In particular, patients with large diameter stems are no more likely to have thigh pain.

PAPER NO. 040

◆Efficacy of Extended Thromboprophylaxis With Fondaparinux on Secondary Measures of Thromboembolism

Louis M Kwong, MD, *Beverly Hills, CA (a, b – Organon Sanofi – Synthelabo)*
Bengt I Eriksson, MD, Goteborg, Sweden (e – Sanofi-Syntyhelabo)
Michael Rud Lassen, MD, Hillroed, Denmark (e – Mitsubishi Pharma, Sanofi- Synthelabo, Borstal Myco Squibb)

INTRODUCTION: The most clinically relevant primary efficacy endpoint in trials of thromboprophylaxis remains debated. In the PENTHIFRA-PLUS trial, pre-defined secondary endpoints were evaluated after surgery for hip fracture: deep vein thrombosis (DVT), proximal DVT, combined proximal DVT and/or pulmonary embolism (PE), and symptomatic VTE. METHODS: All patients received fondaparinux 2.5 mg once daily for 7 days after surgery, and 656 patients were randomized double-blind to receive placebo or to continue to receive fondaparinux for 19 to 22 additional days. The primary efficacy outcome was VTE defined as DVT detected by mandatory bilateral venography, documented symptomatic DVT or PE at the end of the treatment period. We also measured other major thrombotic events, namely all DVT, proximal DVT, proximal DVT and/or PE, and symptomatic VTE. RESULTS: Extended prophylaxis with fondaparinux significantly reduced VTE rates (3/208, 1.4 percent) vs placebo (77/220, 35.0 percent, P < 0.001, relative risk reduction: 95.9%) without increasing clinically relevant bleeding. Fondaparinux was also significantly more effective than placebo in all secondary endpoints considered: DVT 3/208 (1.4%) vs 74/218 (33.9%, P < 0.001); proximal DVT: 2/221 (0.9%) vs 35/222, (15.8, P < 0.001); combined proximal DVT and/or PE: 2/221, (0.9) vs 38/224 (17.0, P < 0.001). Most importantly, the extended administration of fondaparinux significantly reduced the incidence of symptomatic VTE (1/326, 0.3%) compared with placebo (9/330, 2.7% P = 0.021, relative risk reduction: 88.8%). DISCUSSION: Extended prophylaxis with fondaparinux up to 4 weeks after surgery was significantly more effective than placebo on all endpoints evaluated, including symptomatic VTE.

PAPER NO. 091

Wear and Osteolysis in Modular and Non-Modular Uncemented Acetabular Cups

Alejandro M Gonzalez Della Valle, MD, *New York, NY (n)*
Edwin P Su, MD, New York, NY (n)
Adriana Zoppi, Rome, Italy (n)
Timothy M Wright, PhD, Stamford, CT (*)
Thomas P Sculco, MD, New York, NY (n)
Eduardo Agustin Salvati, MD, New York, NY (n)

Introduction. Wear of the polyethylene liner of modular cementless cups occur at the articulating surface and at the backside. Preassembled cups only wear at the articulating surface. It is the purpose of this study to compare the wear at intermediate follow-up (5 to 8 yrs) of the Trilogy cup which has a modular liner assembled at the time of surgery and the Implex cup in which the liner is preassembled at the factory. Materials and Methods. Sixty-three patients (65 hips) with a Trilogy cup and 64 patients (65 hips) with an Implex cup were matched paired for sex (63% females), age (mean: 66 years, range: 36-87), height (mean: 166 centimeters, range: 146–190), weight (mean: 77 kilograms, range: 46-163), and diagnosis (osteoarthritis). All patients had a cemented stem with a 28-millimeters head and a successful clinical and radiographic result. After an average follow-up of 5.82 years (range: 5 to 8) radiographs were studied by one independent observer to determine the total penetration, utilizing the Livermore technique (95%CI ±0.06 mm), and the presence of osteolysis. Results. The average total wear in the Trilogy group was 0.47 millimeters (range 0-1.95), and in the Implex cup 0.43 millimeters (range 0-1.45) (p>0.99). One patient in each group presented periacetabular osteolysis (p>0.99). Twenty one patients with Trilogy cups and 27 with Implex presented reabsorption of the calcar (p=0.28). Discussion: After a minimum follow up of 5 years, patients with a modular Trilogy cup, which may potentially produce backside wear, did not present a higher prevalence of periprosthetic osteolysis, when compared to a group with a non-modular cup.

PAPER NO. 092

Do Modular Femoral Components Impact Acetabular Impact Acetabular Component Performance?

John C Clohisy, MD, *Saint Louis, MO (e – Zimmer)*
Lloyd Johnson, MD, Indianapolis, IN (*)
Yoon-Je Cho, MD, Saint Louis, MO (*)
Sang-Min Lee, MD, Saint Louis, MO (*)
William J Maloney MD, Saint Louis, MO (n)

Purpose: We analyzed midterm radiographic results of primary cementless total hip replacements performed with a modular femoral component. Methods: Radiographic analysis was performed on 79 hips (68 patients) with a modular S-ROM femoral stem. An Arthropor (41 hips) or a Harris-Galante (38 hips) acetabular component fixed with screws was used in each case. The average patient age was 51 years and the mean follow-up 7.3 years. Results: Sixteen (20 percent) of the 79 acetabular components have failed at an average of 6.9 years. Eleven of these failed components were Harris-Galante and five were Arthropor. Nine had a re-operation for polyethylene wear and acetabular osteolysis associated with a well-fixed acetabular shell. Three had an acetabular revision for aseptic loosening and osteolysis. The other four acetabular components are pending re-operation; three for aseptic loosening and one for polyethylene wear and osteolysis. Ten (16 percent) of the remaining 63 acetabular components have associated osteolysis but are stable. The mean polyethylene wear rate was 0.17 mm/year. All 79 femoral components were stable and none have required revision for loosening or lysis. Proximal femoral osteolysis was present in 9 (11 percent) cases primarily in Gruen zone I. Conclusion: In this series of primary total hip replacements the S-ROM femoral component demonstrated excellent fixation and survivorship. Nevertheless, we observed a high rate of acetabular osteolysis, aseptic acetabular component loosening, and a high mean polyethylene wear rate. This raises concern about potential third body wear with this modular femoral component in primary THA.

PAPER NO. 093

Corrosion of Modular Titanium-Alloy Femoral Stems in Cementless Primary and Revision Hip Replacement

Robert M Urban, *Chicago, IL (n)*
Joshua J Jacobs, MD, Chicago, IL (a – Zimmer Inc, Wright Medical)
Jeremy Gilbert, PhD, Chicago, IL (*)
William J Maloney MD, Saint Louis, MO (n)
Nadim Hallab, Chicago, IL (*)

Crevice corrosion of titanium-alloy femoral stems has been rarely reported in association with pain and aseptic loosening of cemented hip replacements. We hypothesized that crevice corrosion might also occur with cementless titanium-alloy components when the stems were modular in design. A total of 14 (8 primary and 6 revision) modular, cementless, titanium-alloy femoral stems (S-ROM, Johnson and Johnson) were removed at revision surgery from 14 patients (mean age 56 yrs.) after a mean of 41 months. The reason for removal was femoral lossening (3), acetabular loosening (3), pain (3), recurrent dislocation (2), infection (2), or osteolysis (1). The stems and periprosthetic tissues were studied by light and electron microscopy, microprobe analysis, electron diffraction, and Raman spectroscopy. Corrosion of the proximal femoral stem and modular sleeve was absent in 4 stems, minimal in 4, moderate in 5 and severe in 1. Corrosion was characterized predominately by etching and pitting of the metal at the level of the proximal sleeve. Thick deposits of solid corrosion products consisting of titanium oxides were found adherent to the stem at the sites of corrosion and as 0.3 to 200 micrometer particles in the periprosthetic tissues within histiocytes and multinucleated giant cells. The generation of solid products of corrosion adds to the particulate burden of the periprosthetic tissues and may accelerate wear by a third-body mechanism. Both of these features can potentiate the development and progression of osteolysis. In addition, corrosion of modular femoral stems can increase the potential for structural failure of the device.

PAPER NO. 094

Assessment and Interpretation of the Early Wear Rates for Marathon Crosslinked Polyethylene Liners

Robert Hopper, PhD, *Alexandria, VA (a – Inova Health Care Services)*
Anthony M Young, Alexandria, VA (a – Inova Health Care Services)
Karl F Orishimo, MS, Alexandria, VA (a – Inova Health Care Services)
James P McAuley, MD, Alexandria, VA (a – Inova Health Care Services, e – DePuy, Johnson & Johnson)

Introduction: With the promise of substantially reducing wear, several manufacturers have introduced highly crosslinked polyethylene liners. In 1999, we began using Marathon liners that were crosslinked with 5.0 Mrad of gamma-irradiation. We also continued to use non-crosslinked Enduron polyethylene liners. This study reports the early wear data from these cases. To evaluate the significance of early radiographic wear data, we also examined the relationship between early and late wear rates among 128 porous-coated cups with long-term follow-up. Methods: Using computer-assisted methods, we measured femoral head penetration on serial x-rays. For cases with minimum 2-year radiographic follow-up, early wear rates were calculated using a linear regression based on at least 2 annual follow-up x-rays. A regression using at least 3 x-rays obtained after 3-year follow-up was used to calculate long-term wear rates. Results: For the 128 hips with long-term follow-up, the mean wear rate (0.10 mm/yr) based on early follow-up was similar to the mean long-term rate (0.12 mm/yr). Based on mean 3.1 year follow-up data and excluding outliers, 96 Marathon polyethylene liners are wearing at a mean rate of 0.07 mm/yr while 89 non-crosslinked Enduron liners are wearing at a rate of 0.18 mm/yr ($p < 0.001$). Discussion and Conclusion: Early wear rate data can be used to predict the mean long-term wear rate for a population. While Marathon liners are wearing at less than half the rate of non-crosslinked polyethylene liners based on early clinical follow-up, the reduction in wear is more modest than in vitro studies have predicted.

PAPER NO. 095

Short-Term In Vivo Wear of Marathon Crosslinked Polyethylene

Christian Heisel, MD, *Los Angeles, CA (*)*
Thomas P Schmalzried, MD, Los Angeles, CA (a – LAOK Foundation, c - DePuy)
Mauricio Silva, MD, Los Angeles, CA (n)
Mylene A Dela Rosa, BS, Los Angeles, CA (n)

Introduction: Crosslinked polyethylene (PE) was developed to reduce volumetric wear. Hip simulator studies have shown promising results. This study evaluated the short-term in vivo wear of a moderately crosslinked PE. Material and Methods: In vivo wear was measured in two different groups of patients after total hip replacement surgery. Thirty-five patients received a crosslinked PE liner (Marathon, DePuy) and 24 patients a conventional non-crosslinked PE insert (Enduron, DePuy). Wear rates were measured on radiographs and compared to patient and implant related factors, including patient activity assessed by a computerized two-dimensional accelerometer (Stepwatch, Cyma, Seattle). Results: Patients with crosslinked PE showed an average volumetric wear rate of 17 mm3/year (range: 0-70 mm3/year, SD= 19 mm3/year). The group with the conventional PE showed a mean wear rate of 88 mm3/year (range: 5-284 mm3/year, SD= 79 mm3/year). Wear in the crosslinked PE group was 81 percent lower than in the conventional PE patients (p: 0.00001). Accounting for differences in patient activity, the adjusted wear rates per million cycles and 70 kg patient weight were 14 mm3 (range: 0-52 mm3, SD=16 mm3) and 53 mm3 (range: 2-191 mm3, SD= 46 mm3), a 73 percent reduction. No other factors were identified that influenced the wear rate other than the type of PE. Discussion: Recognizing that the creep contribution to linear penetration is similar with both polymers during the first two years, the results of this study are promising. The in vivo wear reduction with this crosslinked PE is consistent with the predictions of previous hip simulator studies.

PAPER NO. 096

Metal-on-Metal vs. Metal-on-Polyethylene Bearings in Hip Arthroplasty:A Matched Case-Control Study

Doug Naudie, MD, *Alexandria, VA (n)*
Christopher Paul Roeder, MD, Berne, Switzerland (n)
Javad Parvizi, MD, Philadelphia, PA (n)
Daniel J Berry, MD, Rochester, MN (a, c – DePuy)
Stefan Eggli, MD, Bern, Switzerland (*)
Andre Busato, MD, Bern, Switzerland (*)

Introduction: This study was performed to investigate the hypothesis that metal-on-metal (M-M) bearings reduce the risk of component loosening when compared with metal-on-polyethylene (M-PE) bearings in total hip arthroplasty (THA). Methods: A matched case-control study was conducted from a computerized joint registry database of over 58,000 THAs. Cases were patients who had undergone primary THA using either a second-generation M-M or M-PE bearing and had documented radiographic aseptic loosening of the stem or cup. Controls were patients who had no documented component loosening. Cases and controls were matched by gender, age, diagnosis, hospital, operation date, length of follow-up, stem and acetabular design. Odds ratios with 95% confidence intervals (CI) were determined to identify the risk of component loosening for either bearing surface. Results: 412 cases and 1,268 controls were identified. M-M had been used in 14.1% of cases and 19.4% of controls. M-PE had been used in 85.9% of cases and 80.6% of controls. Compared to the reference of 1.0 for M-PE, the odds ratio for stem and/or cup loosening of M-M was 0.377 (CI: 0.121-1.175; p=0.093). The odds ratio for stem loosening only was 0.305 (CI: 0.065-1.435; p=0.133), and for cup loosening only was 0.454 (CI: 0.082-2.515; p=0.366). No statistically significant differences were identified. Conclusion: M-M bearings demonstrated a lower risk of component loosening than M-PE bearings, however, this was not statistically significant. This data suggests that the better wear characteristics of M-M bearings may reduce loosening rates, but this may not be statistically significant.

PAPER NO. 097

Serum Metal Levels after Bilateral Metal-on-Metal Total Hip Arthroplasty

Paul T H Lee, MD, *Leicester, United Kingdom (n)*
Michael T Clarke, MD, Syracuse, NY (n)
Arvind Arora, Cambridge, United Kingdom (*)
Richard N Villar, MD, Cambridge, United Kingdom (*)

Introduction. Metal-on-metal (MOM) total hip replacement (THR) has been associated with elevated serum metal levels and has raised concerns over long tern side effects. Considering that the risks may be related to the level of these ions in the body, we compared the serum cobalt and chromium ion levels in patients with unilateral versus bilateral 28 mm diameter MOM THR. MethodsFrom our database, we identified 108 patients with Ultima (Johnson and Johnson, Leeds) MOM THR with 28 mm bearing made of cobalt-chromium alloy. Of these, 11 patients with bilateral THR were prospectively matched to 11 patients with unilateral THR by date after surgery, activity level and body mass. Blood serum was taken with full anti-contamination protocols and serum analysed via inductively coupled plasma mass spectrometry. ResultsThe serum cobalt ion level after unilateral MOM THR was 4.4 times normal (median 22 nmol/L, range 15 to 37 nmol/L) compared to 8.4 times normal (median 42 nmol/L, range 19 to 221 nmol/L) for bilateral MOM THR (p=0.001). The serum chromium ion level after unilateral MOM THR was 3.8 times normal (median 19 nmol/L, range 2 to 35 nmol/L) compared to 10.4 times normal (median 52 nmol/L, range 19 to 287 nmol/L) for bilateral MOM THR (p=0.04). Conclusions This study has shown that the serum cobalt and chromium ion levels in patients with bilateral MOM THR are significantly higher than those in patients with unilateral MOM THR. With levels of up to 50 times the upper limit of normal, this finding may be relevant to the potential development of long-term side effects.

PAPER NO. 098

Risk of Metal Ion Toxicity in Small and Large Bearing Metal-on-Metal Hip Arthroplasty

Paul T H Lee, MD, *Leicester, United Kingdom (n)*
Michael T Clarke, MD, Syracuse, NY (n)
Arvind Arora, Cambridge, United Kingdom (*)
Richard N Villar, MD, Cambridge, United Kingdom (*)

Metal-on-metal (MOM) total hip arthroplasties are associated with elevated serum metal ion concentrations and have raised concerns about long-term side effects. One potential modifier of ion release is bearing diameter. Resurfacing MOM bearings have a large surface area available for corrosion compared to the 28 mm total hip replacement (THR) but may benefit from improved lubrication and reduced production of corrodible wear debris. We compared the level of ion release in patients after large bearing MOM hip resurfacing arthroplasty with patient after small bearing MOM THR. We measured the serum cobalt and chromium levels from 22 patients with large bearing diameter MOM hip resurfacing arthroplasty (Cormet 2000 and Birmingham Hip Resurfacing) and compared them to the serum cobalt and chromium levels of 22 patients with small bearing diameter (28 mm) MOM THR (Ultima). Patients were prospectively matched for activity level, body mass and date after surgery at blood sampling. All were at least 6 months after surgery.We found the median cobalt and chromium levels after hip resurfacing arthroplasty to be 7.6 times normal (median 38 nmol/L, range 14 to 144 nmol/L) and 10.5 times normal (median 53 nmol/L, range 25 to 165 nmol/L) respectively. This is compared to 4.4 times normal (median 22 nmol/L, range 15 to 87 nmol/L) for cobalt and 3.8 times normal (median 19 nmol/L, range 2 to 58 nmol/L) for chromium after 28 mm MOM THR (p=0.0021 and p<0.0001). We concluded that large diameter MOM bearings result in greater release of cobalt and chromium ions than do small diameter MOM bearings. This may be of relevance when the potential side-effects of long-term exposure to elevated these metal ions is considered.

PAPER NO. 099

US Experience with Alumina Ceramic-Ceramic THA. An FDA/IDE Study

Stephen B Murphy, MD, *Roxbury Crossing, MA*
(e – Wright Medical Technology)
Benjamin E Bierbaum, MD, Boston, MA (*)
Jonathan P Garino, MD, Philadelphia, PA
(a – Wright Medical Technology)
William R Kennedy, MD, Sarasota, FL (*)
Richard Edward Jones, MD, Dallas, TX
(e – Wright Medical Technology)
Eric L Hume, MD, Wynnewood, PA
(a, b – Wright Medical Technology)
Kristaps J Keggi, MD, Waterbury, CT
(a – Wright Medical Technology)
Kenneth J. Kress, MD, Atlanta, GA
(a – Wright Medical Technology)

Introduction. Alumina ceramic-ceramic articulations in THA may address the common problems UHMWPE wear debris and debris-associated osteolysis. The current study reviews the results of an FDA-IDE study of alumina ceramic-ceramic THA. Methods. 1620 ceramic-ceramic THA were implanted (Ceramic TRANSCEND® Hip System, Wright Medical Technology, Inc.) were implanted at 12 centers in the US from April, 1997 to February, 2003 and studied prospectively (Ceramic TRANSCEND® Hip System, Wright Medical Technology, Inc.). Of these, 580 hips were followed for a minimum of 24 months (range 24 to 56.6 months), mean 30.5 months. Patients were aged 53 +/- 12 years (range 18-79 years). Results. Of the 1620 THA's, reoperations included failure of osseointegration of an uncemented femoral component or loosening of a cemented femoral component in 6 (0.4%) and of the acetabular component in 3(0.2 %). 6 hips were revised for recurrent instability (0.4%). Of these, one had a chipped liner at revision (0.06%). 1 hip was revised for impingement-associated wear without lysis (0.06%). 3 hips were revised for infection. 3 hips were reoperated for inadvertent mismatch of bearing diameter. There have been no other cases of wear and no cases with osteolysis. Discussion and Conclusion. Results of this prospective FDA/IDE demonstrate that the alumina ceramic-ceramic bearings are reliable and show very few early problems. The bearings continue to demonstrate the absence of osteolysis in this series of up to 6 year follow-up.

PAPER NO. 100

THA: Alumina-on-Alumina Ceramic Bearings: 4-7 Year Follow-up

James A D'Antonio, MD, *Moon Township, PA*
(a, b, e – Stryker)
William N Capello, MD, Indianapolis, IN (e – Stryker)
Michael T Manley, PhD, Ridgewood, NJ
(a, d, e – HowMedica Osteonics)
Benjamin E Bierbaum, MD, Boston, MA (*)

Introduction: Alumina ceramic bearings have known superior wear resistance, lubrication, scratch resistance, and do not carry a risk of metal ion release. A US IDE clinical trial began in 1996 utilizing new improved alumina ceramic materials and implant design. Methods: 514 hips were implanted in a multicenter, prospective, randomized study comparing alumina-alumina ceramic to a control cobalt chrome-polyethylene bearing. Two-thirds (349 hips) received ceramic bearings and one-third (165 hips) control bearings. A second arm of the study (1999-2000) implanted 209 hips with the Trident" alumina insert. This design features a pre-assembled outer metal sleeve that increases the strength of ceramic, and protects against intraoperative chipping. Results: In the first study arm, (mean follow 48 months) there is no significant difference in clinical performance between the two patient cohorts and no ceramic bearing failures. In the second study arm, Trident", patient demographics as well as clinical and radiographic results (mean follow 36 month) are consistent with the original cohort patients. There are no ceramic fractures or alumina bearing failures. Discussion and Conclusion: The patients in these study groups had a mean age of 52 years and noninflammatory hip disease. They are reported to have excellent clinical results with mean HHS of 96 and 98% patient satisfaction. This new alumina-alumina ceramic bearing provides for a safe and effective option for the young and active patient population.

PAPER NO. 201

Severe Femoral Bone Loss in Failed THA: Revision with a Modular, Extensively Coated Component

David Kent DeBoer, MD, *Nashville, TN (*)*
Michael J Christie, MD, Nashville, TN (a – Biomet)
J Craig Morrison, MD, Nashville, TN (a – Biomet)
Martha Brinson, RNCS, Nashville, TN (n)

INTRODUCTION: Achieving stable fixation in femoral revision with significant bone deficiency requires the ability to independently match diaphyseal and metaphyseal anatomy. This ability allows the surgeon to bypass the compromised bone of the proximal femur and achieve stable fixation on structural host bone. If bone loss is extensive, this is extremely difficult with non-modular devices. This study reports the outcomes of revision total hip arthroplasty with a modular, extensively-coated revision stem for severe bone loss. METHODS: 84 patients (86 hips) were revised using the Mallory-Head Modular Calcar (MHMC) femoral implant (Biomet). Thirteen patients died prior to minimum follow-up and 6 were lost to follow-up, leaving 67 hips (65 patients) with mean follow-up of 5.7 years (range, 3 to 7 years). Preoperative bone deficiency was classified according to the methods of Paprosky and the AAOS. RESULTS: Clinically, post-operative Harris Hip Scores improved to a mean of 82 points (range, 38 to 100 points). Radiographically, 94 per cent of hips are stable according to the criteria of Engh. Complications included one hip that was re-operated to reattach a displaced greater trochanter; two hips re-revised for multiple dislocation; and three post-operative periprosthetic fractures treated with open reduction internal fixation. One stem was exchanged for a custom MHMC for a periprosthetic fracture between a total hip and total knee. No other stem has been removed. DISCUSSION AND CONCLUSION: The MHMC component predictably obtains stable fixation and addresses the most catastrophic cases of femoral bone loss. .Awaiting long-term follow-up, this series demonstrates excellent mid-term results

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

PAPER NO. 202

Mid to Long-Term Results of Revision THR using Cemented, Collarless, Double-Tapered Femoral Stems

Donald Howie, PhD, *Adelaide, Australia (n)*
James Wimhurst, PhD, Cambridge, United Kingdom (a – Zimmer, Stryker Howmedica Osteonics)
Margaret A McGee, BSc, South Australia, Australia (n)
Tania Knight, BS, Adelaide, Australia (n)
Shah Badrul, Adelaide, Australia (*)

Introduction: This study reviews the mid- to long-term results of revision THR with cemented, collarless double-tapered (CCDT) stems. Methods: We prospectively studied 195 revisions of femoral stems, in 187 patients, using 85 standard and 110 long Exeter or CPT CCDT stems. Results were analysed according to the stem length, extent of preoperative deficiency (Paprosky I:II:IIIa:IIIb:IV=4:19:44:21:12%) and intra-operative bone loss. Post-operative radiographs were independently analysed for loosening and stress shielding. Risk factors of poor outcome were examined by multivariate logistic regression. Results: The median follow-up was 6 years (2 - 17 years) with 59 patients having died (30%) and no cases lost to follow-up. There were 4 stem re-revisions for sepsis (2%), 3 for aseptic loosening (1.5%) and 3 for instability (1.5%). The survivorship to femoral re-revision for aseptic loosening at 8 years was 95% (95%CI=86-100%) for standard stems and 95% (85-100%) for long stems (p=0.83). Migration was less than 5 mm in unrevised stems. Survivorship and outcomes was independent of the Paprosky grade. Conclusions and Discussion: Advantages of using a CCDT stem included immediate fixation allowing full weight bearing without the risk of early subsidence, minimal bone removal from reaming and the ability to proceed in the presence of femoral angular deformity without the need for osteotomy. The CCDT stems were inexpensive, major stress shielding was not seen and thigh pain was not a problem. CCDT long stems are suitable for most femoral revisions in middle-aged and older patients without severe segmental deficiency.

PAPER NO. 203

Cemented Femoral Revision in Total Hip Arthroplasty: Results at a Mean Ten-Year Follow-up

Ramin Mehin, MD, *North Vancouver, Canada (n)*
Chris Haydon, London, Canada (n)
Robert Stephen Burnett, MD FRCSC, St Louis, MO (n)
Cecil H Rorabeck, MD, London, Canada (a, c – Smith & Nephew)
Robert Barry Bourne, MD, London, Canada (n)
Richard W McCalden, MD, London, Canada (n)
Steven J MacDonald, MD, London, Canada (n)

Background: Cemented femoral revision total hip arthroplasty has been associated with early mechanical failure by aseptic loosening. This study was performed to determine the long-term survival of cemented femoral revision arthroplasty and to identify factors predictive of failure. Methods: One hundred and twenty-nine cemented femoral revision cases were reviewed to determine component survival. Ninety-seven hips with a minimum follow-up of five years were included for survival analysis and tests of significance. Harris Hip scores were used to quantify clinical outcomes. Complete radiographic series were reviewed. Kaplan-Meier survival curves were calculated. Clinical and surgical factors were analysed to determine if they were predictive of failure. Results: Individual Harris Hip scores improved to a mean of 71 at the most recent follow-up from a mean preoperative score of 52 ($p<0.001$). Kaplan-Meier survival at 10 years was 91% with revision for aseptic loosening of the femoral component as the endpoint and 71% with mechanical failure as the endpoint. Patients older than sixty years experienced greater long-term component survival and less pain than patients younger than sixty years ($p<0.05$). Good quality post-operative cement mantles were associated with better long-term radiographic fixation ($p<0.001$). Poor femoral bone quality was significantly associated with an increased rate of re-revision for aseptic loosening ($p=0.021$). Conclusions: Revision THA using a cemented femoral component remains an option in selected patients with an acceptable ten year survival rate and fair radiographic fixation. Patients demonstrated acceptable clinical outcomes (Harris Hip scores) at ten years and few experienced significant pain. The best results may be achieved in older patients (¡_60 years) with adequate bone stock and by using modern cementing techniques.

PAPER NO. 204

Femoral Impaction Grafting in Revision Total Hip Arthroplasty: 2-15 Year Follow-Up of 540 Cases

Tony Lamberton, MD, *Auckland, New Zealand (a, b – Stryker HowMedica Osteonics)*
John Anthony Forsyth Charity, MD, Exeter, United Kingdom (a, b – Stryker)
Patrick Joseph Kenny, FRCSI, Dublin, Ireland (n)
John Timperley, Exeter, United Kingdom (a, b – Stryker)
Graham Allan Gie, MD, Exeter Devon, United Kingdom (*)

Introduction: Impaction bone grafting in conjunction with a cemented polished double-taper stem as a technique for revision of the femoral component was introduced in 1987 at our institution. Methods: As at January 2000, 540 cases in 487 patients had been performed by multiple surgeons. All procedures have been studied prospectively, and there are no patients lost to follow-up. We present the survivorship and outcome data for these patients. Results: Survivorship at 15 years is 90.6 percent. Averaged clinical scores taken pre-operatively, 2 years post-operatively, and at latest follow-up show marked and sustained improvement: Charnley Pain 2.7, 5.5, 5.3; Charnley Function 2.1, 4.1, 3.6; Charnley Range of Motion 4.0, 5.4, 5.3; Harris Pain 19, 38, 36; Harris Function 18, 32, 28; and Oxford Hip Score 41, 22, 25.There have been 45 failures (8.3 percent) at an average 7.6 year follow up (range 2.6 – 15.3 years). Technical error contributed to 13 of the 24 non-infective complications, but with improved technique plus the addition of long stemmed impaction grafting, there have been no technical errors since 1996. Conclusion: Our results show that revision of the femoral component with impaction bone grafting is a reliable and durable technique with an acceptably low complication rate with excellent survivorship at up to15 years.

PAPER NO. 205

Impaction Allografting with Cement for Revision of the Femoral Component

Joshua M Hickman, MD, *Bountiful, UT (n)*
Richard A Berger, MD, Chicago, IL (n)
Aaron Glen Rosenberg, MD, Chicago, IL (*)
Joshua J Jacobs, MD, Chicago, IL (*)
Hany Elrashidy, BA, Chicago, IL (*)
Wayne Gregory Paprosky, MD, Winfield, IL (*)
Jorge O Galante, MD, Chicago, IL (*)

Impaction allografting, tapered stems, and fully coated stems have been used in the treatment of complex femoral revisions. We report the results of impaction grafting. 30 patients had femoral revision using impaction allografting with a Harris precoat stem. Impaction grafting was performed in younger patients where the goal was bone reconstitution or in patients with Paprosky 3 or 4 femoral defects. Mean follow-up was 116months. 10 patients died and all had a functioning prosthesis. No patient was lost. Harris hip scores improved from mean 54 to 82points. Kaplen-meir survival analysis for failure was 81 percent at 116months. Femoral diaphyseal diameter was 19.1mm. Failure rate was 16percent. 4 hips were revised for aseptic loosening and subsidence at 36,72,96, and 117months. 1patient failed due to hematogenous infection at 73months. Subsidence occurred in 4 patients. Complication rate was 66%. In patients with type 3b and 4 femurs, impaction grafting is a viable alternative to porous coated implants or tapered femoral stems with an acceptable revision rate at 10 years. It may be particularly valuable in younger patients where preservation of proximal bone stock is important. However, the complication rate is high.

PAPER NO. 206

Fracture of Extensively Porous Coated Stems

William J Maloney MD, *Saint Louis, MO (n)*
Yoon-Je Cho, MD, Saint Louis, MO (*)
Cecil H Rorabeck, MD, London, ON Canada (a – Zimmer, c – Smith & Nephew)
Wayne Gregory Paprosky, MD, Winfield, IL (c – Zimmer)
Robert L Barrack, MD, New Orleans, LA (e – DePuy, Smith & Nephew)
Miguel E Cabanela, MD, Rochester, MN (c, e – Stryker HowMedica Osteonics)

Purpose: Extensively porous coated stems have become the workhorse in revision THA. As confidence with the ability to obtain diaphyseal ingrowth has grown, these stems are being increasingly used in cases with severe proximal bone loss. The purpose of this study is to report on extensively porous coated stem fractures in cases with minimal or no proximal bone support. Materials and Methods: Fourteen patients (15 hips) were identified with fractured extensively porous coated femoral components. In each case, clinical records and radiographs were reviewed. Patients ranged in age from 44 to 76 years, in weight from 65 to 109 kilograms, and activity level varied. Results: Time from implantation to fracture ranged from 2 to 5 years. Stem diameter ranged from 10.5 to 13.5 millimeters. Clinically, fracture was associated with increased thigh pain. Radiographically, the distal segment appeared bone ingrown while the proximal segment looked loose. These findings were confirmed at revision surgery. Stem analysis revealed a fatigue fracture pattern. Conclusion: It is clear from this data that extensively porous coated stems that are distally potted and ingrown are at risk for fracture when there is little or no proximal bone support. When there is severe proximal femoral bone loss and patient's anatomy dictates the use of a relatively small diameter stem, the surgeon should consider warning the patient about stem fracture risk. Despite the fact that some of these stems may fracture, they represent the best solution for some of these complex problems and their continued use is justified.

PAPER NO. 207

Minimally Invasive Total Hip Arthroplasty Using a Two Incision Technique

Richard A Berger, MD, *Chicago, IL (a, e – Zimmer)*

Introduction: Minimally invasive surgery has the potential for minimizing surgical trauma, pain, and recovery. The first 30 minimally invasive total hip arthroplasties (THA) using a two-incision technique are reported. Methods: A minimally invasive two-incision THA technique, which does not cut any muscle or tendon, was developed. One incision is for acetabular preparation and component placement; the other is for femoral preparation and component placement. Fluoroscopy is used for component preparation and placement. Eighteen procedures were preformed on males, 12 on females. The average age was 54 years (range: 29 to 68). The average follow-up was 25 months (range: 24 to 30 months). No patient was lost to follow-up. Results: There was one complication; one proximal femoral fracture occurred during preparation. No other complications have occurred. There have been no dislocations, no failure of ingrowth, and no re-operations. Radiographically, since fluoroscopy is used during insertion, 91% of the femoral stems have been in neutral alignment (range: neutral to 3° valgus). The abduction angle for acetabular components averaged 45° (range 36° to 54°). The postoperative recovery was carefully tracked. The average time on crutches was 5 days and a cane 8 days. The average time to be off all narcotics was 6 days. The average time to return to work was 8 days. Discussion: Minimally invasive THA show great promise with excellent component placement and a rapid return to function. However, this technique is technically challenging and should only be attempted after proper hands-on training.

PAPER NO. 208

The Effect of Incision Size on Clinical Outcomes and Recovery after Total Hip Arthroplasty with the Antero-lateral Approach

Ormonde M. Mahoney, MD, *Athens, GA (c, e – Stryker HowMedica Osteonics)*
Isao Asayama, MD, Fukuoka, Japan (n)
Tracy Kinsey, RN, Athens, GA (n)

Introduction: In total hip arthroplasty (THA) many surgeons have recently begun using modified approaches that minimize incision size, citing possible benefits of improved clinical outcomes, decreased hospitalization, and faster recovery. This study evaluates clinical outcomes and recovery measures in patients who underwent THA surgery via anterolateral approach through minimum and traditional incisions. Methods: We reviewed all cases (n=102) of uncomplicated, uncemented, primary unilateral THA's that a single surgeon performed via anterolateral approach in 18 months. Surgery was performed through a <10 cm incision in 52 cases and a traditional size (15-20 cm) incision in 50. Patients were blinded to approach type. Radiographic and clinical measures related to efficacy and short term recovery were analyzed. Results: The average hospital stay was 2.95 days and 92% of patients ambulated the day after

surgery. Both the surgeon and anesthetists estimated lower blood loss with minimum size incisions (48.1 ml and 29.5 ml average difference respectively), but otherwise hematological measures, transfusions, operative time, hospitalization time, narcotic usage, rehabilitation, discharge disposition, complications and component placement were not significantly different related to approach. The traditional incision group was significantly heavier (86.6 kg vs. 75.8 kg) and more obese (28.7 kg/m2 vs 26.1 kg/m2). Discussion: Quality of component placement did not appear to be limited by mini-incision approach, however we found no objective evidence that minimal incision size benefited these patients, who were blinded to approach type. Practitioners' perceptions of decreased blood loss with smaller incisions could not be validated by objective means.

PAPER NO. 209

The Mechanics of Minimally Invasive Hip Replacement

Matthew Thompson, *Houston, TX*
(a – Institute of Orthopaedic Research and Education)
Philip Noble, PhD, Houston, TX
(a – Institute of Orthopaedic Research and Education)
Kenneth B Mathis, MD, Houston, TX (*)
Eric Matthew Heinrich, MD, Houston, TX (n)
Sabir Ismaily, Houston, TX
(a – Institute of Orthopaedic Research and Education)

Introduction: Minimally invasive surgery has recently become popular in THR for faster recovery and improved cosmesis. Little is known about the forces imposed on the surgical site, and the deformations to the surrounding tissues during these procedures. In this study, we apply several novel techniques to evaluate the steps in the MIS hip procedure that impose the greatest stress to the surrounding soft tissues. Materials and Methods: Eight hip replacement procedures were performed in fresh cadavers via 6cm incisions using the posterior approach by two experienced joint surgeons. Prior to surgery, a grid of points was tattooed onto the skin to allow monitoring of the motion and deformation of the operative site. At several stages and at the conclusion of each procedure, skin deformation was measured via computer analysis of digital photographs of the incision and grid. During reaming of the acetabulum and femur, the force exerted on each retractor and the pressure exerted between each retractor and the wound edges were measured. Tensile strain along the length of the incision during each stage of the procedure was determined from changes in length between grid points. Results: In procedures in which the acetabular reamer was contacting skin to maintain proper alignment, it contributed significantly more force and compressive stress than the other retractors (reamer force: 104N±12N, avg. retractor force: 40.2N±8.2N, $p<0.01$). The average tensile strain during acetabular and femoral reaming along the incision length measured 141%±9.0% strain, although the only instances of skin perforation occurred near the ends of the incision. In general, the increase in incision length during surgery (1.4±0.1cm) was due to the stretching of the wound area an average of 245% during acetabular preparation, and 263% during femoral preparation. The average strain around the incision perimeter measured 180%. Discussion and Conclusions: Although the exact correlation of skin deformation to soft tissue damage and recovery time is unknown, MIS procedures exert stresses and strains to the surrounding soft tissue not seen during traditional THR. Particular care should be taken to minimize the severe tissue deformation and forces created during MIS surgery.

PAPER NO. 210

The Feasibility and Safety of Outpatient Total Hip Arthroplasty

Richard A Berger, MD, *Chicago, IL (a, e – Zimmer)*

Introduction: As surgical techniques and patient management improve, more procedures are being performed in the outpatient setting. To assess the feasibility and safety of outpatient total hip arthroplasty (THA), a comprehensive perioperative management protocol was developed and implemented. Methods: One hundred consecutive patients were selected and enrolled in this prospective study; this constituted 23% of all patients undergoing THA during this time. The average patient age was 56 years (29-76 years). Preoperatively, the patients attended a teaching class and crutch training. Intraoperatively, regional anesthesia combined with minimally invasive THA technique, which does not cut any muscle or tendon, were used. Postoperatively, patients receive physical therapy and oral analgesia. Results: No intraoperative complications occurred. Ninety-one of the 100 patients chose to go home the day of surgery; 9 patients went home the day after surgery, within 23 hours. All patients were discharged to home. Post-operatively there have been no complications, no readmissions, and no dislocations. All patients were followed for 3 months with none lost to followup. Conclusion: Outpatient total hip arthroplasty can be done safely in selective patients. Currently, 23% of all patients undergoing THA are enrolled in this outpatient protocol; 91% of patients enrolled are discharged the day of surgery. In these selected patients, outpatient THA is safe; readmission and complications after discharge have not been a problem. This comprehensive approach to arthroplasty in the future may make it possible for THA to be done as an outpatient in specialized surgicenters.

PAPER NO. 241

Retroacetabular Osteolysis in Cementless THA: When to Operate?

Ramin Mehin, MD, *North Vancouver, BC Canada (n)*
Xunhua Yuan, Lund, Sweden (*)
Chris Haydon, London, Canada (n)
Kuang-Ying Yang, MD, Singapore, Singapore (n)
Husam Elkassem, BS, London, Canada (n)
Steven J MacDonald, MD, London, ON Canada (n)
Richard W McCalden, MD, London, ON Canada (n)
Robert Barry Bourne, MD, London, ON Canada (n)
Cecil H Rorabeck, MD, London, ON Canada (n)

INTRODUCTION: Problem: The timing of liner exchange for retroacetabular osteolysis in THA remains uncertain. Liner exchange should be done before the shell becomes loose. Purpose: To determine the radiographic quantity of osteolysis that will predict impending loosening of the cementless shell.Hypothesis: Osteolytic areas differ between loose and stable shells.METHODOLOGY: Between 1992 to 2002, 71 cementless shells of the same design were revised at our institution; forty-six were for aseptic retroacetabular osteolysis. Radiographs and a computer-assisted technique were used to quantify osteolytic areas and percent of shell circumference associated with lesions. Implant stability was confirmed intraoperatively. RESULTS: Of 26 stable and 20 loose shells, the average area of osteolysis on AP radiographs showed no significant difference (Stable 591mm2, Loose 630 mm2, p greater than 0.05); whereas, lateral radiographs demonstrated a significant difference (Stable 546 mm2, Loose 837 mm2, p 0.05). The percentage of shell circumference with associated osteolysis on

AP and lateral films demonstrated a significant difference (AP: Stable 60, Loose 75, p 0.042; LATERAL: Stable 49, Loose73, p 0.016). Diagnostic criteria of 50 percent shell circumference associated with osteolysis on AP films has sensitivity 1, specificity 0.27 while the same criteria on lateral films has sensitivity 0.84, specificity 0.54 for shell loosening. CONCLUSION: Percent of shell circumference with surrounding osteolysis appears to be more predictive of cementless shell loosening than the area of osteolysis. When greater than fifty percent of the shell circumference has osteolysis on AP or lateral films, liner exchange is necessary.

PAPER NO. 242

Morbidity of Modular Polyethylene Exchange for Excessive Wear and Osteolysis

William L Griffin, MD, *Charlotte, NC*
(a, b, c, e – DePuy Johnson & Johnson)
Susan Marie Odum, MED, Charlotte, NC (n)
Thomas K Fehring, MD, Charlotte, NC
(a, e – DePuy Johnson & Johnson)
J Bohannon Mason, MD, Charlotte, NC
(e – DePuy Johnson & Johnson)
Thomas H McCoy, MD, Charlotte, NC
(a, b, e – DePuy Johnson & Johnson)

Background: To determine the morbidity associated with treating excessive polyethylene wear and osteolysis with modular exchange of polyethylene liners and femoral heads. Methods: 196 out of 1252 patients were revised for polyethylene wear and osteolysis between 1986 and 2003. 55 of these patients underwent modular polyethylene liner and femoral head exchange with retention of the acetabular and femoral components. Patients were followed until death, revision surgery, dislocation, or last clinical follow up. Average follow up was 27 months. No patient had a dislocation prior to the revision surgery. Results: Postoperative dislocation occurred in 10 of the 55 (18%) patients with 3 patients requiring repeat surgery for recurrent instability. No other significant complications were identified. Two additional patients required subsequent femoral component revision for implant fractures. Average Harris Hip Scores increased from 77 to 93. Thirty-four patients had major osteolysis and 29 of these were treated with bone grafting. 22 patients were revised to smaller heads, improving polyethylene thickness. Four patients were revised to larger heads. 29 patients had no change in femoral head size. Average blood loss was 323 cc. Seven patients required transfusion. There were no statistically significant correlations between dislocation and head size, head/neck ratio or patient demographics. Discussion and Conclusion: Treatment of polyethylene wear and osteolysis with modular polyethylene liners and femoral head exchange is associated with significant risk of dislocation. Defining the morbidity associated with modular exchange will improve the decision making process for the treatment of polyethylene wear and osteolysis.

PAPER NO. 243

Acetabular Deficiency in Revision THA: A Novel Classification and Results of Jumbo Cup Reconstruction

Vijay J Rasquinha, MD, *New York, NY (n)*
Vasilios Mathews, MD, Houston, TX (*)
Chitranjan S Ranawat, MD, New York, NY (n)
Jose A Rodriguez, MD, New York, NY (n)

Purpose: The objectives of this study were to evaluate acetabular bone deficiency in revision THA with a simple classification on the antero-posterior pelvis radiograph and correlate the results of cementless hemispherical porous coated cup and cancellous bone graft reconstruction. Materials:70 acetabular revisions reconstructed employing large 'jumbo' porous coated cups with cancellous allografting were evaluated at a mean follow-up of 9 years (range 8 – 10 years). During this time period 7 additional acetabular reconstructions required impaction grafting, cage reinforcement and cemented cups. Pre- and post-operative measurements of acetabular bone loss and the position of the revision component were performed with respect to a previously described triangle defining the placement and size of an ideal cup. Impaction bone allografting techniques were employed to fill defects. A minimum of 40% implant contact to host bone, especially in the weight-bearing dome region was attained in all cases and a minimum of 2 screws supplemental fixation to the ilium. Clinical evaluation comprised the HSS score and a patient assessment questionnaire (PAQ). Radiographically, cups were examined for filling of defects, ingrowth, graft consolidation, and stability. Results: The mean HSS score improved from 18 to 33 out of a maximum of 40. The mean superior bone defect was 18 mm (range 10 – 25mm) and the mean medial bone defect was 7 mm (range 0 – 22mm). All the cementless acetabular components were bone ingrown with the exception of one stable fibrous union. Allograft incorporation occurred at a mean of 7 months after surgery. Neither the status of Kohler's line nor the Paprosky class correlated with eventual radiographic or clinical results. Conclusion: We present a simple method of evaluation of acetabular bone deficiency on the A-P pelvis radiograph employing a triangle that locates the ideal center of rotation of the hip. Superior bone loss upto 25 mm and medial migration as much as 22 mm has been successfully reconstructed employing impacted, cancellous allograft, large porous coated hemispherical cementless acetabular components and screw fixation with excellent outcomes at intermediate-follow-up. Larger defects necessitate complex reinforced cage reconstruction.

PAPER NO. 244

Use of Jumbo Cups for Revision of Acetabulae with Large Bony Defects

Kenneth A Gustke, MD, *Temple Terrace, FL*
(a, c – Centerpulse Orthopedics)
Thomas L Bernasek, MD, Tampa, FL
(e – DePuy Johnson & Johnson)
Steven Thomas Lyons, MD, Tampa, FL (n)

Introduction: Several methods of treatment are available in the revision of loose acetabular components associated with bone loss. Jumbo cups are the preferred treatment for large acetabular defects with segmental and cavitary defects. By definition, a jumbo cup has a minimum diameter of 62mm in women, 66mm in men, or is greater than 10cm larger than the normal contralateral acetabulum. They are easier to use than cages and

Proper technique is for bone to be moved, not removed. The acetabulum should then accommodate the large shell and maximize the shell host bone contact for long-term biological fixation. They are only contraindicated in acetabulae that lack the superior lateral acetabulum and the posterior column and in irradiated bone. Methods: In a retrospective review of 564 acetabular revisions from 1986-2001, jumbo cups were used in 176 (31%) of the cases. Significant bony deficiencies were present; 60% were AAOS type III (combined cavitary and segmental defects), 69% Paprosky type II and 25% Paprosky type III. The average follow-up was 5.6 years. 9% of patients had expired by 5 years and 36% at 10 years. Summary and Conclusions: There were five revisions; one for infection, one for loosening, and three for recurrent dislocations. The probability of survival of the jumbo cups was 97% at five years and 94% at 10 years.

PAPER NO. 245

Allograft Reinforcement of Massive Acetabular Defects in Revision Hips: A 6 to 9 Year Follow-up

Wayne Gregory Paprosky, MD, *Winfield, IL (e – Zimmer)*
Scott M Sporer, MD, Wheaton, IL (n)

Management of massive acetabular defects in revision hip arthroplasty can be difficult for the reconstructive surgeon. The objective of this work is to determine the clinical and radiographic effectiveness of reconstruction with allograft and ring at a minimum 6 years follow-up. METHODS: Twenty-nine consecutive reconstruction ring and allograft reconstructions in revision hip arthroplasty were evaluated at a minimum 6 years follow-up (range 4 to 7 years). At the time of surgery, all patients had less than 40% host bone present, non-supportive acetabular rims and absent anterior and or posterior column support. Nine cases presented as catastrophic failures of previous acetabular components. The posterior approach was used. Three types of reconstructions rings were used - 18 Osteonics, 8 Depuy and 3 Ganz. The reconstruction rings were rigidly fixated onto allograft and host bone and acetabular components cemented appropriately. Sixteen patients received structural allograft and thirteen received bulk cancellous allograft. D'Aubigne and Postel pain and walking scores were obtained pre and post op and radiographs were analyzed for component migration, hardware fracture or loosening and incorporation of allograft. RESULTS: There were 16 females and 13 males. There was an average of 2.7 revisions prior to these reconstructions. Mean age was 67.5 years (range 35 to 81). Pre-op D'Aubigne and Postel pain and walking scores improved from 2.8 to 7.5 and there was one persistent nerve palsy and one chronic infection. Radiographic results are excellent with the exception of one case of component migration in a patient with previous radiation to the hemi-pelvis. There were two cases of lucencies around screws with non-progression and bone graft incorporation present in all cases. DISCUSSION: Our results indicate that reconstruction with allograft and reinforcement ring provides a stable, reproducible and secure means of reconstructing the most difficult of acetabular bony deficiencies with good results at short term follow-up.

PAPER NO. 246

Structural Allografts for Acetabular Reconstruction

Scott M Sporer, MD, *Wheaton, IL (n)*
Wayne Gregory Paprosky, MD, Winfield, IL (n)
Michael R O'Rourke, MD, Iowa City, IA (*)

The aim of this paper is to determine the fate of cups in the Type IIIA acetabular defects reconstructed with structural allograft and porous coated cups. We will determine if graft resorption leads to failure of reconstruction. METHODS: Between January 1985 and December 1990, we studied 30 consecutive acetabular reconstructions for Type IIIA defects. 29 patients are included in this clinical and radiographic follow-up of 13 to 18 years (average 15.3 years). There were 16 male and 14 female patients. Patients ranged in age from 40-81 years (average 63 years). Previous surgical procedures ranged between 1 and 5 (average 3.2). The reason for revision was as follows: 26 revisions due to aseptic loosening and 4 revisions due to infection. Femoral components revised included 25 cemented components and 3 uncemented compnents. Charnely classification included 24 in Class A, 5 in Class B and 1 in Class C. Bone grafting consisted of frozen distal femoral femoral allografts. RESULTS: Radiographically, there was no evidence of change in cup position. 28 cups had evidence of bone ingrowth; 1 cup was stable in position but failed prior to minimum follow-up. Harris hip scores averaged 26 pre-op and 83 post-op. 16 patients required no assistive devices for ambulation post-op. 7 patients required a cane part time for long distances and 6 patients used a cane full time to assist in ambulation. DISCUSSION: At an average 15.3 years follow-up, only 1 of 29 revisions with strucutural allograft have clinically or radiographically failed. Although difficult to quantitate, no gross resorption of graft has occurred. Cup position has been maintained indicating bone ingrowth of porous cup. We find that acetabualr revision in Type IIIA defects utilizing porous coated acetabular components and structural allograft have held up at an average 15 years follow-up.

PAPER NO. 247

Two to Eight Year Follow-up of Acetabular Cages in Revision Hip Arthroplasty

Michael R O'Rourke, MD, *Iowa City, IA (n)*
Wayne Gregory Paprosky, MD, Winfield, IL (n)
Aaron Glen Rosenberg, MD, Chicago, IL
(a, c, e - Zimmer Inc.)

The purpose of this study was to evaluate the results of cage reconstruction for severe acetabular defects. Our hypothesis was that the mechanical failure rates will increase in the midterm follow-up due to graft remodeling and fatigue failure. Forty-five revision acetabular cage reconstructions (41 patients) were followed-up at an average 5 years (range 2-8 years). The classification included 4 type 2C, 21 type 3A, and 20 type IIIB defects. Outcomes included Merle D'Aubigne scores, revision, radiographic loosening, and complications. Structural allograft was used in 11 cases (including 3 total acetabular transplants) and cancellous allograft was used in 26 cases. Constrained liners were used in 16 cases. Nine (20%) were revised or resected due to aseptic loosening (7/9) and sepsis (2/9) at an average 49 months. An additional eleven hips (24%) are definitely or probably loose and three (7%) are on chronic antibiotics for infection. Merle D'Aubigne for pain and walking increased from 4.4 to 7.8 at the final follow-up. Complications included 6 infections, 5 nerve palsies, and 3 dislocations. Acetabular cages enhance the mechanical stability of a cemented cup and protect underlying allograft when bone loss precludes the use of an ingrowth prosthesis. The failure rate of cage reconstructions for these difficult cases is concerning at intermediate follow-up and emphasizes the need for alternative solutions.

PAPER NO. 248

High Failure Rate of a Constrained Acetabular Liner in Revision Total Hip Arthroplasty

Craig Della Valle, MD, *Chicago, IL (a, b, e – Zimmer Inc)*
Dennis H Chang, MD, Denver, CO (*)
Scott M Sporer, MD, Wheaton, IL (n)
Wayne Gregory Paprosky, MD, Winfield, IL (n)

Introduction: Constrianed acetabular liners have been advocated as one solution to both treat and prevent dislcoation at the time of revision total hip arthroplasty (THA). The goal of this study is to report our experience with a constrained acetabular liner in revision THA. Methods: Fifty-nine consecutive revision THAs in 56 patients where a constrained acetabular liner (DePuy, Warsaw, IN) was used were reviewed. Forty-sx constrained liners were placed for recurrent instability (mean 4 dislocations, range 1 to 18) and 13 were placed for inadequate stability at the time of revision THA. The mean age of the cohort was 63 years and 37 of the hips were in female patients (62.7 percent). Thirty-eight of the 59 hips had a constrained liner placed without revision of the components. At the most recent evaluation 4 patients had died (4 hips) and 4 patients were lost to follow-up (4 hips) leaving 51 hips in 48 patients who evaluated clinically and radiographically at a minimum of 2 years. Results: Nine of the 51 hips (16.7 percent) sustained a dislocation after placement of the constrained liner at a mean of 19 months postoperatively (range 2 weeks to 58 months). Eight of these 9 dislocations occurred in patients who had a revision to a constrained liner without revision of the femoral or acetabular components. Discussion: The constrained liner studied in this report performed poorly with a failure rate of 17.6 percent and thus we no longer use this device.

PAPER NO. 249

10-Year Radiographic Results of a Cement Augmented, Canal-Filling Femoral Component for Primary THA

Ronald P. White, MD, *Sarasota, FL (a – Zimmer Inc)*
William R Kennedy, MD, Sarasota, FL (*)
Thomas A Gruen, MS, Wesley Chapel, FL (e – Zimmer Inc)
Robert W Eberle, PhD, Apex, NC (n)

PURPOSE: We report the prospective results of a thin-layer femoral cement technique for primary total hip arthroplasty. MATERIALS AND METHODS: A prospective study was conducted on 114 hips in 107 patients with using a thin-layer femoral cement technique for primary THA. Patient serial radiographs were independently evaluated. Serial radiographs were classified based on cement grade, cement voids, evidence of positive or negative remodelling, femoral osteolysis and cement debonding. RESULTS: The average patient age was 73 years (± 5 years, range: 62 years – 84 years).There was one patient death not related to the primary THA. The average time to follow-up was 10 years (± 2 years, range: 8 years – 13 years). At the most recent follow-up, cement mantel grade was A (12%), B-1 (17%), B-2 (11%), C-1 (0%), C-2 (31%), and D (30%). Femoral osteolysis was seen in 18 hips and was confined to zones I or VII. Femoral remodelling was generally observed in the proximal femoral zones (positive remodelling: 13 hips, negative femoral remodelling: 50 hips). There were cement voids in 31 of 114 hips. At time of latest review there were no clinical failures. CONCLUSION: A thin-layer cement mantel and, at times, incomplete, may allow direct load bearing between the femoral component and host bone thus not relying on the complete cement mantel for stress transfer.

PAPER NO. 250

The Mechanics of Aseptic Loosening of Cemented Hip Replacements: A Retrieval Study

Philip Noble, PhD, *Houston, TX (a – Institute of Orthopaedic Research and Education, Zimmer Inc)*
Bin Du, MD, Houston, TX (a – Institute of Orthopaedic Research and Education, Zimmer Inc)
Jerry W Alexander, BS, Houston, TX (a – Institute of Orthopaedic Research and Education, Zimmer Inc)
James D Johnston, Houston, TX (n)

Introduction: Many authors have proposed theories to explain the pathomechanics of aseptic loosening of cemented femoral stems. However, there has been no systematic explanation of the relative order and importance of the events leading to component failure. In this retrieval study, we present a detailed analysis of cement mantles retrieved at revision surgery, in combination with clinical and radiographic data, which demonstrate the relative contribution of mechanical events to the etiology of femoral loosening. Materials and Methods: Eighteen cemented femoral stems with complete cement mantles were retrieved at revision surgery after an average of 42 months in situ. The outer and inner surfaces of the cement mantle and the surface of the femoral component were carefully examined with stereo microscopy. The area, location and severity of surface abrasion and cement cracking were recorded by Gruen zone. The predominant displacement mode of each implant was classified as torsional, varus-bending, end-loading and/or collar loading. Results: Areas of burnishing of the stem and the matching surface of the cement mantle were present on all but two cases (89%), independent of the duration of implantation. Regions of polishing of the outer surface of the cement mantle were observed in implants (revised for aseptic loosening (100%), but only one (14%) of the components revised for other causes . The volume of cement removed by external abrasion of mantle exceeded that removed through stem contact by at least an order of magnitude. Cracks were visible within almost half (45%) of the mantles revised secondary to loosening, but none of the infected or dislocated cases. Cracks were visible within almost half (45%) of the mantles revised secondary to loosening, but none of the infected or dislocated cases. Discussion and Conclusions: Early debonding and stem/cement motion appear to be a universal characteristic of cemented femoral stems. Abrasive wear of the outer surface of the cement mantle may be a more common cause of osteolysis and accelerated wear than abrasion of cement within the mantle.

PAPER NO. 271

Transtrochanteric Posterior Rotational Osteotomy for Osteonecrosis of the Femoral Head

Takuaki Yamamoto, MD, *Fukuoka, Japan (n)*
Goro Motomura, MD, Fukuoka, Japan (n)
Yasuharu Nakashima, MD, Fukuoka, Japan (n)
Toshihide Shuto, MD, Fukuota, Japan (n)
Seiya S Jingushi, MD, Fukuoka, Japan (n)
Yoichi Sugioka, MD, Fukuoka, Japan (n)
Yukihide Iwamoto, MD, Fukuoka, Japan (n)

Introduction: Most osteonecrosis undergo collapse and instability, which subsequently results in osteoarthritis. When osteonecrosis locates mainly in the mid-to-posterior portion,

transtrochanteric posterior rotational osteotomy (PRO) is indicated, which transposes the necrotic area to the posterior non-weight-bearing portion. PRO thus has a merit for stabilization of the joint. The purpose of this study is to evaluate its clinical outcomes. Patients: Cases consist of 51 hips in 47 patients with osteonecrosis of the femoral head, who had been performed PRO by one surgeon from 1981 to 1996. Underlying causes were idiopathic (4), alcoholic (12), traumatic (14), and corticosteroid-induced (21). Thirty-three were male, and 18 female. Average age was 37 at the time of surgery. Thirty-six hips were in ARCO stage III-C, and 15 in stage IV. Results: Forty-five hips out of 51 were followed (follow-up rate: 88%; 3 died, 3 hips dropped out). Average follow-up duration was 10 years. The average preoperative Harris Hip Score of 57 points improved to an average of 83 at the latest follow-up. Radiographically osteonecrosis in 30 hips (67%) healed or had no progression of collapse, and 13 (28%) showed slight joint space narrowing and/or osteophyte formation. In 2 cases, conversion to THA was performed due to osteoarthritis and femoral neck fracture. Conclusion: PRO is useful not only for healing of the necrotic lesion but also for the prevention of osteoarthritis. Since over 130 degree of posterior rotation is safely performed, PRO is a promising treatment option even for the extensive necrosis with advanced collapse.

PAPER NO. 272

Minimally Invasive Periacetabular Osteotomy for the Treatment of Hip Dysplasias

Masatoshi Naito, MD, *Fukuoka, Japan (n)*
Yuichiro Akiyoshi, MD, Fukuoka, Japan (n)
Kei Shiramizu, Fukuoka, Japan (*)

Introduction We developed a minimally invasive periacetabular osteotomy (MIPO) for the treatment of hip dysplasias. The incision is small and gluteal muscles are not detached in this osoteotomy. Methods A 10- to 13-cm anterior incision is made and the direct anterior approach is used through osteotomy of the anterior iliac spine with the inguinal ligament and sartorius muscle attached. Then, the iliacs muscle of the supra-acetabulur portion is detached. The triple osteotomy is done with a curved osteotome, designed to approximately correspond to the circumferential curvature of the acetabulum. A C-shaped osteotomy of the inner table of the pelvis is done with the osteotome being directed distally in the distal part of the quadrilateral surface, posteriorly in the proximal part of the quadrilateral surface, and proximally in the supraacetabular portion. All iliac osteotomy is done from the inside of the ilium. An incomplete cut of the ischium and a complete cut of the pubis are performed in the similar manner as those of the Bernese periacetabular osteotomy. Results From 1995 to 1999, MIPO was performed on 88 consecutive hips in 83 patients. The average age of the patients at the time of operation was 37.4 years. The average lateral center-edge angle was 7 degrees preoperatively, compared with 32 degrees postoperatively. Bone union of the iliac osteotomy was obtained in all hips. The average Harris hip score improved from 62 points to 94 points. Conclusion In MIPO, solid union of the iliac osteotomy can be accomplished by limiting the dissection.

PAPER NO. 273

Vascularized versus Nonvascularized Fibula Graft for Large Lesion of Femoral Head Osteonecrosis

Shin Yoon Kim, MD, *Daegu, Korea, Republic of (n)*
Yong-Goo Kim, MD, Taegu, Korea, Republic of (n)
Joo-Chul Ihn, Daegu, Korea, Republic of (n)

Introduction:The purpose is to compare the effectiveness of nonvasularized fibula (NF) and vascularized fibula (VF) for the prevention of collapse and progression of large lesions of osteonecrosis of femoral head (ONFH). Methods: A prospective comparative review matched according to Steinberg classification was performed. Each group consisted of 23 hips; IIc in 10, IIIc in 2, IVc in 11 respectively. The mean duration of follow-up was 48 months in NF and 47 months in VF with a minimum more than three years. Excellent or good rating was considered as a clinical success. Radiographic results were evaluated by the presence of collapse and depression more than 2 mm. Results: VF group: Most recent follow-up HHS was 82. Clinical success rate was 74%. There were 7(30%) hips without collapse and 8 (35%) hips with depression no more than 2 mm. Radiographic success rate was 65%. Three (13%) hips were converted to THA.The mean depression was 2.8mm. The mean time to collapse was 24 months. NF group: Most recent follow-up HHS was 69. Clinical success rate was 33%. There were 4 (17%) hips without collapse and 3 (13%) hips with depression no more than 2mm. Radiographic success rate was 30%. Five (24%) hips were converted to THA. The mean depression was 4.3mm. The mean time to collapse was 23 months. VF was superior to NF getting a better clinical and radiographic success, and it decreased the amount of depression significantly ($p<0.05$). However, there was no significant difference between two groups in conversion to THA and for the time to collapse of femoral head ($p>0.05$). Discussion: The present study suggested strut effectiveness with VF is better to prevent the collapse or depression less than 2mm of large lesions of ONFH.

PAPER NO. 274

Multi Directional Intertrochanteric Correction Osteotomy for Primary or Secondary Osteoarthritis- Results after 15 to 28 Years

Daniel Haverkamp, MD, *Amsterdam, Netherlands (a – AO Foundation)*
Rene K Marti, MD, Amsterdam, Netherlands (a, e – AO Foundation)

Introduction Although total hip replacement (THR) is the treatment of choice in osteoarthritis, in the young and active patients the life-expectancy of the prosthetic implant is shorter than that of the patient. Therefore delaying the need for a THR by means of joint preserving therapy, and improving the quality of life, with leaving the possibility of performing a THR at a later stage is of great importance. In this retrospective study we analysed the survival rate of intertrochanteric correction osteotomies for various conditions. Methods and Materials Between 1974 and 1987 276 intertrochanteric osteotomies in 216 patients were performed by the senior author (R.K.M). In 166 hips the osteoarthritis (OA) was secondary to acetabular dysplasia (average sharp-angle of 42,9 degrees and average CE angle of 20,6 degrees), 48 hips were classified as idiopathic OA, 23 as having a posttraumatic OA, 14 as OA after slipped capital femoral epiphysis and 5 after a Perthes disease. ResultsOf the 276 osteotomies, 139 (51%) had a consecutive THR or arthrodeses after an average of 9.4 years. Osteotomies performed for post-

traumatic osteoarthritis had a 10 year survival of 91 %. After intertrochanteric osteotomies for osteoarthritis grade 0 or I secondary to acetabular dysplasia in patients younger than 45 years a 10 year survival rate of 100 % and a 15 year survival rate of 97 % was reached. ConclusionAn intertrochanteric correction osteotomy is a good alternative to a THR in the young patient, especially when done for osteoarthritis secondary to acetabular dysplasia or to trauma. For all other indications good results may be achieved, but the outcome is less predictable.

PAPER NO. 275

Surgical Difficulties and Complications in Total Hip Arthroplasty of Neglected CDH

Kosmas Stafilas, *Ioannina, Greece (n)*
Panaviotis S Koulouvaris, MD, Ioannina, Greece (n)
Alexandros Mavrodontidis, MD, Ioannina, Greece (n)
Grigoris Mitsionis, MD, Ioannina, Greece (n)
Theodoros Xenakis, MD, Ioannina, Greece (*)

Total hip arthroplasty (THA) in neglected congenital dislocation of the hip (CDH) constitutes a challenging procedure, with surgical difficulties and complications. The purpose of this study was to analyse the complications of THAs in CDH. Between June 1983 and September 2002, 418 THAs were performed in 356 patients with CDH, with a mean follow-up 108 (7-237) months. The mean age at surgery was 53.3 (24-79) years with 325 females and 31 males. 83 patients had CDH in high position. 307 arthroplasties were cementless, 39 cemented and 72 hybrids. 40 stems were custom made. The cup always was positioned at the true acetabulum. 24 shortening osteotomies of the femur, 8 corrective supracondylar and 6 trochanteric osteotomies were performed. Preoperatively the average Merle d'Aubigne-Postel hip score was 1.1 for pain, 4.8 for range of motion and 3.1 for walking ability. Postoperatively the average hip score was 5.2, 4.7 and 5.3 respectively. The average length discrepancy was 8 cm (3-12) preoperatively and 1.5 cm remained in 8 patients. Complications included 7 intraoperative fractures of the femur, 12 dislocations, 4 peroneal nerve palsies that recovered, 25 heterotopic ossifications, 7 deep vein thromboses, 3 pulmonary embolisms, early mechanical loosening in 4 cemented and 10 cementless cups and 3 infections. Complications were diminished dramatically last years due to improved surgical technique, new available implants and preoperative evaluation of the hip with CT and CAD-CAM-CAE study that allowed better surgical planning with trial stem implantation from a series of stem designs and custom made femoral components manufacturing.

PAPER NO. 276

1158 Revisions for Infection from the Swedish National Hip Registry:Epidemiology and Risk Factors

Marieke Ostendorf, MSc, *GA Utrecht, Netherlands (n)*
Henrik Malchau, MD, Goteborg, Sweden (a, e – Centerpulse, DePuy Johnson & Johnson, Link Smith & Nephew, Zimmer)
W J A Dhert, PhD, Utrecht, GA Netherlands (n)
A J Verbout, PhD, Utrecht, Netherlands (*)
Peter Herberts, MD, Goteborg, Sweden (n)

1158 Revisions for Infection from the Swedish National Hip Registry: Epidemiology and Risk Factors. INTRODUCTION. Deep infection following total hip replacement (THR) remains a very serious complication for patients and a costly phenomenon for society. Therefore the aim of this study is to investigate the characteristics of 1158 patients who had a revision for infection after THR and to estimate risk factors for revision for infection by comparison with the primary population. METHODS. All revisions for primary and haematogenous deep infection from 1979 until 2000 were collected from the revision database of the Swedish National Hip Registry. A subgroup of 352 patients was compared with the original population receiving primary THR using regression analysis. RESULTS. The revised population consisted of 645 men and 513 women. The mean age at revision was 69.4 years and the mean follow-up was 9.6 years. 277 were one-stage revisions, 654 were two-stage procedures and 227 were permanent extractions. The most common bacteria in intraoperative cultures were coagulasenegative staphylococci (CNS) ((40 percent)) and S. aureus, (134(19 percent)). We found a significant shift in types of bacteria over the years (Chi-square test, p smaller than 0.001): an increase in the CNS group and a decrease in Gram-negative aerobes. Risk factors for revision for infection were male gender (OR 1.7,(CI 1.4-1.2)) and the use of non-antibiotic bonecement at primary THR (OR 1.6,(CI 1.2-2.0)). CONCLUSION. These results support the use of AB-containing bonecement, increased attention for prevention of infection in male patients and awareness of changing bacterial spectra.

PAPER NO. 277

The One Stage Exchange for Periprosthetic Infection in THA Results of a 6 Year Follow-up of 30 Cases

Joachim Friedrich Karl Wodtke, MD, *Hamburg, Germany (n)*
Stefan Luck, HR, Hamburg, Germany (n)
Alexander Katzer, MD, PhD, Hamburg, Germany (n)
Joachim F Loehr, MD, Zurich, Switzerland (n)

INTRODUCTION: Periprosthetic infection is still one of the most severe complications in THA. Despite many efforts to improve this procedure, the problem has still not been solved today. Two-stage and one-stage revision procedures have been advocated. We report on a six year follow-up of patients treated by one-stage revision. METHODS: 30 patients, which had undergone one-stage revision in 1996 were reviewed after a minimum follow-up of six years. The investigation included laboratory testing, radiographic follow-up as well as clinical examination and in two cases aspiration of the joint for queery infection. RESULTS: All 30 patients had left the hospital after the one-stage exchange without any clinical signs of infection. At follow-up one patient was found to have had a recurrent infection of the affected joint and was treated by a second one-stage exchange leading to no recurrence up to this point. In four patients radiographic radiolucencies were noted not yet having progressed or requiring revision surgery. The laboratory parameters were negative for persistant infection except in one case. DISCUSSION AND CONCLUSION: Compared to the two-stage exchange procedure a one-stage procedure will lead to excellent results while at the same time reducing the surgical risk for the patient as well as being economically superior. The success rate for this series was by clinical parameters 97 % after six years which is well comparable to reports on two-stage procedures. Prerequisite for success are a close relationship between a specialised clinical microbiologist and an experienced surgical unit.

PAPER NO. 278

◆A New Metal-On-Metal Hybrid Surface Arthroplasty: Two to Six Year Follow-Up

Harlan C Amstutz, MD, *Los Angeles, CA*
(a, e – Wright Medical Technology)
Paul E Beaule, MD, Los Angeles, CA (*)
Michael J LeDuff, MA, Glendale, CA (n)
Frederick Dorey, PhD, Los Angeles, CA (n)
Patricia A Campbell, PhD, Los Angeles, CA (a – Wright Medical Technology)
Thomas A Gruen, MS, Wesley Chapel, FL (*)

INTRODUCTION: The conservative nature and stability of Surface Arthroplasty (SA) are appealing. This paper presents the clinical and radiographic results with a new metal on metal (MM) hybrid SA. METHODS: The first 400 hybrid MMSA in 355 patients have an average of 3.5 years follow-up (range, 2-6). The average age was 48 years, 73% were men and 35% had secondary osteoarthritis. All patients were evaluated prospectively at 3 months and then yearly. RESULTS: All clinical measures pain, walking, function and range of motion showed significant improvement and the majority of the patients returned to a high level of activity, including sports. At 4 years, the Kaplan-Meier overall survivorship rate was 94.4%. There were 12 revisions (3.0%) to total hip replacement and 1 revision of an acetabular component. Seven conversions were due to femoral loosening at an average of 35 months. There were 3 neck fractures at 1, 2 and 20 months, 1 hematogenous sepsis at 36 months, and 1 subluxation due to impingement at 50 months. Radiolucencies were seen around 16 metaphyseal femoral stems (4.2%), and were interpreted as the result of micromotion at the implant-bone interface. The most important risk factors for femoral loosening were large cyst formation (p=0.029), height (p=0.032), female gender (p=0.005), and smaller component size in male patients (p=0.005). No femoral lucencies were observed among the 59 cases in which the metaphyseal stem was cemented. CONCLUSIONS: The preliminary experience with this hybrid metal-on-metal bearing is encouraging. Optimizing femoral bone preparation and fixation in hips with substantial anatomical deformities are critical towards improving durability. MMSA also provides an excellent option for revision and is preferable to previous SA designs with polyethylene.

PAPER NO. 279

The Role of Hydroxyapatite in Third-Body Polyethylene Wear in THA

Vijay J Rasquinha, MD, *New York, NY (n)*
Amar S Ranawat, MD, New York, NY (*)
Jose A Rodriguez, MD, New York, NY (n)
Chitranjan S Ranawat, MD, New York, NY (e – Biomet)

PURPOSE:Polyethylene wear debris is the main contributing factor that leads to aseptic loosening and osteolysis. The main objective of this study was to evaluate the role of hydroxyapatite (HA) in third-body polyethylene wear in total hip arthroplasty. MATERIALS:199 primary cementless THA's (174 patients) performed by a single surgeon were enrolled in a prospective randomized study comprising hydroxyapatite and non-hydroxyapatite coated femoral implants. The femoral component had metaphyseal-diaphyseal fit design with proximal plasma sprayed titanium circumferential porous coating. The hydroxyapatite coating was 50 – 75 micrometers over the porous surface with the components of identical design. The acetabular component was plasma sprayed titanium porous coated shell without hydroxyapatite. The polyethylene liners were machined molded from ram extruded Hi-fax 1900H polyethylene resin gamma-sterilized in argon (inert) gas. Clinical and radiographic evaluation was performed employing HSS scores and Engh criteria. RESULTS:At a mean follow-up of 8 years, the radiographs of 83 HA and 73 Non-HA hips were evaluated by two independent observers utilizing computer-assisted wear analysis described by Martell et al (1997). The radiographs demonstrated no case of osteolysis or aseptic loosening of any component. DISCUSSION:The mean linear wear rate in HA group was 0.19mm/yr and in the non-HA group was 0.21mm/yr, which was not significant (p>0.05). Both groups had comparable outcomes in terms of HSS scores, walking ability and sports participation. This study has attempted to demonstrate through an appropriately controlled in vivo study that hydroxyapatite does not play a significant role in third-body polyethylene wear in THA at a mean follow-up of 8 years. The concern of three-body wear with hydroxyapatite coating is no greater than porous coated cementless implants.

PAPER NO. 280

Survival of Hydroxyapatite (HA) versus Non-HA Acetabular Components in a Community Hip Registry

Thomas Krebs Comfort, MD, *Saint Paul, MN*
(b – Osteonics, DePuy Johnson & Johnson)
Kathleen Killeen, OT, Saint Paul, MN (n)
Katherine Grimm, MPH, Saint Paul, MN (n)
Susan Clay Mehle, BS, Saint Paul, MN (n)

Introduction: Early failure of acetabular components of specific design utilizing HA coatings has been previously reported. Designs providing improved initial stability and texture for bony ingrowth have subsequently been developed. The benefit of HA coating continues to be debated. The purpose of this study is to evaluate the performance of acetabular components, with or without HA coatings, in primary THA, utilizing our community hip implant registry. Methods: Since 1991, 2,598 ingrowth and hybrid THAs performed by 51 surgeons in 5 hospitals have been added to our community joint implant registry. Recalled Sulzer Inter-op acetabular components were eliminated from analysis. Of the remaining 2568, 145 THAs needed revision by 12/31/02. We reviewed isolated acetabular component revisions, excluding those performed for recurrent dislocation. Remaining were 25 revisions for early wear, aseptic loosening, or osteolysis, which were the focus of this study. We compared old HA acetabular components, associated with early failure in previous studies, to newer HA designs and to non-HA acetabular components. Of the new HA designs, 96% were Howmedica Osteonics Secur-Fit HA. Revision was defined as removal, exchange, or addition of any prosthetic component. Death was considered a censored event, as was revision for any other reason. Survival and cumulative revision rates were calculated with Kaplan-Meier survival function. Results: The cumulative 11.25 year survival rate of all 2568 THAs was 89.2% (87.0%, 91.5%). The mean time to revision for cases studied was 5.3 years with a cumulative survival of 97.5% (96.4%, 98.5%). Cumulative survival differed significantly with the type of acetabular component. Non-HA acetabular survival was 99.5% (99.0%, 100%) versus 90.1% (86.0%, 94.2%) for old HA designs versus 99.3% (97.8%, 100%) for newer HA acetabular designs. Non-HA acetabular survival did not differ significantly from newer HA designs (p=.2348), but both differed significantly from old HA designs (p<.001 and p=.0124, respectively.) Discussion and Conclusion: Old HA designs failed at a rate significantly greater than either of the other groups. New HA and non-HA acetabular components both have excellent survival.

POSTERS

POSTER NO. P001

MRI Screening for Multiple Osteonecrosis in Patients with Osteonecrosis of the Femoral Head

Takashi Sakai, MD, *Suita, Japan (n)*
Nobuhiko Sugano, MD, Suita, Japan (*)
Takashi Nishii, MD, Osaka, Japan (*)
Hidenobu Miki, MD, Suita, Japan (*)
Masaki Takao, MD, Osaka, Japan (*)
Kenji Ohzono, MD, Suita, Japan (*)
Hideki Yoshikawa, MD, Osaka, Japan (*)

INTRODUCTION: The purpose of this study was to investigate the incidence of multiple osteonecrosis, that is defined as disease involving two or more separate anatomic sites, in patients with steroid-related, alcohol-related, and idiopathic osteonecrosis of the femoral head using MRI screening. METHODS: A total of 200 patients with femoral head osteonecrosis were investigated. There were 104 females and 96 males. MRI screening was performed for hip, knee, shoulder, and ankle joints regardless of symptom. RESULTS: Osteonecrosis affected bilateral hips in 126 out of 151 steroid-related (83 percent), 25 out of 36 alcohol-related (69 percent), and 6 out of 13 idiopathic patients (46 percent). Multiple osteonecrosis was found in 107 patients (54 percent), who consisted of 92 steroid-induced (61 percent), and 15 alcohol-related patients (42 percent). There was no multiple osteonecrosis in 21 idiopathic patients. The knee lesion was most common (96 patients), followed by the shoulder (28 patients), the ankle (12 patients). Between multiple osteonecrosis patients and non-multiple osteonecrosis patients, there were significant differences in age at diagnosis, gender, and related factors. Multiple osteonecrosis tended to occur in steroid-related, young female patients. The collapse rate was 27 percent for the knee, 25 percent for the shoulder, and 17 percent for the ankle. DISCUSSION and CONCLUSION: Streroid-related and alcohol-related osteonecrosis tended to develop in multiple joints, whereas idiopathic osteonecrosis did not develop as multiple lesion. Besides, the rate of bilateral involvement was lower in idiopathic patients than in steroid-induced and alcohol-related patients. Idiopathic osteonecrosis is not systemic disease, but developed locally.

POSTER NO. P002

The Effect of Total Hip Arthroplasty Cup Design on Wear Rate

John M Iskander, III, *Alexandria, VA*
(a – Inova Health Care Services)
Robert Hopper, PhD, Alexandria, VA
(a – Inova Health Care Services)
Anthony M Young, Alexandria, VA
(a – Inova Health Care Services)
C Anderson Engh Jr, MD, Alexandria, VA (a – Inova Health Care Services, e – DePuy & JJ Company)

Background: Implant design is believed to play a fundamental role in the wear process. In the context of five different cup designs, this study sought to identify those factors that influenced polyethylene wear rates. The objective was to identify those generic and design-specific features that contributed to wear. Methods: We identified 619 porous-coated cups that had minimum 5-year radiographic follow-up and at least 3 annual x-rays. The mean follow-up was 8.6 years (range 5.0 to 18.6 years). This group included 15 AML TriSpike, 80 Arthropor, 85 ACS Triloc+, 26 Harris-Galante and 413 Duraloc cups. Serial head penetration measurements were made with computer-assisted techniques and used to calculate a wear rate for each hip. Using a multiple linear regression analysis, the effects of implant-specific design features and other factors were examined. Results: When accounting for patient factors and generic implant characteristics, implant design generally did not play a prominent role in the wear process. The important implant factors associated with a decreased wear rate proved to be terminal sterilization with gamma-irradiation, use of a 28 mm, ceramic head, cup abduction angle, barrier packaging and a short shelf life for gamma-irradiated Hylamer liners. Patient-related factors that contributed to decreased wear rates included increased age at surgery, female gender and increased body mass index. Discussion and Conclusion: Although polyethylene wear is commonly characterized for specific implant designs, this study demonstrated that there are several common factors that influence wear rates.

POSTER NO. P003

Degradation of Surface and Material Properties of Zirconia Femoral Heads with Time In Vivo

Erick M Santos, MD, *Birmingham, AL (n)*
K David Moore, MD, Birmingham, AL (n)
Yogesh K Vohra, PhD, Birmingham, AL (n)
Shane Aaron Catledge, PhD, Birmingham, AL (n)
Jack E Lemons, PhD, Birmingham, AL
(a – Biomet, Zimmer, Synthes, Wright, S&N, Stryker, Allvac, DePuy, J&J, Medtronics, Lifelore)
Michelle D McClenny, RNC, Pelham, AL (n)
Monique Cook, BS, Birmingham, AL (n)

INTRODUCTION: The use of Tetragonal Zirconia Polycrystal (TZP) ceramic femoral heads have been advocated in total hip arthroplasty (THA) as a means of decreasing polyethylene wear. Clinical data supporting the superiority of TZP heads in decreasing polyethylene wear is scarce. We tested the null hypothesis that there would be no degradation of surface and mechanical properties with increasing time of implantation of TZP femoral heads. MATERIALS AND METHODS: Sixteen TZP femoral heads explanted samples obtained after revision THA and five factory-sealed controls were examined using light microscopy (LM), scanning electron microscopy (SEM), glancing angle x-ray diffraction (XRD), nanoindention (NI) and were subjected to ultimate compression loading (UCL) in a hydraulic press. RESULTS: LM and SEM revealed evidence of metallic transfer, increased surface roughness, and pitting in explanted samples. UCL strength averaged 561.25 MPa with standard deviation (SD) of 344.14 for explanted samples, with controls averaging 1253.4 MPa with SD of 850.18. XRD and NI testing showed good correlation between increasing surface monoclinic phase and decreasing surface hardness. Samples with longer times of implantation had increasing monoclinic phase conversions and lower UCL strength. DISCUSSION AND CONCLUSION: TZP implants show increasing monoclinic phase transformation with time and a strong trend toward decreased hardness and UCL strength leading to surface defects that increase roughness. These suggest that the use of TZP heads may result in increased wear of polyethylene and degradation of the ceramic head's mechanical properties over time.

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

POSTER NO. P004

Femoral Component Revision in Complex Conditions in Hips with Important Bone Loss

Guido Grappiolo, MD, *Pietra Ligure (SV), Italy (a – Fondazione Scienza E Vita)*
Lorenzo Spotorno, MD, Morgantown, WV (a – Fondazione Scienza E Vita)
J David Blaha, MD, Ann Arbor, MI (*)
Brad L Penenberg, MD, Beverly Hills, CA (*)

Introduction:T.H.A. revisions are constantly increasing: and it's known that bone defects - expecially if severe like in rirevision cases - are the main problem to manage during the revision surgery. Since 1988, we have chosen to bypass the bone defects by using an "elastic" non-invading tapered stem (SL Wagner); morsel bone graft is rarely necessary, we never use a massive one. According to our philosophy in revisioning, stability should be obtained by a diaphysary anchorage as proximal as possible. Methods: Our research concerns 150 cases of SL revision stems implanted from December '88 to December '91. The average age is 67 years old, complete clinical evaluation and survivorship analysis for the entire study cohort was performed from 8 to 12 years follow-up, radiographic analysis in 81 cases with 101 months avg. follow-up (min. 60 - max. 143). Results and discussion:4 cases required rirevision; 20 patients deceased; 12 were lost to follow-up; 96 examinated.Clinical evaluations show an average score of 78 (acc. to HHS); 82,3 percent of patients are pain free, while slight pain still persists in a 13,7 percent pain in a 3,9 percent.The radiographic analysis has put into evidence only 1 case of mobilization, and suffering bone in 4 percent of cases; by contrast, 79,5 percent show astonishing endosteal bone formation.

POSTER NO. P005

Removal of Well-Fixed Cementless Acetabular Components During Revision Hip Arthroplasty

Philip Mitchell, FRCS, *Surrey England, United Kingdom (n)*
Donald S Garbuz, MD, Vancouver, BC Canada (*)
Bassam A Masri, MD, Vancouver, BC Canada (n)
Clive P Duncan, MD, Vancouver, BC Canada (a – Zimmer)

Introduction: Removal of well-fixed cementless acetabular components during revision hip arthroplasty may result in significant host bone damage that can compromise reconstructive options. A new technique has evolved using an instrument specifically designed to remove these components. We have tested the hypothesis that use of this new technique results in minimal host bone damage and hence more straightforward reconstruction. MethodsThe first 31 consecutive patients undergoing revision of well-fixed cementless acetabular components using the Explant (Zimmer, Warsaw, Indiana) Acetabular Removal System were included in the study. All pre-operative radiographs were assessed fro implant stability and acetabular bone loss, according to AAOS criteria. Pre-operative templating was performed by a surgeon blinded to the operative procedure. The size of acetabular component removed, the size of the final reamer used during reconstruction and time taken to remove the component was recorded. Results:The indications for revision were malposition, polyethylene wear, infection and locking mechanism failure. In all cases the acetabular component was removed in less than 5 minutes. The mode difference between size of implant removed and diameter of final reamer used was 4mm (range 0 - 10). In all cases, the pre-operative templating matched the size of component actually implanted. In no case did the classification of acetabular deficiency change after component removal, and no bone was removed at the time of component removal. In 3 patients, additional reaming was performed to facilitate implantation of a constrained component. Conclusion:The Explant Acetabular Removal Sysytem enables a safe and reliable technique for removal of well-fixed cementless acetabular components during revision hip arthroplasty.

POSTER NO. P006

Routine Postoperative Ultrasonography Screening for Venous Thrombosis: A Study of 1766 Arthroplasties

Kuang-Ying Yang, MD, *Singapore, Singapore (n)*
Robert Barry Bourne, MD, London, ON Canada (n)
Cecil H Rorabeck, MD, London, ON Canada (n)
Steven J MacDonald, MD, London, ON Canada (n)
Richard W McCalden, MD, London, ON Canada (n)
Ramin Mehin, MD, North Vancouver, BC Canada (n)
Robert Stephen Burnett, MD FRCSC, St Louis, MO (n)

Introduction: Duplex ultrasonography is an effective tool for detection of lower limb deep vein thrombosis (DVT). However, its role in routine post-operative surveillance for DVT is not well defined. We report the effectiveness of our screening program in the management of thromboembolism. MethodsOver a 2-year period, routine post-operative duplex ultrasonographies were performed for patients with total hip or knee arthroplasties. Patients with hip fractures or those without duplex scans were excluded from the review. The standard prophylaxis includes in-hospital warfarin with aspirin for 6 weeks after discharge. All patients had minimum 3 months of prospective follow-up. ResultsIn the study period, 1766 total joint surgeries were performed on 1510 patients with 879 hips and 887 knees. Ultrasound screening between 4th and 5th day detected 76 cases of acute DVT of which 15 were symptomatic (20%). A further 11 patients had DVT after discharge from hospital, giving an overall DVT rate of 5.0%. There was 1 case of fatal and 3 cases of non-fatal pulmonary embolism. The mean age of the patients was 66.5 (21-98) and patients above 70 had significantly higher risk of developing DVT (p=0.001). Revision knee but not hip surgery was also more prone to DVT (p=0.02). Other factors including sex, body weight, body mass index, surgery time, type of anesthesia, use of tourniquets and weight bearing status had no significant influence. ConclusionDuplex ultrasonography screening was effective in detecting early asymptomatic DVT in our study. Extended use of warfarin and the cost of warfarin monitoring can be avoided in 95% of our patients with only 0.7% risk of developing late DVT.

POSTER NO. P007

Acetabular Component Revision with a Modular Anti-Protrusio Cage

Christopher L Peters, MD, *Salt Lake City, UT (c – Biomet)*
Jill Erickson, PA, Salt Lake City, UT (n)

Current antiprotrusio cage designs are non-porous coated, one-piece and require cementation of a polyethylene liner into the cage. These factors limit the ability to gain permanent fixation by bone ingrowth, perform a trial reduction, and use different liner types to enhance hip stability. Results of a completely modular

porous coated antiprotrusio device (MAPC) designed to improve fixation and simplify intraoperative insertion were reviewed. 71 acetabular component revisions with a MAPC were performed from 1998-2001 by two surgeons. Average follow-up was 29 months (range 24-50). The 46 females and 25 males had average age 65. 36/71 operations were acetabular revisions only. Preoperatively 61/71 acetabulii had AAOS Type III, 9/71 Type IV, and 1/71 Type V bone loss. Five hips required bulk structural allograft (3 distal femur and 2 femoral head), the remainder cancellous graft only. 64/71 (90 percent) MAPC remain in place. Seven components were removed, 4 for infection, and 3 for loosening. Ten hips dislocated requiring four reoperations. One MAPC is definitely radiographically loose and four others have migration over 5-mm but patients remain asymptomatic. No MAPC has visible osteolysis. The Harris hip score improved from 33 to 77. At short-term follow-up, the MAPC is comparable to conventional one-piece antiprotrusio cages in terms of fixation and complications. Advantages include bone-ingrowth and long-term fixation, surgical technique similar to placement of a large hemispherical acetabular component, the ability to use trial components, and complete bearing surface modularity.

POSTER NO. P008

◆Periprosthetic Fractures of the Distal Femur: A New Method of Interprosthetic Fixation

David George Nazarian, MD, *Philadelphia, PA (e – Zimmer)*
Joshi Tapankumar, MD, Philadelphia, PA (e – Zimmer)
Robert Emrey Booth Jr, MD, Philadelphia, PA (a,c – Zimmer)

INTRODUCTION: Femoral fractures around a total hip or knee arthroplasty can be difficult problems to manage. This study focuses on the treatment of distal femoral fractures all below a well fixed hip implant with a new intramedullary device designed to connect the femoral component of the hip implant with the femoral component of a total knee implant. METHODS: Eight patients were treated at one institution with a distal femoral periprosthetic fracture. Three fractures occurred above a failed knee implant, three occurred between stable hip and knee implants, and two fractures occurred above a severely arthritic native knee. All patients were reconstructed with an IB-CCK knee implant, which was connected to the morse taper of a custom made intramedullary sleeve. The sleeve was mated to the hip implant and locked with set screws. Clinical and radiographic evaluation was performed according to the Knee Society. RESULTS: The average postoperative knee scores went from 42 preoperatively to 85 postoperatively and range of motion was 3 to 98_ . All patients healed their fracture within 6 months after surgery. There were no signs of progressive radiolucency or component loosening at an average follow up of 4.2 years (range 3-6.1). DISCUSSION AND CONCLUSION: The results of periprosthetic fracture treatment can be less than satisfactory. The poor quality of bone from osteoporosis, osteolysis and compromised vascularity may result in a slow healing rate. An intramedullary device is not only more durable but relies less heavily on bone quality than other techniques for fracture fixation. The favorable results exhibited in this limited group of patients make this technique an attractive salvage alternative when standard methods of fracture fixation will not provide adequate stability.

POSTER NO. P009

American Experience with Alumina-Alumina Bearings in THA

Stephen B Murphy, MD, *Roxbury Crossing, MA (e – Wright Medical Technology)*
Benjamin E Bierbaum, MD, Boston, MA (*)

Introduction. Wear, particulate debris, and resulting osteolysis are common problems following THA. Alumina ceramic-ceramic bearings have demonstrated low wear, both in vitro and in vivo. The current study documents clinical results of alumina ceramic-ceramic bearings. Methods. Between June, 1997 and February, 2003, 363 THA in 325 patients were performed using alumina ceramic-ceramic bearings as part of a prospective FDA/IDE study (Wright Medical Technology, Memphis, TN). The acetabulum consisted of an alumina liner joined to a titanium shell with an 18 o taper. The liner is positioned flush with the shell, with no additional metal sleeve adapter.Mean patient age at surgery was 51 years (SD: 11 years, Range: 18 – 78). 61% were male, 39% were female, 11% were bilateral. Results. Mean follow-up time for all cases was 16 ± 14 months. Of the 245 cases with a minimum of 2 years f/u, average time to f/u was 33 ± 11 months. All components remain well fixed. Reoperations included one for bearing diameter mismatch (head exchange) and one for I and D for acute infection. One liner malseated and replaced on post-op day 3. 3 hips dislocated once and were reduced. There are no cases of wear or osteolysis thus far and no cases of post-operative bearing fracture. This study of 2 to 6 year results demonstrate that this type of alumina ceramic-ceramic THA is at least as reliable clinically as traditional THA without evidence of early failure or bearing fracture.

POSTER NO. P010

Stem Subsidence after Revision Hip Surgery with Femoral Impaction Grafting Using Irradiated Bone

Mo Hassaballa, MD, *Bristol, United Kingdom (n)*
Sanchit Mehendale, MD, Bristol, United Kingdom (n)
George Kalantzis, MD, Bristol, United Kingdom (n)
Ian D Learmonth, Cape Town, South Africa (a – Stryker/Howmedica)
Evert Smith, Devon, United Kingdom (n)

IntroductionBone stock loss is one of the most significant factors precluding a successful revision total hip arthroplasty. Impaction grafting is arguably one of the most important tools in the management of bone stock deficiency. In this study, we assessed patients who had hip revision with femoral impaction grafting in our centre. Material and method A retrospective study in which a consecutive series of all patients who had a revision hip replacement with femoral impaction grafting in the period from 1994-2001 were assessed. Radiographic measurement for stem subsidence on Pre-operative x-rays films and post-operative films at 6 months, 1 year, 18 months and 2 years was done by 2 independent observers. Radiographic analysis for graft incorporation and trabecular remodelling was also done. Irradiated bone grafts were used in all cases. Results79 hips were assessed. Radiographic analysis revealed graft incorporation in 38% of cases but no evidence of trabecular remodelling. Moderate subsidence (5-10 mm) occurred in 11 cases (13.9%), and massive subsidence (>10 mm) occurred in 8 cases (10%). Complications included 9 dislocations, 4 per-prosthetic fractures and 5 stem revisions. Conclusions: Impaction grafting in revision hip replacement produces satisfactory results for most patients but a few hips perform poorly. We are currently looking at the possible reasons. We have concerns about irradiated bone grafts, as the characteristic changes of graft remodelling are not seen.

POSTER NO. P011

Revision of Failed Cementless Primary Femoral Components with Insertion of a Femoral Stem with Cement

Michael George Ryan, MD, *Carlsbad, CA (n)*
Paul M Pellicci, MD, New York, NY (n)
Douglas E Padgett, MD, New York, NY (*)
Thomas P Sculco, MD, New York, NY (*)
Eduardo Agustin Salvati, MD, New York, NY (n)
Bryan J. Nestor, MD, New York, NY (*)

Introduction/Materials & Methods: We studied 26 hips in 23 patients who underwent cemented revision for aseptic failure of an uncemented femoral component between January 1985 and January 1993. This study examined the ability of cemented revisions to form a lasting microinterlock with the endosteal surface of bone following an uncemented primary hip. Pre- and postoperative Harris Hip Scores were obtained for each patient. Preoperative radiographs were evaluated for osseous deficiencies based on the classification system of Mallory. The cementing technique was graded according to the criteria of Barrack et al on the postoperative x-rays. Radiographic loosening of the femoral component was classified according to the system of Harris and cGann. Results: Twenty patients (23 hips) with a cemented revision were followed clinically and radiographically for a minimum of seven years with an average follow-up of 98 months (range 7-12yrs). No patients were lost to follow-up. During this follow-up, there were three femoral components (13%) that required a repeat revision for aseptic loosening. Additionally, there were three stems that were probably loose and one stem that was definitely loose. Patients with type II bone loss were significantly more likely to be loose or require a revision (Fishers exact test, $p<0.05$). Patients with good bone had less loosening (Mann-Whitney test, $p= 0.004$). If the cement technique was ranked A for best and C for poorest, as the cement technique declined there was more loosening (Spearman correlation, rho=0.4, p=0.04). This association of loosening or revision with grade C cement technique was increased if the patient additionally had poor bone (correlation rho=0.7, p=0.001). Conclusion: In conclusion, preoperative bone loss and cement technique can effect the long-term durability of a cemented revision following aseptic loosening of an uncemented stem. Alternative reconstructive techniques may need to be employed in patients with Type II bone loss or greater. Cement technique must be emphasized during this recontruction as patients with Grade A or B cement achieved lasting results.

POSTER NO. P012

◆Further Experience with the PROSTALAC Hip System at an Alternate Site

Angela Scharfenberger, MD, *Indianapolis, IN (n)*
Marcia Clark, MD, Edmonton, AB Canada (n)
Edward Masson, MD, Edmonton, AB Canada (n)
Gregory J O'Connor, MD, Edmonton, AB Canada (n)
Lauren Beaupre, PhD, Edmonton, AB Canada (n)
Guy John Lavoie, MD, Edmonton, AB Canada (*)

Treatment of deep peri-prosthetic infection is two-stage exchange arthroplasty. The interval period with a temporary cement spacer leaves the patient with a painful, flail limb. The PROSTALAC system was designed to address patient function while delivering antibiotics for treatment of infected Total Hip Arthroplasty (THA). There are no published functional scores on patients in the interval period. All PROSTALAC data are from the developing center.A standardized retrospective chart review identified patients treated with the PROSTALAC. Patients in the interval period were assessed with WOMAC, SF-36, and Harris Hip Scores (HHS). Retention of prosthesis post second stage was used as the primary outcome.Thirty-nine patients treated with PROSTALAC were identified. Eighteen patients were assessed during the interval period. The mean age of the subjects was 68(29-93)years and 20(51percent) were male. The mean WOMAC pain score was 75(range 25-100) with a mean function score of 63(range 30-90). The mean SF-36 scores were never lower than age-stratified US norms for comparative age groups. The median HHS score was 66(21-87). Thirteen patients proceeded to second stage after negative joint aspirates with PROSTALAC in situ. Two patients had positive intra-operative cultures at forty-eight hours and were treated with a second course of antibiotics. All patients have retained their prosthesis to date at an average of 19 months (11-36 months).Most interval period patients are doing well with minimal pain and good function. Retention of prosthesis is currently 100percent. The PROSTALC system is a reliable prosthesis to use in two-stage exchange arthroplasty for infected THA.

POSTER NO. P013

Sterilization and Polyethylene Wear: Clinical Studies to Support Laboratory Data

Christi Sychterz, MS, *Wyomissing, PA (n)*
Karl F Orishimo, MS, Alexandria, VA
(a – Inova Health Care Services, d,e – Johnson&Johnson)
C Anderson Engh Jr, MD, Alexandria, VA
(a – Inova Health Care Services, e – DePuy)
Charles A Engh Sr, MD, Arlington, VA
(d,e – Johnson&Johnson)

This study compared how the in vivo wear performance of highly-crystalline and conventional polyethylene acetabular liners was affected by two new sterilization strategies (gas plasma and gamma irradiation in vacuum-barrier packaging) as compared to traditional gamma irradiation in air. Radiographic wear data from 385 total hip arthroplasties (252 Enduron, 133 Hylamer liners) were analyzed using multivariate linear regression analysis. For conventional polyethylene, the baseline wear rate for liners gamma-irradiated in air was 0.09 mm per year. Wear rates for vacuum-barrier packaging were not statistically different (p equals 0.10); however, gas plasma sterilization significantly increased the baseline wear rate of conventional liners to 0.18 mm per year (p less than 0.01). For highly-crystalline polyethylene, the baseline wear rate for liners gamma-irradiated in air was 0.18 mm per year. Gamma irradiation of these liners in vacuum-barrier packaging significantly decreased the wear rate to 0.11 mm per year (p equals 0.01), whereas gas plasma sterilization did not change the wear rate significantly (p equals 0.69).For conventional polyethylene, the clinical wear performance of the gamma-irradiated component, either in vacuum-barrier packaging or in air, was superior to the performance of the non-irradiated gas plasma sterilized components. This confirms the value of irradiation and cross-linking with conventional polyethylene; the clinical information can help surgeons make informed decisions concerning sterilization and implant selection. However, conventional and highly-crystalline polyethylene liners responded differently to gamma irradiation in air. For highly-crystalline polyethylene, only irradiation in vacuum-barrier packaging reduced the in vivo wear rates; the highly-crystalline components irradiated in air wore at the same high rate as the gas plasma sterilized liners. Likely, this is due to the difference in structures of the two polyethylenes and the resulting

greater susceptibility of highly-crystalline polyethylene to oxidative degradation. These data demonstrate that structural differences between polyethylenes (as with new highly cross-linked polyethylenes) can affect a polymer's response to sterilization and its clinical wear behavior.

POSTER NO. P014

Comparison of Cemented Femoral Components With Identical Geometry But Different Surface Finishes

John J Callaghan, MD, *Iowa City, IA*
(a,b,c,e – DePuy, Zimmer)
Steve S Liu, MD, Wichita, KS
John Gaffey, BS, Iowa City, IA (a, b, c, e – DePuy)
Jesse Ellis Templeton, MD, Cleveland, OH
Devon D. Goetz, MD, West Des Moines, IA
(a, b, e – DePuy)
Patrick M Sullivan, MD, West Des Moines, IA (n)
Richard C Johnston, MD, Iowa City, IA (c – Zimmer)

INTRODUCTION: The objective of this study was to evaluate the results of two cemented femoral components with identical stem geometry but different surface finishes at 13 to 15 year follow-up. METHODS: Two consecutive non-selective cohorts of hips performed by a single surgeon sequentially (Group I 1984-1985 304 hips, Group II 1986 120 hips) were evaluated for femoral revision for aseptic loosening and radiographic loosening and osteolysis. Group I had a TiBac cemented acetabular and 20-30 microinch surface roughness cemented femoral component and Group II had a cementless HG I acetabular and 80 microinch surface roughness femoral component of identical geometry. In both series contemporary cement technique was utilized. RESULTS: No patient was lost to follow-up. Hips with the smoother femoral component and those with a rougher femoral component were followed for 13 to 15 years. In group I the femoral revision rate for aseptic loosening was 2% and in Group II it was10%. In group I the radiographic loosening rate was 3.6% and in Group II 13.3%. Femoral osteolysis occurred around 7% of Group I hips and 13% of Group II hips. The difference between groups was significant for all three parameters (p=.001). DISCUSSION & CONCLUSION: This study unlinks the surgeon the femoral component geometry, and cement technique as potentially confounding variables. This study supports the use of femoral components with smoother surface roughness in cemented THR. The smoother stem performed as well as any other cemented femoral component that has been reported at 15 year follow-up.

POSTER NO. P015

Analysis of Bone Support of Cementless Acetabular Cups Using Computed Tomography

James Howard, MD, *London, ON Canada*
(a – Smith & Nephew)
Andrew Hui, MESc, London, ON Canada (n)
David W Holdsworth, London, ON Canada
(c – Enhanced Vision Systems, Corp)
Robert Barry Bourne, MD, London, ON Canada
(e – Smith & Nephew)
Cecil H Rorabeck, MD, London, ON Canada (n)
Steven J MacDonald, MD, London, ON Canada (n)
Richard W McCalden, MD, London, ON Canada (n)

Introduction: The initial stability and long-term survivorship of cementless acetabular cups is partially dependent on the bone-prosthesis contact pattern. Presently, there is no imaging modality that can accurately assess these contact patterns. The purpose of this study was to determine the amount and distribution of bone-prosthesis contact for three acetabular component designs using a novel image analysis technique. Methods: Eighteen embalmed cadaveric hemipelvis specimens were randomly assigned to receive a hemispherical, dual geometry, or a spiked cup. After radiogaphic templating, an experienced orthopedic team prepared the specimens and implanted the acetabular cups. A custom CT platform was designed to optimize imaging of the acetabular cups. After cup implantation, specimens were mounted on the platform and imaged in a spiral CT scanner. Contact analysis was performed using custom developed imaging software. Contact was defined as a bone-prosthesis distance of 0.5mm or less. Results: The mean amount of cup contact was 48.6 percent in the hemisphere group, 31.9 percent in the dual geometry group, and 35.1 percent in the spiked group (ANOVA p 0.05). A comparison between groups for amount and distribution of contact was performed. Discussion and Conclusion: This study outlines a novel CT analysis technique to evaluate bone-prosthesis contact for cementless acetabular cups. The designs analyzed in the study demonstrate differences in the amount and distribution of bone-prosthesis contact. Future work will involve the use of the technique with different cup designs and reaming techniques.

POSTER NO. P016

◆Image Free Computer Assisted Navigation in Total Hip Replacement

Andrew Yun, MD, *Inglewood, CA*
(a – Centerpulse and Orthosoft)
Lawrence D Dorr, MD, Inglewood, CA
(a – Centerpulse and Orthosoft)
Zhinian Wan, MD, Inglewood, CA (n)
Cambize Shahrdar, MD, Playa Vista, CA (*)

Introduction: Our purpose was to evaluate the accuracy of an image free computer assisted navigation system (CAS) in establishing targeted component positions and hip length equalizations in primary THR. Materials and methods: Thrity consecutive patients prospectively underwent primary cementless THR in the lateral decubitus position. Image free optical based computer navigation without preoperative CT or fluoroscopy was used to assist in the preparation and placement of acetabular components. Hip length change was measured prior to dislocation and after insertion of real components. Values were compared with immediate postoperative fluoroscopic evaluation of cup position and standardized validated postoperative radiographic eval-

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

uation. Results: With acetabular target angles of 40 degrees abduction and 20 degrees anteversion using computer navigation, the mean abduction angle on postoperative radiographs was 40 plus/minus 1 degree. The mean difference between acetabular anteversion intraoperatively using computer assisted navigation and postoperative using fluoroscopy was 2 degrees. Accuracy of hip length restoration was within a mean of 2.5mm. Integration of CAS required 10 additional minutes of operative time. Discussion: By providing immediate intraoperative feedback to the surgeon, CAS afforded predictable and reproducible results with accurate assistance in acetabular component placement and hip length restoration. The high cost of the system remains a potential disadvantage.

POSTER NO. P017

Relationship Between Surgical Volume and Early Outcomes of Total Hip Arthroplasty

Peter F Sharkey, MD, *Philadelphia, PA*
(a – Stryker Howmedica Osteonics)
Javad Parvizi, MD, Philadelphia, PA (n)
William J Hozack, MD, Philadelphia, PA (n)
Richard H Rothman, MD, Philadelphia, PA (*)

Introduction: The mortality and complication rates of many surgical procedures, including joint arthroplasties, are inversely related to hospital and surgical volume. The purpose of this study was to report the early outcome of total hip arthroplasty from a single institution with very high volume of joint arthroplasties. The study sought to explore the relationship between volume of total hip arthroplasties and the rate of postoperative mortality and early complications. Methods: We conducted a retrospective detailed review of the medical records of patients who underwent primary and revision total hip arthroplasty, between July 1998 to June 1999, at our institution. There were 1,002 hip replacements performed in 934 patients with 782 primary and 220 revision operations during the study period. All patients were followed for a minimum of 180 days. The mortality rate and prevalence of complications were determined. Results: The combined medical and orthopedic complication rate for primary and revision THA was 7.7 per cent and fifteen per cent respectively. There were six deaths (0.59 per cent) within the first six months after surgery of which four died following primary hip arthroplasty (0.51 per cent) and two (0.91 per cent) died after revision hip replacement. Conclusions: High-volume surgery, besides improving proficiency, is likely to reduce complications and mortality after hip arthroplasty. The reduction in complication rate, however, reaches a plateau and does not improve even despite an increase in the surgical and hospital volume. Total hip arthroplasty despite its safety and effectiveness in relieving pain and function, is associated with potential complications and occasional deaths.

POSTER NO. P018

Acetabular Revision for Hip Dislocation. Frequent Failures and Multiple Re-operations

Wayne M Goldstein, MD, *Des Plaines, IL*
(a, c – Smith & Nephew, a – DePuy)
Matthew L Jimenez, MD, Des Plaines, IL (n)
Thomas F Gleason, MD, Glenview, IL (n)
Kimberly A Berland, CST, Warrenville, IL (n)
Jill Branson, BSN, Kildeer, IL (n)

INTRODUCTION: Recurrent dislocation with a well fixed hip usually requires revision. We hypothesized it involved frequent failures and repeat procedures. METHODS: We revised 81 acetabular components (69 patients) with well-fixed stems over 17 years. From review of our outcome database, we categorized cases as successful if dislocation did not recur within one year follow-up. If the stem was well-fixed, we revised to a new head and augmented liner (if the shell position was adequate). The head, shell and liner were changed for shell malposition or if the shell did not accept an augmented liner. A bipolar technique was used for soft-tissue instability or as last salvage. We utilized the bipolar as a fixed-bearing cup (FB) by over-sizing the shell 1mm. RESULTS: In the 69 patients, 21 (30 percent) failed after first revision. In these 21 patients, we successfully revised nine, and four were successfully done elsewhere. Of the remaining eight, two were revised a third time with one successful and one failure. Six remain chronic dislocators and two died. In 25 hips with a fixed-bearing bipolar, one failed due severe stem retroversion and one disengaged the inner head and was revised to a new bipolar component (8 percent failed). 25 patients had a liner and shell change at revision and seven were failures (28 percent). 32 patients had a liner change only and eleven failed (34 percent). CONCLUSION: Only 70 percent were successful with first revision and 82 percent of those after the second revision. Press fit bipolar with 92 percent success, was an inexpensive alternative to constrained cups. Frequent failures need to be explained preoperatively.

POSTER NO. P019

A New Technique for 3-D Measurement of Polyethylene Wear in THR using Plain Radiography

Charles R Bragdon, BS, *Boston, MA (a – William H Harrison Foundation)*
John M Martell, MD, Chicago, IL (*)
Johan Nils Karrholm, MD, Gothenburg, Sweden (n)
Mary C O'Keefe, BA, Boston, MA (*)
Daniel M Estok II, MD, Newton, MA (*)
William H Harris, MD, Boston, MA
(a – William H Harrison Foundation, a, b,c – Zimmer, Inc, Centerpulse, Inc)

Introduction: For measurement of polyethylene wear in vivo, a 3-D method using plain radiography which has high resolution would be of great advantage. The critical limitation of current techniques is the reliance on the poor resolution of the cross table lateral radiograph. We hypothisize that a new technique of obtaining two views of the hip at right angles by taking two standing Judet views of the pelvis which are 90° apart will have identical resolution and superior image quality. Materials and Methods: To validate this technique we compared the existing 3-D Martell method versus the new method in vitro using a 3-D phantom test model of progressive femoral head penetration into the socket. Results: Not only is the quality of the films vastly superior using the new technique, the accuracy and precision of the new technique are interchangable with the existing method under ideal conditions in vitro. When the new projections were used, there was no statistical difference in the total average error or the accuracy and precision of the 2-D or 3-D vectors compared to the standard Martell projections. Conclusion: By using two oblique A/P projections, the major disadvantages of using the cross-table lateral to create a 3-D reading of femoral head penetration into the polyethylene are eliminated. This advance substaintially enhances the utility, (i.e. the number of patients who must be excluded from reading due to the poor quality of the cross table lateral film), of 3-D wear measurements in vivo using plain films.

POSTER NO. P020

Effect of Smoking on Long-Term Implant Stability in Total Hip Arthroplasty (THA)

Russell D Meldrum, MD, *Indianapolis, IN (n)*
L Daniel Wurtz, MD, Indianapolis, IN (*)
Judy Feinberg, PhD, Indianapolis, IN (n)
William N Capello, MD, Indianapolis, IN (*)

INTRODUCTION: Smoking adversely affects fracture healing and increases peri-operative complications with THA. Long-term effect of smoking on implant stability has not been studied. METHODS: Inclusion criteria for this study were: primary THA between 1985 and 1991; single surgeon; osteoarthritis or avascular necrosis diagnosis; and five-year minimum follow-up. Implants were limited to the Omnifit porous coated cup and Omnifit cemented or porous coated stem due to reported low failure rates. Patients were categorized as current (S) or previous/non-smokers (NS) at the time of THA. Follow-up included smoking status since THA, clinical outcomes, satisfaction, and additional hip surgery. RESULTS: Of 147 patients (165 hips) in the study, 31 patients (34 hips) and 116 patients (131 hips) were identified as S or NS, respectively. Mean follow-up was 13 years. No NS became smokers, and 5 of 32 S had stopped smoking one to14 years post-THA. There were 33 reoperations in 26 patients and 13 component revisions for aseptic loosening in 10 patients (7 cups, 1 porous coated and 5 cemented stems). Reoperation rates did not differ between groups, however revision rates for aseptic loosening were 12% and 2% in the S and NS groups, respectively. ($p < .001$) DISCUSSION AND CONCLUSION: Based on these results, it appears that smoking may negatively affect long-term stability of hip implants. Limitations of this study include the small sample size and retrospective, correlational design. Authors recommend further study to determine to what extent smoking may contribute to implant failure in relationship to other known contributing factors.

POSTER NO. P021

The Utility of Bladder Catheterization in Total Hip Arthroplasty

Richard Iorio, MD, *Burlington, MA (n)*
William W Whang, MD, Modesto, CA (*)
William L Healy, MD, Burlington, MA (n)
Soheil Najibi, MD, Canton, MI (*)
David M Appleby, MD, Grants Pass, OR (*)

Introduction: The use of a urinary bladder catheter in total hip arthroplasty (THA) is controversial. Universal insertion of an indwelling catheter prior to THA, and insertion of a catheter postoperatively as necessary, are accepted variations of care. The purpose of this study was to determine which method of bladder management minimizes complications and maximizes cost effectiveness. Methods: From 1993 to 1999, 719 primary, unilateral THA were randomized by surgeon into two groups: universal preoperative insertion of an indwelling catheter (340 patients) and postoperative cathterization as necessary (379 patients). Patients were followed with a THA database which recorded all complications. Hospital records, morbidity and mortality reports were reviewed to confirm the validity of the data. Results: The universal catheter insertion group developed urinary tract infections (UTI) in six patients (1.8%). The postoperative catheter as necessary group developed a UTI in 9 patients (2.4%) (P=0.6). Female gender and increasing age were associated with a higher risk of UTI in both groups (P< .05). Type of anesthesia (general vs. regional) did not effect the incidence of either UTI or urinary retention. In the catheter as necessary group, 77.8% of patients did develop urinary retention requiring subsequent catheterization. The universal catheter group generated on average a $590 greater hospital cost for THA which was statistically significant (P< .001). Co-morbidities, hospital length of stay, and number of subsequent catheterizations were not statistically different among the two treatment groups. Conclusions: Routine preoperative bladder catheter insertion may not be warranted in THA. In this study, there was no significant difference in UTI incidence between the preoperative universal catheter and the postoperative catheter as necessary groups. Female gender and increasing age were associated with a higher risk of UTI in both groups. Postoperative catheterization as necessary was, however, significantly more cost effective.

POSTER NO. P022

Early Modes of Failure of an Anatomic Hydroxylapatite Coated Femoral Component at Mid-Term Follow-up

Thomas J Blumenfeld, MD, *Sacramento, CA (n)*
William Lamont Bargar, MD, Sacramento, CA
(a,c – DePuy)

INTRODUCTION: Most femoral components designed to achieve bony attachment with an anatomic proximal body and bioactive coating have enjoyed good success. The purpose of this study is to describe two modes of early failure observed with a particular design of this type of femoral component. METHODS: From 1993 to 2001, 216 patients (117 males, 99 females) underwent 265 cementless total hip arthroplasties using the Stature (Depuy) femoral component. This component is proximally filling, anatomic, proximally grooved except laterally and proximally circumferentially hydroxylapatite (HA) coated over a 20 grit blasted surface. Mean patient age was 57.2 years (range 30-74) and the most common diagnosis was osteoarthritis (seventy-five percent). RESULTS: Mean follow-up was 69 months (range 2-102). All implants appeared to achieve initial fixation. Thirteen patients (5 percent) underwent or will undergo femoral component revision due to the following: Five patients sustained a femoral fracture after a fall in the early post-operative period (11-58 days, average 32 days). Three patients sustained a late fracture after a fall (22-86 months, average 54 months). Five patients developed femoral component loosening at an average of 49 months after surgery (range 43-73 months). DISCUSSION/CONCLUSIONS: Survivorship at mid-term follow-up is ninety-five percent. Two potential design flaws may have contributed to the early failures. The lack of a sufficiently roughened surface may have allowed osteolytic debris to loosen the implant after the HA is resorbed. Postoperative peri-prosthetic fracture may be more likely due to the large proximal body with abrupt transition to a cylindrical stem.

POSTER NO. P023

Long-Term Results Of Total Hip Arthroplasty In Rheumatoid Arthritis

Atul B Joshi, MD, *Lubbock, TX (n)*
LJubisa Markovic, MD, Whaley, United Kingdom (*)
John Murphy, MD, Lubbock, TX (*)

Introduction: Total hip arthroplasty is one of the most successful surgical procedures performed over last 40years. However, there are very few long-term reports published for rheumatoid arthritis. Aim : of this study is to evaluate the long-term results of the total hip arthroplasty in patients with rheumatoid arthritis.. Material and Methods: One hundred and sixty-nine total hip arthroplasties in 107 patients were carried out in patients with rheumatoid

arthritis. Clinical and radiographic evaluation were carried out. Survivorship analysis was done using the Kaplan-Meier method. Results: The mean follow-up was 15.5 years. There were 86 men and 101 women. Average age at surgery was 49.6 years. The average overall wear was 1.01 millimetres and the rate of wear was 0.07 millimetre per year. Complications occurred in 36 hips (21%). Failure occurred in sixteen (9.4%) hips, including four hips due to infection. The probability of survival of the hip implant at 26 years was 72 %. The survival of the stem was 78% and that of the acetabular component was 87% at 26 years. Conclusions: The only significant factor was the wear of acetabular polyethylene in the outcome similar to osteoarthritis patients. In patients with rheumatoid arthritis, cemented total hip arthroplasty provides satisfactory results on a long term basis.

POSTER NO. P024

Impaction Grafting for Revision of the Femoral Component Using a Collared, Textured Revision Stem

Jonathan P Van Kleunen, MD, *Philadelphia, PA (n)*
Dinh Vu, BSE, Philadelphia, PA (n)
Jonathan P Garino, MD, Philadelphia, PA
(e – Smith & Nephew)

Introduction: Femoral impaction allografting has demonstrated success in the repair of osteolytic defects in revision total hip arthroplasty. A versatile collared, textured stem system with a good track record for cement may be a reasonable option for the technique. Methods: We present a prospective study of 77 hips in 70 patients with substantial osteolytic bone loss that underwent revision total hip arthroplasty with impaction grafting. According to the AAOS classification system, 23 hips were type IIA, 11 were type IIB, and 39 were type III defects. All patients received a collared, textured stem and an average of 144 cc cancellous allograft. Patients were followed clinically and with serial radiographs for an average of 5 years. Results: At an average follow-up of 5 years, 68 of 77 hips (88%) remain a success. The average Harris hip score in successful cases improved from 51 (6 to 79) preoperatively to 78 (32 to 100) at most recent follow-up. Nine stems failed- three for aseptic loosening, two for infection, three for fracture, and one for dislocation. Radiographic loosening was seen in five hips including the three requiring further revision. Discussion: Utilization of a revision cemented stem with multiple head and neck lengths enhances the versatility of the technique. Collarless, polished, tapered stem have been commonly utilized but are not a prerequisite for successful outcome.

POSTER NO. P025

Posterior Capsular Repair Decreases Incidence of Dislocation Following Primary Total Hip Arthroplasty

Arthur L Malkani, MD, *Louisville, KY (n)*
Omar N Osmani, MD, Tempe, AZ (n)
Brent Walz, MD, Louisville, KY (*)
Dale Baker, BA, Louisville, KY (*)

Introduction: The purpose of this paper was to demonstrate the importance of reattachment of the posterior capsule to minimize dislocation following total hip arthroplasty. Methods: 216 consecutive primary total hip arthroplasties performed by the same surgeon were divided into two groups. In Group A the posterior capsule was excised entirely, and in Group B the posterior capsule was preserved and reattached to its origin under the greater trochanter. In Group A there were 113 patients, with an average age of 62 years (range 20 to 89). In Group B there were 93 patients, with an average age of 63 years (range 19 to 92). Results: The overall dislocation rate in Group A was 4.4 percent which decreased to 1.1 percent in Group B. Four out of five patients in Group A who dislocated were females and became recurrent dislocators requiring revision surgery. In Group B, one patient dislocated three and a half months following the primary procedure due to a fall and became a recurrent dislocator requiring revision surgery. Discussion and Conclusion: Repair of the posterior capsule decreased the incidence of dislocation in primary total hip arthroplasty. Posterior capsule repair minimizes the patient's ability to internally rotate the hip preventing dislocation. We advocate routine posterior capsule repair in patients undergoing total hip arthroplasty using the posterolateral approach.

POSTER NO. P026

Mental Health and Outcome in Primary Joint Replacement of the Hip and Knee

Carlos J Lavernia, MD, *Miami, FL*
(a,d,e – Zimmer, d – Johnson&Johnson)
Michele R Dapuzzo, MD, Hialeah, FL (n)
Victor Hugo Hernandez, Miami, FL (*)
Rodrigo M Diaz, MD, Miami, FL (n)
Rafael J Sierra, MD, Rochester, MN (*)

Introduction: Depressed patients have been shown to have suboptimal outcome in multiple surgical and medical interventions. Our objective was to utilize the SF-36 to assess the effects of mental health in the outcome of primary joint replacement surgery of the hip or knee. Methods: A cohort of 569 patients with a minimum 2 year follow up was studied. Preoperative QWB, SF-36 and WOMAC were collected. The Mental Health domain of SF-36 was utilized to assess clinical depression; patients with scores less than 52 were considered depressed. ANOVA, T-test and Stepwise Multiple Regression Analysis (SMRA) were performed. A $p<.05$ was considered significant. Results: Preoperative domains showed that the depressed cohort had significant lower preoperative quality of life scores as measured by the QWB (.498 ±.005 SE vs. .525 ±.003 SE; $p<.001$) and WOMAC (70.98±1.37 SE vs. 60.75±.78 SE; $p<.001$). Postoperatively QWB at the last follow-up was higher in the patients that were not depressed (.571±.003 SE vs. .546±.007 SE; $p=.001$). Depressed patients showed less improvement in the pain ($p<.001$), function ($p<.001$) and stiffness subscales ($p<.001$) of the WOMAC when compared to the non depressed patients, as well as in all the domains of the SF36 ($p<.001$) except physical component. Conclusions: Our results clearly demonstrate that depressed patients have a worse outcome when compared to normal patients. The patient's mental status as assessed by the SF-36 is an excellent predictor of outcome in primary joint replacement. It might be possible to, design a pharmacologic intervention in these patients to improve the outcome.

POSTER NO. P027

Failure Of Total Hip Arthroplasty: Analysis Of Variables

Atul B Joshi, MD, *Lubbock, TX (n)*
LJubisa Markovic, MD, Whaley, United Kingdom (*)
John Murphy, MD, Lubbock, TX (*)

Introduction: The implant failure is complex issue. Many questions remained unasnwered.Aim: Aim of the study was to analyze the association of factors and aseptic loosening of total hip arthroplasty. Materials and Methods: 609 cemented total hip arthroplasties with minimum 9 years of follow-up. Detail clin-

ical and radiographic assessment were carried out.. Results: The combined total failures (clinical and radiographic) were in 130 components. The cumulative total failure correlated with polyethylene wear (p<0.0001). The acetabular loosening (p=0.0008) correlated with total wear and with degree of the wear (p<0.0001, Phi =0.15) but not for the femoral stem failure. Number of zones of demarcation in cup had correlation to degree of wear (p=0.005). Regression analyses showed only wear was significant for cup (p<0.0001), not for stem. Analysis of radiographic features for stem showed no correlation with degree of wear except for endosteal cavitations (p=0.04). For the predilection of the zones to degree wear showed the trend only for endosteal cavitations in zone 3 (p=0.01) and in zone 7 (p=0.004). In bilateral simultaneous hips the failure of the cup, stem and both component combined similar. Conclusion: This study looks at influence of the variables for the failure of the implant in total hip arthroplasty.

POSTER NO. P028

Survival of Uncemented versus Cemented Femoral Stems in a Community Hip Implant Registry

Thomas Krebs Comfort, MD, *Saint Paul, MN*
(b – Osteonics, Johnson&Johnson, DePuy)
Kathleen Killeen, OT, Saint Paul, MN (n)
Katherine Grimm, MPH, Saint Paul, MN (n)
Susan Clay Mehle, BS, Saint Paul, MN (n)

Background: Surgeon preference for femoral fixation technique for total hip arthroplasty (THA) has changed with time. A community joint registry has shown variation in preference between cemented and uncemented stems. The purpose of this study is to evaluate the performance of uncemented versus cemented femoral stems in a large series of patients. Methods: Since 1991, 2,581 ingrowth and hybrid THAs performed by 53 surgeons at 5 hospitals have been added to our community joint implant registry. Implants removed from the market due to a known high rate of failure were eliminated from analysis. From the remaining 2391, 119 THAs needed revision by 12/31/02. The main reason for revision was aseptic loosening, wear or osteolysis, with 8 involving the cup and 26 involving the stem. Revision was defined as removal, exchange, or addition of any prosthetic component. Death was considered a censored event, as was revision for any reason other than cup or stem. Survival and cumulative revision rates were calculated with Kaplan-Meier survival function. Results: The cumulative 11.25 year survival rate of all 2391 THAs was 90.5% [88.2%, 92.9%]. The mean time to revision of the stem alone was 4.4 years with a cumulative survival of 97.2% [96.0%, 98.4%]. Use of uncemented stems dropped from 60% in 1992 to 10% in 1996, and returned to 50% in 2002. Survival of uncemented and cemented femoral stems did not differ significantly. Neither gender nor age differed significantly between the two groups. Conclusions: There was no difference in survival of uncemented and cemented stems in our community hip implant registry.

POSTER NO. P029

A 5 to 7 Year Prospective Report of 136 Hips Utilizing Hylamer Polyethylene in Older Patients

Thomas Kent Donaldson, MD, *Loma Linda, CA (n)*
Mark Sutton, MD, Loma Linda, CA (n)
Ian C Clarke PhD, San Bernardino, CA (*)

Introduction: Hylamer polyethylene has been reported to demonstrate early wear and agressive osteolysis in hips in young people. This study demonstrates a prospective study of 136 hips with hylamer polyethylene with a minimum of 5 to 7 year follow up. Method: From 1/95 to 4/98 136 primary hips were performed in 127 patients utilizing Hylamer polyethylene.The mean follow up was 72 months. Thirteen patients were lost to follow-up. There were 36 males and 90 females. Nine patients had bilateral hips replaced. The patients were followed up at yearly invervals with Harris hip scores and radiographic review. Findings: The average age was 71 years. Early results demonstrated an improvement of Harris hip scores from 39 to 97 points. The function score improved from 42 to 84. Radiographic evaluation demonstrated gross acetabular loosening in 8 cases. 12 additional cases with significant acetabular osteolysis. The femoral side demonstrated significant osteolysis in gruen 7a an 1a in 30 cases with wignifican osteolysis in zone 7 in 12 cases. Polyethylene wear rate of .44mm/year in the high wear and osteolysis cases and a wear rate of .35mm/yr overall was seen. Sixteen revisions were performed for severe osteolysis and pain. An additional ten patients are pending revision. This represents a 19 percent failure at this early date. Discussion: This study is consistant with other reports involving early and agressive wear rates with Hylamer. This study is unique because of the age of the patients involved. Some of the worst cases involving ostolysis were in patients over 80. Conclusions: Hylamer demonstrates high wear and failure rates in older non active patients in this prospective group of patients.

POSTER NO. P030

◆Tolerability and Efficacy of Polymerized Bovine Hemoglobin in Orthopaedic Surgery: A Phase III Study

Jonathan P Garino, MD, *Philadelphia, PA (n)*
Jonathan S Jahr, Los Angeles, CA
(a,b – Biopure Corp, Hemosol, Inc)
Colin McKenzie, MD, Baltimore, MD
(a, e – Biopure Corp)
Scott Dulchavsky, MD, Detroit, MI (*)
Dinh Vu, BSE, Philadelphia, PA (n)
John Williams, MD, Pittsburgh, PA (a,b – Biopure Corp)

Introduction: Concerns about transfusion include infection transmission, clerical error, previous alloimmunization, rare blood types, religious beliefs as well as the reduced oxygen-carrying ability of red blood cells (RBC). A polymerized bovine hemoglobin solution HBOC-201, given as an alternative to allogeneic red blood cells (RBC), was evaluated in acutely anemic orthopedic surgery patients. Methods: Patients were prospectively randomized 1:1 to HBOC-201 or RBC at the first perioperative transfusion decision.. Efficacy was defined by the proportion of patients in the HBOC-201 group who did not receive RBC. Results: 350 patients were randomized to HBOC-201 and 338 to RBC. At randomization, mean hemoglobin levels were similar (~9 g/dL) for the two groups (p=0.760). In the HBOC-201 group, transfusion was avoided in 337 (96.3%) patients on day 1, 246 (70.3%) patients through day 7, and 208 (59.4 %) patients through day 42. Fewer units of allogeneic red cell units were administered in the HBOC-201 group than in the RBC group, 1.4 units verses 3.1 units (p<0.001). Adverse events in the HBOC –201 group were comparable to RBC group. There was no significant between-group difference in mortality (p=0.450). Discussion and Conclusion: The efficacy of HBOC-201 was demonstrated by the avoidance of allogeneic RBC in about 60% of patients over a six week period receiving this oxygen-carrying

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

solution. HBOC-201 was well tolerated and appears to be a feasible alternative to RBC in anemic orthopedic surgery patients requiring increased oxygen carrying capacity.

POSTER NO. P031

◆RSA Evaluation of the Influence of Post-Operative Weightbearing on Uncemented Femoral Stem Migration

Edwin P Su, MD, *New York, NY (n)*
Mathias P G Bostrom, MD, New York, NY (n)
Fritz Boettner, New York, NY (*)
Mark W Zawadsky, MD, New Jersey, NJ (n)
Thomas P Sculco, MD, New York, NY (n)
Leif Ryd, Linkoping, Sweden (n)

Introduction: Micromotion of a porous coated prosthesis may interfere with bony ingrowth, leading to fibrous tissue formation and early loosening. Because of this possibility, there has been an ongoing controversy about the postoperative rehabilitation of cementless total hip replacements (THR). We hypothesized that because of the initial implant stability obtained intraoperatively, there would be no difference in migration of the femoral stem between a weight-bearing as tolerated (WBAT) group versus a toe-touch weight bearing (TTWB) group. We conducted a prospective study to determine the influence of weightbearing upon uncemented femoral stem migration, using RSA. Methods: Thirty-three patients underwent 42 primary, uncemented THR with implantation of tantalum beads for subsequent RSA analysis. Patients with unilateral THR were randomized to either WBAT or TTWB for 6 weeks post-operatively. Patients with bilateral THR were included in the WBAT group. After 6 weeks, all patients were advanced to WBAT. RSA radiographs were taken at 3 days postoperatively, 6 weeks postop, and 6 months postop. Results: There was a trend towards increased stem subsidence in the WBAT vs. TTWB group in the 6 week postop period (0.82 mm vs. 0.16 mm, p=0.07). This difference decreased at 6 months (0.74 mm vs. 0.25 mm). In the WBAT group, increasing weight was correlated with an increase in the amount of stem micromotion (r = 0.7), whereas age was inversely related to the amount of micromotion (r = -0.57). Discussion: Femoral stem micromotion following uncemented THR was influenced by the amount of weight placed on the operated extremity, as evaluated by RSA. Although the mean amount of motion was not significantly different between the two groups, increasing patient weight did correlate with increased stem migration. This information may influence surgeons' choice of rehabilitation protocol following THR, particularly in heavier patients.

POSTER NO. P032

The Effects of Femoral Offset and Head Size on Stability of the Artificial Hip Joint

Tetsuya Jinno, MD, *Tokyo, Japan (n)*
Yoshinori Aso, MD, Tokyo, Japan (*)
Daisuke Koga, MD, Tokyo, Japan (*)
Sadao Morita, MD, Tokyo, Japan (*)
Takeshi Muneta, MD, Tokyo, Japan (*)
Kenichi Shinomiya, MD, Tokyo, Japan (*)

INTRODUCTION: Dislocation is a major complication following total hip arthroplasty (THA). We examined intraoperatively the effects of offset and head size of the femoral component on stability of artificial hip joint. METHODS: Data were obtained from thirty cementless primary THAs performed via posterolateral approach. After the fixation of the acetabular shell and the insertion of the final femoral rasp, trial reduction was repeated using provisional femoral neck with neck angle of 132_‹ and 127_‹ in combination with the provisional heads in diameter of 26mm and 32mm. The 127_‹ neck had a 6mm larger offset than the 132_‹ neck. The joint stability was examined manually each time. To evaluate the posterior stability, range of internal rotation prior to subluxation was measured using goniometer in various hip flexion/adduction positions.Possible range of external rotation also was measured in 0 degrees of hip extension to evaluate the anterior stability. RESULTS: The effect of femoral offset on posterior stability was significant. When the 127_‹ neck (larger offset) was used, whether with the 26mm head or the 32mm head, 10_‹ more internal rotation by an average was possible than when the 132_‹ neck was used. On the other hand, the effect of head size on posterior and anterior stability was not significant. DISCUSSION: In this study, the theoretical advantage of a larger head size was not demonstrated, while a larger offset apparently improved the joint stability. The results suggest that when the implants were situated in proper position, the osseous, not the prosthetic, impingement is the primary cause of dislocation.

POSTER NO. P033

Population Cost and Outcome of Highly Crosslinked Acetabular Components for THA in the U.S.

Michael T Halpern, MD, *PhD, Alexandria, VA (n)*
Steven M Kurtz, PhD, Philadelphia, PA (n)
Rose M Ray, PhD, Menlo Park, CA (n)
John M Martell, MD, Chicago, IL (*)
William J Hozack, MD, Philadelphia, PA (a,e – Stryker)
Richard H Rothman, MD, Philadelphia, PA (*)

Introduction: Recent studies suggest highly-crosslinked UHMWPE components reduce THA wear rates; however, long-term clinical performance hasn't been determined. To explore societal changes in hip prosthesis costs and outcomes (revision rates) with crosslinked prostheses, we developed a U.S. population model. Methods: The model projected the proportion of patients receiving hip prosthesis revisions from initial implant to death and assessed total costs of performing THA between 2003 and 2030 for two scenarios: use of crosslinked liners remaining constant with current levels (45% of all THA); and use of crosslinked liners doubling to 90%. Results: Our model predicts that total costs (initial procedure and subsequent revisions) for THA in the U.S. through 2030 will be approximately $36 billion (in 2003 dollars). If use of crosslinked liners increases to 90%, cost-savings will depend on changes in revision rates. A 10% decrease in revisions for crosslinked components would increase total cost, but by only 0.2% of the total spent on THA. If highly crosslinked liners decrease subsequent revision rates by 20% or more, increased use of crosslinked liners will result in net savings as well as improved patient quality of life. Discussion/Conclusions: Our model indicates that crosslinked prostheses have the potential to provide cost-savings. More accurate national projections may be available in the future from analysis of Medicare data. Despite limitations, the economic modeling approach used in this study can also be used to evaluate the cost-effectiveness of other alternative bearing technologies for hip replacement, including metal-on-metal and ceramic-on-ceramic bearings.

POSTER NO. P034

Results of Total Hip and Total Knee Arthroplasty in Patients with Synovial Chondromatosis

Patrick W Lett, MD, *Enterprise, AL (n)*
Michael J Stuart, MD, Rochester, MN (*)
Robert T. Trousdale, MD, Rochester, MN (n)
Javad Parvizi, MD, Philadelphia, PA (n)

Introduction: This retrospective review is the first known study evaluating the results of total knee and total hip arthroplasty in patients with synovial chondromatosis. Methods: Thirteen patients with a mean age of 61 years underwent total knee arthroplasty (5 patients) and total hip arthroplasty (8 patients) between 1970 and 2003. Clinical and radiographic follow-up on all patients averaged 8 years. Results: The mean interval from diagnosis of synovial chondromatosis to joint replacement surgery was 5.7 years (range, 0 to 13 years). Pain and functional status improved significantly in all patients according to Knee Society and Harris Hip Scores. No known infections occurred in either group. Knee range of motion increased from a mean range of -20 to 83 degrees pre-operatively to –5 to 102 degrees post-operatively. Three knees required postoperative manipulation under anesthesia for stiffness and two required synovectomy for recurrence of disease (40%). None of the knees were revised for component loosening. Two hips underwent re-operation for recurrence of disease (25%) and one for component loosening. Discussion and Conclusions: Total knee and hip arthroplasty in patients with synovial chondromatosis results in predictable pain relief and functional improvement. However, re-operation for disease recurrence is not uncommon. Postoperative knee range of motion is less than the norm, but consistent with the preoperative stiffness observed in this cohort.

POSTER NO. P035

Femoral Component Revision Using an Extensively HA-Coated Stem

Arthur L Malkani, MD, *Louisville, KY (n)*
Charles Crawford, MD, Louisville, KY (n)
Stephen J Incavo, MD, Burlington, VT
(e – Stryker Howmedica Osteonics)
Hugh B Morris, MD, Winter Park, FL
(e – Stryker Howmedica Osteonics)
Ryan Krupp, MD, Louisville, KY (n)

Introduction: The purpose of this study was to determine the results of femoral component revision with an extensively hydroxyapatite-coated stem. We hypothesize that hydroxyapatite coating will improve the clinical and radiographic results of extensively coated femoral revision stems. Methods: This was a retrospective review of 59 consecutive patients with historical controls. The average age was 70 years (range 32 to 94 years). There were 31 males and 28 females. The average length of follow up was 4.3 years (range 3 to 6.5 years). Patients were evaluated at regular postoperative intervals. Radiographs were evaluated for fracture, loosening, subsidence, stress shielding, osteolysis, and bone condensation. Results: At latest follow up, two patients had died and eight were lost to follow up leaving 49 patients available for review. The average preoperative Harris Hip Score was 42 points which improved to 85 points (p less than 0.01). Thirty-eight patients had no evidence of stress shielding. Nine patients had bone condensation at the proximal femur. There was only one case of mechanical failure which occurred following a recognized intraoperative fracture treated with cerclage wiring. Additional complications included two cases with postoperative fractures of the greater trochanter, two deep infections, and two cases of acetabular component loosening. Discussion and Conclusion: The results of this series using an extensively HA-coated stem are comparable to those using an extensively porous-coated stem. Long-term clinical follow up is required to determine if an extensively HA-coated implant, which can provide proximal ingrowth and minimize stress shielding, will be superior to an extensively porous coated implant.

POSTER NO. P036

Five Year Results of a Second Generation Hydroxyapatite Coated Acetabular Implant

Peter M Bonutti, MD, *Effingham, IL (e – Stryker)*
Ms. Colleen Kazmareck, Baltimore, MD (n)
Margot McMahon, RN, Effingham, IL (n)

Introduction: Hydroxyapatite (HA) coated total hip arthroplasty has shown excellent femoral survivorship (98% for 8-10 year follow-up). However, first generation HA coated acetabular components have shown a high failure rate (10-12%) occurring 2 to 4 years post implantation. The original design, HA over a smooth titanium acetabular component, appeared to contribute to these failures. The goal of this study was to evaluate whether a second generation HA coated acetabular component over a grit blasted titanium surface would improve acetabular survivorship beyond 4 years. Methods: 209 consecutive total hip arthroplasties performed by a single surgeon were followed radiographically for a minimum of 4.5 years (range, 4.5 -6 years). Patients had a mean age of 72 years (range, 37-92) with 118 women and 91 men. All components were cementless HA coated acetabular implants of the same design with additional screw augmentation. Results: At final follow-up, all but one acetabular implants were well fixed. One patient was revised and at revision had minimal acetabular on-growth but a stable femur. A biopsy showed Paget's disease, two patients died and two lost to follow-up. Four patients showed evidence of poly wear - 1 revised. Three re-operations occured for instability and four revisions. All femoral and all but one acetabular components were radiographically stable and well fixed. Discussion: Second generation HA acetabular components appear to have eliminated loosening problems of the orginal design identified at 2-4 year follow-up. These second generation HA acetabular components show 99% acetabular and 100% femoral survivorship at this intermediate follow-up.

POSTER NO. P037

Alternative Prophylaxis for Total Joint Arthoplasty

Craig Della Valle, MD, *Chicago, IL (a,b,e – Zimmer)*
Eric Chang, MD, New York, NY (n)
Paul E Di Cesare, MD, New York, NY (n)

INTRODUCTION: Infection by low virulent microorganisms is a devasting complication of total joint arthroplasty. Antibiotics commonly used for prophylaxis do not always provide adequate coverage. The pupose of this study was to evaluate the major organisms infecting total joint arthroplasty and their sensitivities to antibiotics. METHODS: A retrospective analysis of the major organisms affecting total joint arthroplasty and their sensitivities from 1990 to present were tabulated. A total of 207 cases from two institutions were evaluated for cultures and sensitivities. The resistance of the major organisms was compared to our normal prophylactic regimen to determine what percentages are resistant to the normal prophylactic antibiotics. RESULTS: The information obtained included the organism grown from culture and the

antibioitic sensitivity and resistance of the organism. The main organisms found in the population were Staphylococcus species (135) 65% {Aureus 71, Epidermis 63} Streptococcus species (21) 10%, Enterococcus species (17) 8%, Corynebacterium species (7) 3%, Pseudomonas species (6) 3%, and all other microorganisms (21) 10%. Their antibiotic sensitivities are: Vancomycin 94.1%, Gentamicin 86.5%, Clindamycin 72.4%, Cefazolin 61.3%, Oxacillin 55.7%, and Penicillin 27.2%. DISCUSSION AND CONCLUSIONS: This study suggests that prophylaxis with vancomycin, gentamicin, or clindamycin will prevent infections more effectively than compared to Ancef. The most frequent organisms to cause infection are the Staphylococcus species, Streptococcus species, and Enterococcus species. Ancef is inadequare to prevent infections with the common organisms seen in total joint arthroplasty.

POSTER NO. P038

Impingement Contributes to Backside Polyethylene Wear and Metallosis of Modular Acetabular Cups

Douglas E Padgett, MD, *New York, NY (n)*
Mordechai Kligman, MD, Queens, NY (*)
Bridgette D Furman, Res Eng, New York, NY (*)
Timothy M Wright, PhD, Stamford, CT (n)

Background: Modular acetabular components with screw fixation are associated with polyethylene liner wear and metallosis. Impingement between acetabular and femoral components produces abnormal loads on the edge of the implant resulting in wear debris and may increase the motion between polyethylene liner and metal shell. The Purpose of our study was to evaluate the effect of impingement on backside polyethylene wear and metallic shell – screw corrosion and fretting. Methods: 86 modular acetabular components were subjectively evaluated by visual and stereomicroscopic examination. Impingement, backside polyethylene damage, corrosion and fretting at the screw – metallic shell interface were assessed on the basis of the location and the severity using a subjective scoring system. Demographic data and revision diagnosis were obtained from each patient's medical records, and component position was determined from radiographsResults: Impingement was found in 62 cups (75 percent). Inner and backside polyethylene wear and screw-metallic shell corrosion and fretting were significantly correlated (p value less than 0.001) with impingement. Polyethylene creep was significantly correlated to backside wear and tended to be higher for the cups that had impingement (p value equal to 0.06). No correlation was found between backside polyethylene wear and implant design or cup position. Conclusion: Impingement in a modular acetabular cup is associated with increased backside polyethylene wear and screw-metallic shell fretting. This association could be due to increased micromotion between the polyethylene liner and screw-metallic shell interface during impingement and to increased polyethylene stresses on the side of the component opposite the impingement as the contact area moves closer to the rim of the component.

POSTER NO. P039

Position of the Acetabular Component after THA: A New Computed Tomography Method

Henrik Olivecrona, MD, *Enebyberg, Sweden (n)*
Lars Weidenhiden, MD, Stockholm, Sweden
(a – KI Funds for Research, d – X3D, Ltd)
Lotta Olivecrona, MD, Stockholm, Sweden (n)
Marilyn Noz, Prof, New York, NY (n)
Gerald Maguire, Jr Prof, Stockholm, Sweden (n)
Michael Zeleznik, Salt Lake City, UT (*)

Retroversion of the acetabular component in total hip arthroplasty (THA) is associated with increased dislocation risk. Surgical intervention to correct misplaced components should be considered early in cooperative patients. Assessment of acetabular component position is usually done on anterior-posterior and lateral radiographs. The position of the patient on the examination table, the direction of the roentgen beams and the plane of the film will affect the angles of the component position. Consequently precision in these assessments is highly variable and no validated three dimensional measurement methods exist to our knowledge. We present a new method to determine the spatial orientation of the acetabular component after total hip arthroplasty using computed tomography (CT). Two CT-scans, 10 minutes apart, were obtained from each of 10 patients after THA. Two independent examiners measured the component position in the pelvis with a locally developed image analysis program. The measurements were repeated after one week. To be independent of patient position during scanning, a 3D volumetric image of the pelvis was first brought into a standard orientation and then the acetabular component position was assessed. It was expressed as anteversion and inclination angle in relation to an internal pelvic reference plane and compared across pairs of volumes between observer and trials. The position could be determined with a precision of 3° for anteversion and 1.5° for inclination which is much higher than with conventional radiographic measurements. There was no difference between intra- and inter-observer measurements. Data was normally distributed.

POSTER NO. P040

The Use of Antibiotic Impregnated Cement in Total Hip Arthroplasty: A Meta-Analysis Study

Derek M Bennett, *Baltimore, MD (n)*
Gracia Etienne, MD, Baltimore, MD (n)
Michael A Mont, MD, Baltimore, MD (n)
Phillip Ragland, MD, Blandsberg, MD (*)
Khaled J Saleh, MD, Minneapolis, MN
(a – Stryker Howmedica Osteonics)
Javad Parvizi, MD, Philadelphia, PA (n)

Introduction It is common to use antibiotic impregnated cement for spacers as an intermediate stage of treatment of infected total hip arthroplasties. It is controversial whether antibiotic-cement should be utilized in primary or revision hip arthroplasty. This study analyzed the literature to assess efficacy and safety of this treatment method. Methods A literature search was performed analyzing reports that contained outcome data on hip replacements performed with antibiotic cement. Strict inclusion criteria for studies encompassed general surveys, prospective and multicenter studies, but excluded less than 20 patient reports. Nineteen studies met this standard including 6,033 hips in 5,659 patients (4 primary hip and 15 revision hip studies). Analysis included survival rates, infection rates, and assessments by types of antibiotics. Results: Overall, there was a survival rate of 98%

(101 failures of 5178 hips) in primaries and 88% (100 failures of 855 hips) for revisions. The infection rate was 1.2% for primaries, which was lower than the 2.3% reported for hips from the same comparison studies. The infection rate for revisions was 11%. Revision hips treated with combinations or culture dependent antibiotics had a lower infection rate (6%). There were no adverse events or complications associated with the use of antibiotic-cement reported. Discussion The use of antibiotic-cement lowered infection rates by approximately 50% in primary hips. For revisions of previously infected hips, combinations or culture- dependent antibiotics lowered infection rates by approximately 40%. The reasons for these findings deserve further investigation.

POSTER NO. P041

Cup Orientation in Total Hip Prosthesis: Influence of Sagittal Posture After Lumbosacral Fusion

Jean Yves Lazennec, MD, *Paris, France (n)*
Michel Gorin, MD, Paris, France (n)
Gerard Saillant, MD, Paris, France (n)

Changes in pelvic orientation between standing and sitting positions modify acetabular tilt in sagittal plane and anteversion in transverse plane. Sagittal posture modifications induced by spine surgery create new anatomical conditions and may have unattended consequences. Material and methods 24 patients with 29 THP were studied prospectively before and after spinal deformity correction (5 long fixations , 8 wedge osteotomies for kyphosis and 11 spinal revisions for flat back) . Sagittal correction was studied on lateral X rays standing and sitting , with special reference to Sacral Tilting angle (ST) Acetabular cup anteversion was studied with CT scan pre operatively, and post operatively (1 and 2 years follow-up). Results In 17 patients spinal surgery induced significant anterior pelvic tilt (ST increased more than 10 degrees) and reduction of cup anteversion (mean 12 degrees ; 6 to 21 degrees). The anteversion variation depended on initial cup position as assessed in 5 bilateral THP . The modifications remained the same at maximum follow-up .Posterior THP dislocations occured in 1 patient. In 2 patients an unexpected posterior pelvic tilt was associated with an increase of anteversion (8 and 13 degrees) . Anterior THP instability occured in 1 patient. In 5 of the patients no significant modification of ST angle was observed and anteversion variation was neglictible Discussion and Conclusion Lumbosacral posture influences sacral tilt and acetabular anteversion . A geometrical model has been developed to calculate anteversion variations. Surgical planning of spinal sagittal correction must analyze consequences on pelvis and hips, especially in patients with THP.

POSTER NO. P042

In-vitro Comparison of Conventional vs. Highly Crosslinked UHMPWE Against 36 and 40-mm Femoral Heads

Brian Burroughs, PHD, *Boston, MA (a – Zimmer)*
Orhun K Muratoglu, PhD, Cambridge, MA (a,c – Zimmer)
Steve Christensen, BS, Boston, MA (a – Zimmer)
Andrew J Lozynsky, Boston, MA (a – Zimmer)
Gordon Plank, Boston, MA (a – Zimmer)
Anna Huang, Boston, MA(a – Zimmer)
William H Harris, MD, Boston, MA (*)

Introduction: The purpose of this study was to evaluate wear, device fatigue behavior, and integrity of the locking mechanism over long-term testing of aged conventional and highly-crosslinked UHMWPE acetabular liners specifically used in conjunction with 36 and 40-mm diameter femoral heads. We hypothesized that the highly-crosslinked UHMWPE would demonstrate not only lower wear but also show no evidence of device fatigue failure. Methods: Liners manufactured from either conventional (gamma irradiated in an oxygenless environment) or highly-crosslinked UHMWPE were tested under simulated gait on a Boston hip simulator to 12 million-cycles. All liners were artificially aged. Conventional liners were tested against 40-mm femoral heads and highly-crosslinked liners were tested against 36 and 40-mm femoral heads (n=4 for each type). Wear was determined gravimetrically. Results: Wear rates for the 40-mm conventional, 36-mm highly-crosslinked, 40mm highly-crosslinked were respectively, 13.7±6.36, 0.23±0.06, and 0.17±0.03-milligrams/million-cycles. At 7 million-cycles, the anti-rotation posts on the rim of the shells began penetrating progressively into the abutting polyethylene in each of the aged conventional liners. At 12 million-cycles, the integrity of the anti-rotation portion of the locking mechanism was lost in the conventional liners. No such degradation of the locking mechanism or other evidence of device fatigue failure occurred in any of the highly-crosslinked liners. Conclusion: In this hip simulator study, highly-crosslinked UHMWPE was shown to have two important advantages, namely, substantially improved wear resistance even against larger femoral heads and superior device fatigue resistance as demonstrated by maintaining the integrity of the anti-rotation locking mechanism.

POSTER NO. P043

Constrained Acetabular Liners: Mechanisms of Failure

Andrew Yun, MD, *Inglewood, CA (n)*
Douglas E Padgett, MD, New York, NY (n)
Paul M Pellicci, MD, New York, NY (n)

Introduction: As the growing usage of constrained acetabular liners has produced a number of unique complications, our purpose was to identify mechanisms of failure using these liners and to recommend strategies to avoid them. Materials and Methods: From a pool of 240 hips treated with constrained liners for recurrent or intraoperative instability, 27 patients with 29 hips who experienced an initial failure of the constrained acetabular construct were studied. Eight of these patients had a second recurrent failure of the constrained liners. Clinical, implant retrieval, and radiographic data were reviewed retrospectively. The time to failure ranged from 0 to 69 months. Results: Four key modes of failure were identified. Of 37 total failures, 16 hips failed by progressive loss of fixation to the pelvis, 12 by dissociation of the constrained polyethylene liner from the metal shell, 7 by biomaterial failure with polyethylene or retaining ring fracture, and 2 by femoral head dislocation. Repetitive impingement of the femoral trunion against the elevated apex of the liner and surgical error contributed primarily to these modes of liner failure. Discussion: Constrained liners are highly subject to mechanical overload. Potential complications may be minimized by reducing prosthetic impingement, modifying liner design, and avoiding technical errors.

POSTER NO. P044

Custom Total Hip Arthoplasty: 3 to 10 Year Follow-up Study

Behrang Mazahery, MD, *Chicago, IL (n)*
Valerie S Harder, Chicago, IL (n)
James Charles Kudrna, MD, Glenview, IL (n)

Introduction: A custom total hip arthroplasty (THA) was designed to match the highly variable anatomy of the proximal femur, obtain intimate bone contact, and allow for stable long term fixation. The purpose of this study was to investigate the clinical and radiographic results of a primary custom THA. Materials and Methods: The custom implant consisted of a proximally porous coated, distally fluted, titanium alloy stem that was dimensioned using patient-specific preoperative radiographs. A total of 126 consecutive primary custom THAs were implanted, by a single surgeon, into 113 patients (46 female, 67 male). The average age was 50.3 years (range 28 to 69), and the average duration of follow-up was 6.1 years (range 3 to 10). Results: The average Harris Hip Score (HHS) improved from 46 preoperatively to 95 at the latest follow-up. Ninety-eight percent had good to excellent HHS results. No acetabular cups were revised, and only 2 femoral stems required revision. One as a result of a traumatic periprosthetic femur fracture and the second due to subsidence of the stem and debilitating thigh pain. Thigh pain was reported in 3 percent of patients. No acetabular or femoral components were loose at the most recent follow-up. Discussion: Custom THA matches the anatomy of the proximal femur to allow for optimal fixation and stability. The higher cost of the custom THA may be offset by our improved success rate (99 percent). The custom THA remains an excellent choice of an implant, especially for patients with deformity or an abnormal anatomy.

POSTER NO. P045

In Vivo Wear Comparison of Traditional vs E-beam Irradiated, Post-Irradiation Melted, Highly Crosslinked Polyethylene

David W Manning, MD, *Chicago, IL (n)*
Peter P Chiang, MD, Boulder, CO (*)
John M Martell, MD, Chicago, IL (*)
Jorge O Galante, MD, Chicago, IL (a,c – Zimmer)
William H Harris, MD, Boston, MA (*)

Introduction: Highly crosslinked polyethylene is an alternate bearing material designed to improve wear performance and reduce particle disease. Hip simulator data demonstrates that E-beam irradiated, post-irradiation melted polyethylene has improved wear compared to traditional polyethylene. The aim of this study was to compare the in vivo wear performance of such highly crosslinked polyethylene and traditional UHMWPE. We hypothesize that in vivo wear rate of highly crosslinked polyethylene is greatly reduced compared to traditional polyethylene. Methods: 109 hips with highly crosslinked polyethylene and follow-up duration of up to 44 months had 243 acceptable radiograph pairs for wear analysis. An age matched population of patients with traditional polyethylene and 4 year follow up served as a control group. Two-dimensional vector wear analysis was performed on each series using the Martell system, which has been shown to determine 90 percent of 3-dimensional femoral head penetration. Steady state and overall wear rates for highly crosslinked and traditional polyethylene were compared. ANOVA was performed to assess the effect of traditional wear variables (head size, gender, activity level, and BMI). Results: Highly crosslinked polyethylene steady state wear rate was 8 micra/year vs. 114 micra/year with traditional polyethylene. Crosslinked polyethylene penetration rate was not effected by traditional wear factors (head size, gender, age, activity level, or BMI). Conclusions: In this in vivo comparative wear study, highly crosslinked polyethylene steady state wear was 93 percent less than similarly determined steady state wear in traditional polyethylene. Traditional wear factors appeared to make no difference.

POSTER NO. P046

Strength and Modularity: Engineering for Successful and Durable Modular Femoral Components in THA

Ronald Sekel, MD, *Kogarah NSW, Australia (a,d,e – Portland Orthopaedics)*
Peta Wingrove, PhD, Double Bay, Australia (*)
Ronen Debi, MD, Double Bay, Australia (n)
Robert W Eberle, PhD, Apex, NC (n)

INTRODUCTION: Recently, much attention has been paid to the effect of modular femoral component design and reported failures. The purpose of this scientific exhibit is to review and recommend the engineering principles for successful femoral component modularity for revision THA in the face of significant proximal femoral host bone deficiencies. MATERIALS AND METHODS: Principles of lever arm mechanics were investigated and the effect of various positioned Morse tapers (mid stem to proximal placement). The effect of deflection and resultant crack propagation were calculated and reported. Reviews were performed at various potting levels and various taper junction positions with common implant materials (CoCr and Ti Alloy). RESULTS: Modeled tests yielded calculated results showing increased deflection properties between materials, and subsequent fatigue failure at the Morse taper junction. The increased strength of material of CoCr in conjunction with component design has led to a recommendation of Morse taper placement. This design allows for adjustability in 4-vectors (stem length, offset, neck version and neck length) without compromising the restoration of normal hip mechanics. DISCUSSION AND CONCLUSION: In lieu of current reported failures of mid-stem modular junction femoral components, we propose specific parameters for successful femoral modularity for revision THA in the face of proximal femoral defects.

POSTER NO. P047

Analysis of Bone Support with Straight and Bowed Total Hip Replacements Using Computed Tomography

James Howard, MD, *London, ON Canada (a – Smith&Nephew)*
Andrew Hui, MESc, London, ON Canada (n)
Jig Patel, FRCS, London Ontario, Canada (n)
John Leander Masonis, MD, Charlotte, NC (n)
Harry A Demos, MD, Charleston, SC (n)
Robert Barry Bourne, MD, London, ON Canada (e – Smith&Nephew)
Cecil H Rorabeck, MD, London, ON Canada (a.c – Smith&Nephew)
Steven J MacDonald, MD, London, ON Canada (n)
Richard W McCalden, MD, London, ON Canada (n)

Introduction: Sraight and bowed total hip replacements have been successful in clinical practice to date. The purpose of this study was to determine how stem design and surgical technique effect bone contact patterns in straight and bowed total hip replacements (Echelon) using computed tomography (CT) scan analysis. Methods: Twenty-five cadaveric femurs were radiogrpahed and templated for bowed or straight Echelon femoral components. An experienced orthopedic team prepared the femurs and implanted the femoral stems. Nine bowed stems and sixteen straight stems (eight line-to-line insertion, eight press-fit insertion) were implanted. After implantation, transverse CT images with 1mm thick slices at 5mm intervals were taken along the length of the stem. Contact analysis was performed using custom developed imaging software. Contact was defined as a bone-prosthesis distance of 0.5mm or less. Results: Mean percentage bone-prosthesis contact was 54.3 percent for line-to-line straight stems, 59.0 percent for the press-fit straight stems, and 38.7 percent for the bowed stems. Regional contact analysis was done for all three groups to evaluate differences in contact patterns. Discussion and Conclusions: This study outlines a CT analysis technique that can be used to evaluate differences in contact patterns with a variety of stem designs and surgical techniques. There was no significant difference in bone-prosthesis contact between press-fit and line-to-line techniques for straight stems. Different contact patterns were identified for the bowed and straight femoral implants.

POSTER NO. P048

Radiographic Evaluation of a Non-Modular Acetabular Cup - A 2 to 5 Year Multi-Center Study

Thomas A Gruen, MS, *Wesley Chapel, FL (e – Implex Corporation)*
Michael J Christie, MD, Nashville, TN (*)
Arlen D Hanssen, MD, Rochester, MN (n)
David G Lewallen, MD, Rochester, MN (*)
Randall Lewis, MD, Brandon, FL (*)
Thomas Joseph O'Keefe, MD, Ann Arbor, MI (*)
S David Stulberg, MD, Chicago, IL (*)
Anthony S Unger, MD, Washington, DC (*)
Charles J Sutherland, MD, Toledo, OH (*)

Introduction: Press-fit acetabular reconstructions have become the standard THA; however, controversies remain. The purpose of this study was to critically evaluate serial radiographs for initial cup stability, i.e. gaps and signs of peri-acetabular interface changes for a porous tantalum monoblock socket. Methods: A multicenter study evaluating 574 primary THRs (542 patients) performed by 9 surgeons at 7 hospitals, all with a monoblock cup without screws. Analyses included clinical outcomes and detailed 2-year minimum (mean, 33 months) follow-up radiographic evaluation by one independent observer. Results: Complications included 9 intra-operative acetabular fractures. Among the 123 cases excluded from radiographic evaluations: deceased (19), lost-to-follow-up (8), 7 early revisions (recurrent dislocations (6) and one trauma-related loosening), and sepsis (3). Patient demographics (414 hips): mean age 65 years (19-93); 58 percent females. Baseline radiographs revealed 113 zones in 85 hips (21 percent) with acetabular gaps; 36 in zone I, 72 in zone II, and 5 in zone III. Of these radiolucencies, 57 zones were 1 mm or less and 56 zones ranged from 2 to 5 mm. At last follow-up, 64 hips (75 percent) had complete gap fill-in, including 100 percent of gaps greater than 2 mm. Discussion and Conclusions: There were no socket migrations, no evidence of lysis, no revisions for loosening, and no complete periacetabular interface radiolucencies. The fill-in of preexisting OA cysts and interface gaps is attributed to adequate initial stability and osteointegration into the porous tantalum. These results suggest that a monoblock cup without screws is an attractive option in THA.

POSTER NO. P049

6 Year Clinical and Radiographic Review of Cementless Proximally Porous Coated Femoral Revision Stems

Matthew W Squire, MD, *Huntersville, NC (n)*
Richard Lynn Illgen, II, MD, Madison, WI (a – Biomet)
Mark Flanum, MD, Madison, WI (n)
John P Heiner, MD, Madison, WI (a – Biomet)

The optimal strategy for femoral component revision after failed total hip arthroplasty is still debated. This study investigated the clinical and radiographic performance of proximally porous coated femoral revision components at intermediate-term follow-up. A 40 patient cohort with 42 proximally porous coated cementless femoral revision stems was identified. For all patients, serial radiographs were reviewed and Harris Hip Scores were computed. Statistical and survival analyses were performed.Average clinical and radiographic follow-up for all patients was 6.4 years. Harris Hip Scores averaged 87 points. The index femoral stem was cementless (group A) in 15 femurs and cemented (group B) in 27 femurs. Within the entire cohort, 16 of 42 (38%) stems subsided. In group A, 2 of 15 (13%) stems subsided. In group B, 14 of 27 (52%) stems subsided. The incidence of subsidence was significantly increased ($p<0.05$) in group B. The overall mechanical failure rate was 9.5% (4 of 42 stems): 2 re-revisions for aseptic loosening and 2 stems with progressive subsidence. There were no stem failures in group A. There were 4 stem failures in group B. Because of limited patient numbers, this difference did not reach statistical significance. Kaplan-Meier analysis predicted 87% of stems to remain in situ at 12 years.At average 6.4 year review, 95% of proximally porous coated revision stems remained in place. However, when the index arthroplasty was cemented, the incidence of stem subsidence was significantly increased and a trend for increased stem re-revision as well as progressive subsidence was identified.

POSTER NO. P050

Comparison of Surgical Approaches in Chiari Pelvic Osteotomy

Hiroshi Ito, MD, *Asahikawa, Japan (n)*
Tadashi Teranishi, MD, Asahikawa, Japan (n)
Meguru Okamoto, MD, Asahikawa, Japan (n)
Takeo Matsuno, MD, Asahikawa, Japan (n)
Akio Minami, Sapporo, Japan (n)

(INTRODUCTION) Chiari originally described the osteotomy technique using an anterior approach and several modified techniques including different surgical approaches have been recommended. Our experience includes use of three different approaches for patients with hip dysplasia. The purpose of this study was to determine whether osteotomy at a more appropriate level and effective distal greater trochanter advancement could be achieved using transtrochanteric approaches. (METHODS) 135 hips in 129 patients with a mean age of 24 years were followed for an average of 16 years (5 to 24). The anterior ilio-femoral approach without trochanteric osteotomy was used in the initial 31 hips. A posterolateral approach was used in the next 79 hips and Ollier lateral U approach was used in the most recent 25 hips, both with trochanteric osteotomy. (RESULTS) An excellent or good clinical result was obtained in 103 hips (77%). Multivariate analysis showed that transtrochanteric surgical approaches ($p = 0.034$), an appropriate osteotomy level ($p = 0.003$), and intraoperative use of radiograph or fluoroscopy ($p = 0.012$) were significant factors. Although the follow-up period was shorter in 104 hips treated using the transtrochanteric approach ($p < 0.001$), clinical results in those were superior ($p = 0.041$), the osteotomy level was more appropriate ($p = 0.018$) and Trendelenburg gait was less frequent ($p = 0.001$) than those in 31 hips treated using the anterior approach. (DISCUSSION AND CONCLUSION) We recommend transtrochanteric approaches to perform the osteotomy at a more appropriate level and achieve effective distal advancement of the high-riding greater trochanter.

POSTER NO. P051

Modular Femoral Head and Liner Exchange for the Unstable Total Hip Replacement (THR)

Ayaz A Biviji, MD, *Irvine, CA*
(a – Scripps Clinic Orthopaedic Research & Education)
Kace A Ezzet, MD, La Jolla, CA (n)
Leslie McCoy, BSN, La Jolla, CA (*)
Pamela Pulido, RN, Encinitas, CA (n)
Mary S Tauson, BA, La Jolla, CA (n)
Mary Hardwick, RN, La Jolla, CA (n)
Clifford W Colwell, Jr, MD, La Jolla, CA (n)

Introduction: Dislocation is a common complication after THR. Modular femoral head and acetabular liner exchange is accepted for recurrent hip instability when acetabular shell and femoral stem are in excellent position. This study evaluates outcomes of femoral head and liner exchange in treating hip instability and examines factors predicting success. Methods: From January 1, 1990 to December 31, 2000, forty-nine revisions were modular exchanges for instability. Demographic, implant, operative, and postoperative data were collected by chart review. Phone survey determined dislocations treated at other facilities and assessed patient satisfaction. Timing and direction of dislocations, previous revision surgery, head and acetabular cup size were possible outcome predictors; failure was defined as two or more redislocations or further surgery. Results: Minimum two-year followup data, mean 54.1 (26-93) months, was available for 42 modular exchanges. Thirty-one primary and 11 revision surgeries were performed before modular exchange. Average time from surgery to first dislocation was 8.9 (0- 45.5) months with equal distribution of anterior and posterior. Average dislocations prior to modular exchange were 3.1 (1-6); average age at modular surgery was 70 (52-88). Twenty-eight patients (67 percent) had no further dislocations. Two patients, one dislocation each, were considered successful (71 percent overall). In twelve patients (29 percent) who failed treatment, 9 (21 percent) had further revision. Factors examined were not found to be outcome predictors. Conclusion: Isolated modular component exchange can be successful in treating recurrent dislocations after THR; a significant failure rate not easily predicted remains even with excellent appearing component position.

POSTER NO. P052

◆Hybrid Ceramic-on-Ceramic THA: Intermediate Follow-Up Results

Jonathan P Garino, MD, *Philadelphia, PA*
(e – Smith&Nephew, Cerantec)
Dinh Vu, BSE, Philadelphia, PA (n)
Reema Marks, BA, Philadelphia, PA (n)

Purpose: The purpose of this study is to report the prospective 5 year minimum follow-up results for modern hybrid ceramic-on-ceramic total hip arthroplasty. Methods: The inpatient and outpatient records of patients enrolled by a single surgeon in two sponsored IDE research trials were prospectively reviewed. Patients received a modular ceramic acetabular component and a cemented femoral component with a ceramic ball. Patients were evaluated pre- and post-operatively at 6 weeks, 3, 6 and 12 months and subsequently on an annual basis. Follow-up evaluation consisted of radiographs, SF-12 questionnaire, and Harris hip score. Results: Between 1997 and 1998, 88 primary hips in 77 patients (40 women, 36 men) were enrolled in the study. Average age: 46 years (range 22 - 76 years). Average follow-up: 5 years (range 5- 6 years). At latest follow-up, no patients had evidence of clinical or radiographic loosening and there were no ceramic fractures. Average Harris hip scores improved from 43.0 to 92.4 post-operatively. Complications included two early revisions for anterior instability, one revision for late infection, one revision for acetabular component migration in a patient with severe osteoporosis. Medical complications included four cardiovascular events, one pneumonia, one pulmonary embolism, one dislocation and two DVT events. There were no complications of the ceramic components. Discussion and Conclusion: Intermediate results for modern hybrid ceramic-on-ceramic total hip arthroplasty are promising and support continued use of this technology.

POSTER NO. P053

Do Failing Femoral Components Create a Varus Femur?

Todd Sekundiak, MD, *Omaha, NE (n)*

Introduction: Osteolysis and aseptic loosening of femoral components commonly leads to varus remodelling femur. A radiographic analysis was performed to determine the extent of remodelling and the alteration in component insertion that was required. Materials and Methods: Two-hundred forty-three consecutive extended trochanteric osteotomies were reviewed when femoral hip revision occurred. Two-hundred thirty-five revision procedures and their radiographs were available for review. All revisions were performed with straight or bowed

cylindrical press-fit components. A minimum two year follow-up was performed on all radiographs. The antero-posterior and lateral femoral radiographs were reviewed pre-operatively and post-operatively. Evidence of trochanteric union, migration, and fragmentation was sought. The medial femoral bone was also identified to determine if fracture or osteotomy occurred indicating remodelling of the femur had occurred to accomodate the straight stems. Results: Five osteotomies did show escape with migration and nonunion at their distal extent. An additional five osteotomies showed no evidence of union but with no migration. Six osteotomies did fragment but went on to unite to the host. Fifty-one of the osteotomies demonstrated a fracture or osteotomy on the medial aspect of the femur which allowed apposition to the femoral component. Forty-eight (94 percent) of the transverse osteotomies healed. Medial femoral bone repositioning demonstrated not only varus but flexion remodelling in these cases. Conclusion: Varus remodelling of the failed femur is real. Twenty-two percent of failed femurs required transverse osteotomies to allow for straight implantation of cylindrical stems. No sequelae were evident with conversion of the lateral osteotomy to a transverse type. Implantation of straight cylindrical stems without osteotomies should therefore be cautioned.

POSTER NO. P054 - WITHDRAWN

POSTER NO. P055

Bilateral Total Hip Arthroplasty

David George Nazarian, MD, *Philadelphia, PA (e – Zimmer)*
Frank P Femino, MD, Belleville, NJ (e – Zimmer)
Robert Emrey Booth Jr, MD, Philadelphia, PA (a,c – Zimmer)

Introduction: Controversy exists whether simultaneous bilateral total hip arthroplasty has a higher risk of complications with poorer outcomes than staged bilateral procedures or in unilateral arthroplasty for unilateral hip degeneration. This study compares a consecutive series of bilateral total hip arthroplasties with a consecutive series of patients who underwent unilateral total hip arthroplasty for unilateral arthrosis. Materials & Methods: One hundred patients underwent bilateral total hip arthroplasty and 100 patients underwent unilateral arthroplasty. All procedures were performed using a direct lateral approach with the patient supine. A cementless acetabular and femoral implant of the same design was used. All patients were placed in a weight bearing as tolerated therapy regimen. Patients were followed, average 4.2 years (range 2-6), radiographically and clinically with a modified Harris Hip Score. Emphasis was placed on evaluation of the relative risks, complications, cost, and the need for post-operative rehabilitation. Results: The average hip scores improved from 48 preoperatively to 86 postoperatively in the bilateral hip group and from 47 to 87 for the unilateral group. The average surgical time was 48 minutes for each hip with an average 15 minute turnover time between sides for bilateral hips. Slightly higher postoperative complications in the bilateral group included postoperative confusion (7 percent versus 3 percent), cardiopulmonary complications (5 percent versus 3 percent), and postoperative rehabilitation time (8 weeks versus 6 weeks) with no statistical significance ($p < .05$). The length of hospital stay (4.9 days versus 4.8 days) was similar in both groups, but there was a significantly higher need for inpatient rehabilitation (6 days versus 2 days) in the bilateral group. Conclusion: The results of this study compare favorably with previous reports of bilateral hip arthroplasty without a significant increase in complications. Several factors, which have contributed to this success rate, include the use of cementless components, rapid surgical time, and the direct lateral surgical approach. Thus, bilateral non-staged hip arthroplasty should be considered a viable procedure with results approaching that of unilateral hip arthroplasty.

POSTER NO. P056

Femoral Revision with the Kent Hip Prosthesis

Shaun Alan Sexton, BA MA MBBS, MRCS, *London, United Kingdom (n)*
Clifford Stossel, FRCS, London, United Kingdom (c,d – Biomet Merck, Ltd)
Fares Sami Haddad, FRCS, London, United Kingdom (n)

Introduction: Revision total hip replacement is challenging when there is severe proximal bone loss. The Kent hip femoral prosthesis – a distally locked femoral stem - was designed to overcome this difficulty, however no study to date has assessed its durability. Methods: We independently reviewed the results of all 145 Kent Hip Prostheses used at one hospital between 1987 and 2000. The indication for revision was aseptic loosening in 75, periprosthetic fracture in 37, septic loosening in 2, and severe bony deformity in 24. In the remaining 7 cases, a Kent hip prosthesis was inserted in the presence of metastatic tumour in the proximal femur to enable mobilisation. A functional evaluation of these patients using the Oxford Hip Score and a survival analysis of the stems was performed. Results: The mean duration of follow-up was 5.1 years (range 2 years to 15 years). The median time to full weight bearing following surgery was 2 days and mean hospital stay was 13 days. Almost all patients experienced substantial improvement in hip related pain and disability (as measured by the Oxford Hip Score). 10 stems required further revision. Taking removal of the stem for any cause as the end point, cumulative survival at 15 years using Kaplan-Meier survivorship analysis was 77 percent. Conclusions: Cumulative survival rates for the Kent hip femoral prosthesis compare favourably with other revision stems used where there is severe proximal bone loss. It enables early full weight bearing and hospital discharge, resulting in a low post-operative medical complication rate. However the need for continuing follow-up remains, since the rate of complications such as locking screw fracture, aseptic loosening, and periprosthetic fracture, may increase in the future.

POSTER NO. P057

Nine Year Survival of a Cemented Femoral Component with Proximal and Distal Centralizers

S David Jarrett, MD, *Chapel Hill, NC (a – Zimmer)*
Paul F Lachiewicz, MD, Chapel Hill, NC (a,e – Zimmer)
Elizabeth S Soileau, RN, Chapel Hill, NC (a – Zimmer)

It has been reported that a roughened surface cemented femoral component with proximal and distal cement centralizers has a high rate of early failure. This study analyzed prospectively obtained data on 166 hybrid total hip arthroplasties performed by one surgeon, with survival analysis to 9 years. Detailed clinical and radiographic analysis was performed for 130 hips with follow-up of 5-11years (mean 7). There were 80 hips in females and 50 in males; mean patient age was 69.5 years. The cement grade was A or B in 79 hips (61%), C1 in 23 hips (18%) and C2 in 28 hips (21%). The mean postop hip score was 87 and 95% of hips were pain free. The overall rate of failure (revision for loosening and radiographic loosening) was 3% (4 of 130 hips), with a survival of 97.1% (C.I. 94-99%) at 9 years. There was a significant association between a poor cement grade and femoral

component failure. A previous study of this femoral component reported a 12.5% rate of early failure. However, that study had the confounding variables of the use of Hylamer polyethylene and ceramic heads. The low rate of failure and revision of this component at 9 years, implanted with standard polyethylene and a cobalt-chrome head is more representative of the results with this cemented femoral component.

POSTER NO. P058

Longer Term Follow-Up Of Total Hip Arthroplasties in Patients with Juvenile Chronic Arthritis

Mychelle Lorrayne Shegog, MD, *Stanford, CA (n)*
Daniel F Haber, MD, San Jose, CA (*)
Susanna N Imrie, PT, Los Gatos, CA (n)
Stuart Barry Goodman, MD, Stanford, CA (*)

Forty-two primary total hip arthroplasties (THA) in 24 patients with juvenile chronic arthritis (JCA) were preformed by one surgeon and followed prospectively. In all patients undersized components were utilized to accommodate the small anatomy of the hip with JCA. The majority of the arthroplasties were cementless (34/42). Of those patients with poor bone stock requiring cemented prostheses, six were hybrid (cemented femur, cementless acetabulum) and two required cement for both components. For the purposes of this report only those hips with more than three years of follow-up were assessed (24/42). The average follow-up period was 97 months (53-176). The six men and nine women underwent surgery at an average age of 21 (14-31). The average Harris Hip score improved significantly from 36 to 73 ($p < .01$), despite polyarticular disease. For the majority of the hips (22/24), the patients had lasting pain relief and maintained their post-operative improvement in activities of daily living. Two cementless hips required revision for acetabular wear and osteolysis; one cemented femoral stem was revised for loosening and osteolysis. One patient died of complications related to JCA and lupus (renal failure). THA in patients with JCA provides a durable reconstruction and enables relief of pain and improved function in the long term. The major problem remaining appears to be periprosthetic osteolysis which compromises the limited bone stock in these young patients.

POSTER NO. P059

A Prospective, Randomized Study Comparing Marathon and Enduron Polyethylene Liners: 3 Year Results

Christi Sychterz, MS, *Wyomissing, PA (n)*
C Anderson Engh Jr, MD, Alexandria, VA
(a – Inova Hospital System, e - DePuy)
Charles A Engh Sr, MD, Arlington, VA
(d,e – Johnson&Johnson)

In 1999, the authors began a prospective, randomized study to compare the clinical performance of DePuy's highly cross-linked polyethylene acetabular liner (Marathon) to that of conventional Enduron polyethylene sterilized by gas plasma. Over two years, 236 hips were enrolled in the IRB approved study. At the writing of this abstract, 126 patients had a minimum follow-up of 3 years (mean 3.4 years). For these patients, we used a computer-assisted radiographic technique to measure polyethylene wear rates. Linear regression analysis modeled temporal head penetration data for each component. The slope of the regression line for an individual liner represented the true wear rate of that component. Mean true wear rate for the group averaged 0.13 +/- 0.35 mm per year. Because we assessed wear at such an early follow-up when head penetration into the cup was typically small, there existed an increased potential for measurement error. As a result, calculated true wear rates had several large positive and negative outliers. Excluding 7 outliers with wear rates outside two standard deviations of the mean, we found that the mean true wear rate for the Marathon liners was significantly less than that of the non-irradiated Enduron liners (0.06 versus 0.20 mm per year). Moreover, a significantly greater percentage of Marathon liners had true wear rates less than 0.1 mm per year than did Enduron liners (66 versus 22 percent). These initial clinical data confirm laboratory tests demonstrating a reduction in wear with Marathon polyethylene as compared to non-irradiated Enduron polyethylene. The reduction in mean wear rate was coupled with a significantly greater proportion of low-wearing liners in the Marathon group.

POSTER NO. P060

◆Custom-Made Femoral Prosthesis for the Treatment of Osteoarthritis Due to Developmental Dysplasia

Takashi Sakai, MD, *Suita, Japan (n)*
Nobuhiko Sugano, MD, Suita, Japan (n)
Kenji Ohzono, MD, Suita, Japan (*)
Seung-Bak Lee, MD, Toyonaka, Japan (*)
Takashi Nishii, MD, Osaka, Japan (n)
Hidenobu Miki, MD, Suita, Japan (n)
Hideki Yoshikawa, MD, Osaka, Japan (*)

INTRODUCTION: The morphology of the dysplastic hip is quite different from normal hip. For severe dysplastic hip, custom-made femoral prostheses or modular prostheses are necessary. The purpose of this study is to investigate the clinical and radiographic outcomes of cementless custom-designed femoral prosthesis for the treatment of osteoarthritis due to developmental hip dysplasia. METHODS: A total of 99 consecutive primary cementless custom-designed THAs were performed in 77 patients with dysplastic hip. The mean follow-up was 90 months (range: 72 -112 months). There were 70 females and seven males. The mean age at operation was 54 years (40 - 73 years). Nine patients had a previous femoral osteotomy. Anatomical custom-designed, 125 mm-long, titanium femoral components with blasted surface were fabricated based on the computed tomography data. This components had modular neck and modular head system in order to adjust leg length discrepancy, femoral offset, and femoral anteversion. RESULTS: The mean Harris Hip Score improved from 43 to 95 points at the latest folow-up. 97 patients (98 percent) had more than 80 points for total score. Radiographically, 82 hips (83 percent) showed obiously extensive bone ongrowth onto the middle part of the stem while 14 hips (14 percent) showed stable fibrous fixation. Proximal stress shielding was seen in 46 hips. Osteolysis was identified around one femoral component. Although there was one dislocation, there were no sciatic nerve palsy or deep venous thrombosis. DISCUSSION AND CONCLUSION: Anatomical custom-designed femoral prosthesis without cement provided favorable results in patients with mild or moderate subluxation.

POSTER NO. P061

Hip Arthroplasty in Patients with Liver Cirrhosis

Young-Wan Moon, MD, *Seoul, Korea, Republic of (n)*
Youn Soo Park, MD, Seoul, Korea, Republic of (n)
Yong Sik Kim, MD, Seoul, Korea, Republic of (n)
Shin-Yoon Kim, MD, Daegu, Korea, Republic of (n)
Soon Yong Kwon, MD, Seoul, Korea, Republic of (n)

INTRODUCTION: The purpose of this study was to evaluate the morbidity and mortality of hip arthroplasty in patients with liver cirrhosis. To this date, there has not been any report on this issue. MATERIALS AND METHODS: Between October 1994 and March 2001, hip arthroplasty was performed in thirty patients who were diagnosed as liver cirrhosis. Fourteen patients were received hip arthroplasty for osteonecrosis, nine for hip fracture, four for loosening of THA, and three were for osteoarthritis. The patients were followed with clinical and radiographic evaluation for a minmum of two years or until death. Perioperative complications and survival were investigated and statistical analyses using SAS 8.0 were performed to identify variables associated with the morbidity and mortality. RESULTS: Eight (26.7 percent) patients had one or more postoperative complications. Wound infection occurred in 3 patients (10 percent) and was the most common postoperative complication. Other postoperative complications included surgical site bleeding, coagulopathy, new-onset or worsening of encephalopathy, gastrointestinal bleeding, pneumonia, arrhythmia, and reoperation. The perioperative mortality rate was 6.7 percent. Risk factors associated with perioperative complications were a high Child-Pugh score and increased amount of postoperative drainage. High mortality was associated with an elevated creatinine concentration and increased drainage. CONCLUSION: Although the operative risk was high in this patient group, the hip arthroplasty provided durable clinical and radiographic results after a minimum of two years of follow-up.

POSTER NO. P062

In Vivo Degradation of Gamma Air vs. Inert-Sterilized (Arcom) UHMWPE Acetabular Liners

Steven M Kurtz, PhD, *Philadelphia, PA (a – National Institute of Health)*
William J Hozack, MD, Philadelphia, PA (n)
Joseph Turner, MD, King Of Prussia, PA (n)
Michelle Marcolongo, PhD, Philadelphia, PA (*)
Clare M Rimnac, PhD, Cleveland, OH (a – National Institute of Health)
Avram A Edidin, PhD, Portola Valley, CA (*)

Introduction: During the 1990s, manufacturers adopted barrier packaging to limit degradation during shelf aging of gamma sterilized UHMWPE. We addressed the question of whether in vivo degradation occurs in historical (air) and barrier (inert) sterilized acetabular liners. Methods: 56 modular liners from one manufacturer were retrieved after 0.1-14.5y (8.4y mean). Liners were a first generation (n=34) and a second, contemporary design (n=22). Patients were 55% female with a mean BMI of 27 kg/m2 and a mean age of 56y. The mean shelf life was 0.7y. Implants were traced using lot codes. We identified 17 (gamma inert) liners (ArCom), implanted up to 7.6y. Mechanical properties were measured with the small punch test. Oxidation was quantified using FTIR; sections were viewed under dark field microscopy to look for white bands. Test data were analyzed using multiple regression ($p<0.05$ for significance). Results: For all 56 liners, average ultimate strength ($r2=0.72$) and toughness ($r2=0.55$) was negatively correlated to implantation time, shelf aging, and resin ($p<0.05$). For the subset of 17 ArCom components, significant associations were found between ultimate strength, toughness and implantation time ($p < 0.02$). FTIR and the presence of white bands in thin sections confirmed in vivo oxidation. Discussion: Our data indicate that the mechanical properties of gamma sterilized UHMWPE degrade during long term implantation, but that variability due to shelf aging and resin type also influence mechanical properties. Our ability to detect in vivo degradation is likely facilitated by the short shelf lives (mean, 0.7y) for this group of retrievals.

POSTER NO. P063

Gait Analysis in Minimally Invasive (MIS) Total Hip Arthroplasty

William T Long, MD, *Inglewood, CA (n)*
Leigh E Sirianni, OPA-C, Inglewood, CA (*)

Introduction: To validate that less muscle injury occurs with posterior MIS THA. Gait analysis was performed at pre-op and 6 weeks, 3 months and 6 month post-op. At 3 months, objective data showed an increase in percentage towards normal functional gait strength and stride over standard incision THA. Methods: 12 patients had pre-op, 6 week and 10-14 week and 6 month post op gait analysis with dynamic EMG's on six patients. GA consisted of stride length, cadence, velocity and single length stance. Results were compared to our previously published GA of standard THA incisions. Discussion: At six weeks there was no significant difference comparing pre-op values. At 3 months there were higher percentages in improvement toward normal gait values in the MIS over the Standard from pre-op values in the following areas: Velocity: MIS 12. 6 percent / Standard 3.8 percent, Cadence: MIS 8.9 percent/ Standard 1.1 percent, Stride Length: MIS 9.4 percent/ Standard 2.4 percent. There were no statistical changes in EMG results. Both incisions had the same abnormal phasic muscle firing patterns at each interval. Conclusion: Gait analysis shows objective data that less muscle injury with posterior MIS THA provides patients with improved functional gait skills at an earlier stage in the recovery process over standard incisions. This improvement is in muscle strength because the phasic firing of muscle maintains the same abnormalities as standard incisions.

POSTER NO. P064

Acute Colonic Pseudo-Obstruction after Total Hip and Knee Arthroplasty

Joshua Aaron Urban, MD, *Alexandria, VA (n)*
Joshua Nelson, BA, MD, Omaha, NE (n)
Thomas L Salsbury, MD, Kansas City, MO (*)
Jason Lowry, MD, Kansas City, MO (*)
Kevin L Garvin, MD, Omaha, NE (e – Smith&Nephew)

INTRODUCTION: Acute colonic pseudo-obstruction (ACPO) is an uncommon complication of THA and TKA characterized by massive colonic dilatation and the potential for significant morbidity/mortality. MATERIALS/METHODS: This is a retrospective case-control-review of 1170 THAs and TKAs performed by one surgeon between 1995-2001 identified 18 patients with Ogilvie's. Radiographs and records were analyzed for risk factors and treatment effectiveness. RESULTS: Ten of 708 (1.2%) THAs and eight of 462 (1.5%) TKAs developed Ogilvie's postoperatively. Seventeen of these 18 (94%) patients had preoperative conditions or medications previously identified as risk factors for Ogilvie's. The use of patient-controlled-analgesia was associated with a trend of shorter times to the development of symptoms.

Colonic decompression was performed in 7 patients and was associated with significantly shorter hospitalizations. CONCLUSIONS: ACPO after arthroplasty of the knee is as prevalent as it is after arthroplasty of the hip. Reports of Ogilvie's after TKA are uncommon- the 7 patients in this study is a considerable addition to what has been reported to date. Most patients that develop ACPO have risk factors that can be identified preoperatively. Knowledge of these risk factors enables the treating physician to anticipate which patients may be at higher risk for developing ACPO, and therefore, warrant hyper vigilance for the development of this condition and judicious use of PCA in at-risk patients. This is the first report to quantify the benefit of decompressive colonoscopy in the arthroplasty population which can both reduce the risk of both perforation and the decrease the length of hospitalization.

POSTER NO. P065

Lateral Trochanteric Pain in THA: A Comparison of Direct Lateral and Posterior Approaches

Richard Iorio, MD, *Burlington, MA (n)*
Paul D Warren, MD, Norfolk, VA (*)
William L Healy, MD, Burlington, MA (n)
Kenneth Dhmitri, MSPT, Burlington, MA (n)

Introduction: Lateral trochanteric hip pain (LTP) has been described following primary THA through a trans-trochanteric approach (17%). Modern THA is more commonly performed through the posterior and direct lateral approaches, which have minimized, but not eliminated LTP following primary THA. The purpose of this study was to evaluate the incidence of LTP following primary THA and identify risk factors for this problem. Methods: From 1993 to 1998, 543 primary THA operations were performed for a diagnosis of osteoarthritis. A direct lateral approach was utilized in 461 (85%), and the posterior approach in 82 patients (15%). Patients were followed with a THA database, which recorded all radiographic and clinical data. LTP was recorded clinically at the time of postoperative follow-up. A patient complaint of localized tenderness over the greater trochanteric area identified by the surgeon or by the patient in the THA outcome questionnaire was used to identify patients with LTP. Results: LTP was identified in 24 of 543 patients. The average interval to onset of symptoms was 12 (3-43) months. The average age at the time of diagnosis was 73.5 (58-87) years. 17 female patients and 7 male patients were affected. The overall incidence of LTP in this cohort was 4.4%. The incidence of LTP for the posterior approach was 1.2% (1 of 82) and for the direct lateral approach 4.9% (23 of 461)(P<.01). Leg length discrepancy, femoral offset, and heterotopic ossification were not correlated with the incidence of LTP. There were no reoperations for this diagnosis in this patient cohort. All of these cases of LTP resolved with non-operative treatment, which included NSAID's, physical therapy, local corticosteroid injection, and/or observation. Conclusion: LTP following primary THA is more common in females and less common in patients who undergo a posteror approach to the hip. Compared to historic controls, LTP is much less common with the posterior and direct lateral approaches to the hip than the trans-trochanteric approach to the hip. LTP is effectively treated with non-operative techniques.

POSTER NO. P066

Follow-Up of Periprosthetic Fractures about the Femur and Tibia after Hip and Knee Replacement

Wolfgang Klauser, MD, *Kiel, Germany (n)*
V Stein, MD, Kiel, Germany (n)
Philipp Lubinus, MD, Kiel, Germany (n)
Robert W Eberle, PhD, Apex, NC (n)

INTRODUCTION: The purpose of this study was to report the intermediate to long-term results following treatment of periprosthetic fractures about the knee and hip. MATERIALS AND METHODS: Between 1992 and 2002, 54 patients that suffered from periprosthetic fractures were retrospectively reviewed. Average f/u was 4.2 years. Average Age was 74.2 years. There were 40 female and 14 male patients. For fractures about the hip, the Harris Hip Score was used, for fractures about the knee the Knee Society Score was used. Fractures were classified radiographically according to the classification of Bethea. RESULTS: Of 54 patients, 53 were treated surgically and one was treated conservatively. There were 11 cases (20%), in which a fracture after knee arthroplasty occurred and 43 cases (80%) after hip replacement surgery. Average time from time of implantation to the time of the periprosthetic fracture in this patient group was 9.2 years. Postoperative HHS in patients with periprosthetic fractures about the hip was 74, of the KSS 98. Postoperative complications included failure of fixation in 4 cases (7,5 %), dislocation after implantation of a total femur in 1 case (1,8%) and dislocation of a hinged knee arthroplasty in 1 case(1,8%). DISCUSSION AND CONCLUSION: In cases of aseptically loosened implants and fractures we recommend intramedullary stabilization using cementless revision components. In good bone stock, a long stemmed cemented femoral component may be used. ORIF should only be used in patients that present with good bone stock and the ability of partial weight bearing after surgery.

POSTER NO. P067 - WITHDRAWN

POSTER NO. P068

The Financial Impact of Dislocation as a Complication of Primary Total Hip Arthroplasty

George John Haidukewych, MD, *Rochester, MN (n)*
Carol J. Boberg, RN, Rochester, MN (*)
Bernard F Morrey, MD, Rochester, MN (n)

Purpose:Dislocation remains a common reason for early reoperation after primary total hip arthroplasty. The purpose of this study was to determine the financial impact of dislocation as a complication of primary total hip arthroplasty in a large consecutive series of patients. Materials and Methods:Between January 1997 and December 2000, 2868 primary total hip arthroplasties were performed at our institution. These were prospectively followed at regular intervals utilizing a total joint registry. 77 patients subsequently dislocated (2.7%). The costs evaluated were normalized at 2002 costs obtained through the use of a commercially available Decision Support cost accounting system with ten years use and validation at our institution. Costs are fully absorbed (direct and indirect costs) and provide a complete cost for the episode, including hospital and surgeon. Results:Of the 77 patients that dislocated, 49 (64%) were treated with closed reduction and 28 (36%) required revision. Compared to the uncomplicated total hip arthroplasty, dislocation increased the cost 25% if closed reduction was preformed and 114% if subsequent revision was necessary to achieve stability. Discussion and Conclusion:Dislocation after primary total hip arthroplasty is a costly complication. Approximately 300,000

primary hip arthroplasties are performed yearly. Based on a dislocation rate of approximately 3% yearly, and predicated on the standard cost of a primary replacement, one could extrapolate the additional cost of managing this complication to approach 100 million dollars annually. Every effort should be made to minimize the risk of dislocation.

POSTER NO. P069

Rheumatoid Arthritis is a Risk Factor for the Dislocation after Total Hip Arthroplasty (THA)

Masataka Kita, *Fukuoka, Japan (n)*
Yasuharu Nakashima, MD, Fukuoka, Japan (n)
Seiya S Jingushi, MD, Fukuoka, Japan (n)
Toshihide Shuto, MD, Fukuota, Japan (n)
Takuaki Yamamoto, MD, Fukuoka, Japan (n)
Shinichiro Takasugi, MD, Fukuoka, Japan (n)
Yukihide Iwamoto, MD, Fukuoka, Japan (n)

Background: Dislocation is one of the most common complications after THA. We analyzed the relative influence of various factors on the dislocation and tested the hypothesis whether rheumatoid arthritis (RA) patients have higher risk of dislocation after THA or not. Methods: Analyzed factors included the patient factors (age, sex, disease, body weight, preoperative and postoperative range of motion of the hip), implant position (anteversion and inclination of the components) and seniority of the surgeon. A group of 252 consecutive THAs approached through a posterior incision with repair of the posterior soft tissues were followed for a mean of 32 months. Data analysis included univariate and multivariate methods. Results: The dislocation rate was 1.1% in the primary osteoarthritis (OA) THAs, 11.1% in the primary RA THAs and 4.3% in the revision THAs. RA showed significantly higher rate of dislocation ($p<0.0028$), and older age and revision THA showed the tendency on the dislocations. Pre- and post-operative range of motion of the hip, implant position and seniority of the surgeon did not show significant influences on the dislocation. Multivariate analysis showed that the dislocation risk was 13 times greater in RA primary THAs compared to OA primary THAs. Conclusions: RA patients showed significantly higher rate of dislocation after THA. Surgeons should pay more attention and make efforts to avoid dislocation after THA in RA patients.

POSTER NO. P070

Revision Hip Arthroplasty Using Uncemented, Modular, Fluted Femoral Stems

Javad Parvizi, MD, *Philadelphia, PA (n)*
William J Hozack, MD, Philadelphia, PA (e – Stryker)
Roberto Binazzi, MD, Bologna, Italy (b – Stryker)

Introduction: Total hip arthroplasty continues to be one of the most cost effective and reliable surgical procedures. With increasing number of hip prostheses being implanted in younger patients, there is a steady rise in the number of revision hip arthroplasties being performed. Fluted conical femoral stems, with the theoretical advantage of providing initial rotational stability, have been used at our institution for the reconstruction of femur with inadequate proximal bone stockMethods: Between June1999 to present day, 95 RestorationTM T3 femoral stems (Howmedica, Rutherford, NJ) have been implanted at our institution. RestorationTM T3 is a modular, titanium stem with heavily grit blasted fluted conical distal segment. Radiographs were scanned digitally and using computer assistance subsidence was measured. The interval during which the subsidence occurred was also recorded at various postoperative intervals. The clinical and radiographic surveillance averages 2.1 years. Results: The mean subsidence from surgery to 6-weeks recovery was 1.24 mm (range, 0-9.06 mm), between 6 weeks to 6 months was 3.9 mm (range, 0-25.5), between 6 months to a year was 1.13 mm (range, 0-2.0 mm), and between 1 to 2 year was 1.9 mm (range, 0.01 to 2.0 mm). Subsidence of greater magnitude occurred in hips with Paprosky type 3 or 4 defects ($p<0.05$). A fair number of complications have been observed in our series mostly related to subsidence of the stem and instability. The dislocation was treated successfully with temporary bracing in 8 out of the 10 hips. Reoperation and revision of the acetabular component was carried out in the other 2 hips to address recurrent instability. Three additional reoperations have been carried out for periprosthetic fracture (1 hip), revision of the fluted stem for aseptic loosening (1 hip), and revision of loose acetabular component (1 hip). Another patient with aseptic loosening of the femoral stem is minimally symptomatic but may require reoperation at some point in the future. Conclusions: Fluted conical femoral stems with the ability for stable diaphyseal fixation have a valuable role for reconstruction of femur with inadequate proximal bone stock. These stems, in spite of their problem with subsidence and other complications, continue to be utilized at our institution with encouraging early results.

POSTER NO. P071

◆Effect of Exercise on Metal Levels in Patients with Three Different Metal-on-Metal Hip Replacements

Tomoki Takahashi, MD, *Kumamoto, Japan (n)*
Jan Herman Kuiper, PhD, Oswestry, Shropshire, United Kingdom (n)
Steve Giles, FRCS, Oswestry, United Kingdom (*)
Christine Elizabeth Sieniawska, PhD, Southampton, United Kingdom (n)
James Richardson, MD, Oswestry, United Kingdom (*)

Introduction. Head size and manufacturing process of metal-on-metal articulations are predicted to affect wear production. The purpose of this study is to test a hypothesis that a controlled exercise can differentiate wear production of different metal-on-metal bearing combinations. Methods:Fifteen patients were enrolled in this study; 5 with Birmingham hip resurfacing (47 mm, as cast, group I), 5 with Cormet 2000 hip resurfacing (48 mm, as cast and HIPed, group II) and 5 with Thrust plate Metasul articulation (28 mm, forged, group III). Three volunteers without implant were control. Subjects were asked to run or walk at their own pace for 60 minutes. They wore a pedometer on their waist to count steps. Blood samples were taken before, immediately after and 1 hour after exercise using metal-free cannula. ResultsGroup I had mean cobalt rise of 9.3 nmol/l, group II 7.2, Group III 1.1 nmol/l. Control group had 0.5 nmol/l decrease. Rise in group III was significantly smaller than group I (p equals 0.021) and group II (p equals 0.047, both Finner's adjusted Mann-Whitney). Difference between group I and II was not significant. Rises were not correlated to levels before exercise, number of steps and duration after surgery. Conclusions28 mm forged articulation (group III) gave significantly less cobalt rise after exercise than larger cast resurfacing heads (group I, II). The hypothesis that controlled exercise can differentiate wear production of different metal-on-metal bearing combinations was confirmed.

POSTER NO. P072

Joint Replacement Resident Education and Physician Extenders: A Cost Effectiveness Study

Carlos J Lavernia, MD, *Miami, FL*
(a,d,e – Zimmer, d – Johnson&Johnson)
Michele R Dapuzzo, MD, Hialeah, FL (n)
Victor Hugo Hernandez, Miami, FL (*)
Enrique Roig, PA, Hialeah, FL (n)
Rodrigo M Diaz, MD, Miami, FL (n)
David Lee, MD, Miami, FL (*)

Introduction: We have previously reported on the cost of training residents in arthroplasty. The recent introduction of physician assistants as surgeon extenders has been controversial. Our objective was to assess resource consumption in an arthroplasty practice. Methods: A prospective observational cohort of 194 consecutive patients (109 PA and 85 residents) that underwent arthroplasty was studied. All the surgeries were performed in the same hospital by the same surgeon. 109 patient were primarily followed by a physician assistant while 85 by a resident service. Both services were supervised by the senior author. True costs were obtained from a cost accounting software system available at our institution, diagnosis, length of stay, age and insurance were collected for each patient. Non-parametric Mann-Whitney Test was utilized to analyze the data. A $p < .05$ was considered significant. Results: Average length of stay when resident present was 7.01 days ± 1.08 SD vs. 4.84 days ± 2.66 SD when compared to physician assistant group ($p<0.001$), and the average hospital cost was $15,382.89 ± 6,437.04 SD vs. 13,471 ± 5,233.61 SD ($p=0.021$) with the resident group having the more expensive values. Discussion: Our results show a significant increase in cost for patients done in a teaching service. The socioeconomic implications of this finding are extremely important in planning resource allocation when developing ways to pay for graduate medical education. Our data clearly shows that a physician extender delivers the same service at a lower cost.

POSTER NO. P073

The Influence of Preoperative Patient Status on Postoperative Outcome After Total Hip Arthroplasty

Andre Busato, MD, *Bern, Switzerland (n)*
Stefan Eggli, MD, Bern, Switzerland (*)
Urs Mueller, MD,MBA, Bern, Switzerland (n)
Christoph Roeder, MD, Bern, Switzerland (n)

Introduction: The study investigated how preoperative status (ambulation, hip flexion, hip pain) influences postoperative outcome of the same parameters. Patient satisfaction and Harris Hip Score were also assessed. Methods: Based on the three parameters, four groups with hip arthritis were defined with excellent (330 patients), good (1270), fair (1038) and poor (732) preoperative status. Postoperative outcomes between one and seven years post arthroplasty were assessed and compared. Results: Preoperative walking capacity was clearly reflected in postoperative performance.Pain alleviation was similarly effective for all patients, independent of preoperative pain status. Preoperative hip flexion range below 30° was significantly limiting postoperative range of motion. Patient evaluation of outcome was best in the preoperatively poor group, but all groups were similarly satisfied. There were no differences in postoperative HHS between the excellent and good group. The preoperatively fair and poor performers showed a worse postoperative HHS. Conclusion: Patients with excellent and good preoperative status (walking longer 30 minutes, flexion greater 30°, moderate or weaker hip pain) have similarly good outcomes post arthroplasty. Fair preoperative status (walking shorter 10 minutes, flexion between 30-90°, severe hip pain) results in lower walking capacity and slightly decreased flexion range but equally good pain alleviation and satisfaction. Poor preoperative status (walking shorter ten minutes, severe/intolerable hip pain, flexion below 30°) severely compromises postoperative ambulation and especially hip flexion. Nevertheless, pain alleviation and satisfaction are as in the other groups. Data advocates surgical intervention in later disease stages. Surgeons should however not wait until functional status is poor.

POSTER NO. P074

Blood Cultures for the Evaluation of Fever after Total Joint Arthroplasty

John T Anderson, MD, *Wichita, KS (n)*
John Donald Osland, MD, Wichita, KS (n)

Introduction: Fever following total joint arthroplasty (TJA) is common. Fearing the potential complications of bacteremia, physicians often obtain blood cultures to evaluate fever after TJA.Method: Retrospectively, the results of 51 sets of blood cultures (50 patients) obtained during the first two postoperative days for the evaluation of fever equal to or greater than 38.3°C were evaluated. All patients were receiving antibiotic prophylaxis. Thirty-nine patients underwent total knee arthroplasty and 11 underwent total hip arthroplasty. Forty-nine operations were primary and one was a revision procedure. Average patient age was 67.3 years. There were 27 males and 23 females. Results: Of the 102 samples of blood obtained, none grew a pathogen. The cultures were obtained by both the surgical (61 percent) and medical teams (39 percent). Currently, it costs $198 to process the two samples of blood routinely obtained for each evaluation. Therefore, the cost of processing the same number of cultures in the current healthcare market would be $10,098. Discussion & Conclusion: We conclude that blood cultures are neither useful nor cost-effective when used to evaluate fever in the immediate period after TJA. We believe the results of this study will be helpful to both the orthopaedist and medical consultant involved in the care of TJA patients.

POSTER NO. P075

In Vitro Wear of Explanted Acetabular Liners. Highly Crosslinked versus Conventional Polyethylene

Orhun K Muratoglu, PhD, *Cambridge, MA*
(a,c – Zimmer)
Keith K Wannomae, BS, Boston, MA (a – Zimmer)
Arin Doherty, BS, Boston, MA (*)
Charles R Bragdon, BS, Boston, MA (a,c – Zimmer)
Brian Burroughs, PHD, Boston, MA (a – Zimmer)
Andrew A Freiberg, MD, Boston, MA (a – Zimmer)
Harry E Rubash, MD, Boston, MA (*)
William H Harris, MD, Boston, MA (*)

Introduction: Surgically explanted highly crosslinked polyethylene acetabular liners with in vivo duration less than one year often show extensive scratching and scuffing on articular surfaces, presumably induced through third body abrasion. The hypothesis of this study was that the early in vivo surface changes will not affect the wear behavior of highly crosslinked polyethylene. Methods: We investigated the wear behavior of nine surgically explanted highly crosslinked and six conventional acetabular liners using in vitro hip simulation of continuous gait for at

least two million cycles. Wear was determined gravimetrically and the evolution of articular surface morphology was followed serially by optical microscopy. Results: Highly crosslinked explants showed no weight loss, actually slight weight gain, attributed to fluid absorption. This is typical of previously reported in vivo wear testing of highly crosslinked polyethylenes. An unexpected finding was that the highly crosslinked explants showed partial healing of the surface scuffs during testing. This healing is thought to be driven by the shape memory of polyethylene. As expected, the original machine marks of the highly crosslinked liners still present at explantation were maintained during testing. In contrast, conventional liners showed a wear rate of -18 milligrams/million-cycles, which led to rapid polishing of surface scuffs and elimination of those original machine marks that were present on some of the explants. Conclusion: The wear behavior of highly crosslinked polyethylenes is not changed by the surface changes that occur during the first year of in vivo service.

POSTER NO. P076

Prognostic Assessment of Osteoarthritis in Hip Dysplasia by Radiography, Bone Scintigraphy and 3D MRI

Takashi Nishii, MD, *Osaka, Japan (n)*
Nobuhiko Sugano, MD, Suita, Japan (n)
Hidenobu Miki, MD, Suita, Japan (n)
Masaki Takao, MD, Osaka, Japan (*)
Tsuyoshi Koyoma, MD, Osaka, Japan (*)
Hideki Yoshikawa, MD, Osaka, Japan (n)

Accurate prediction of osteoarthritis progression of dysplastic hips is important to consider subsequent therapy planning and determine preserving osteotomy surgery, however no reliable index has been obtained. The current study compared predictive ability of radiography, bone scintigraphy, and 3D MRI for subsequent osteoarthritic progression. 55 dysplastic hips in 45 patients with pre- or early stage of osteoarthritis consecutively received anteroposterior radiographs and 3D SPGR MRI with fat saturation using 1.5-T MR system. During follow-up, 8 patients were lost. Remaining 43 hips in 37 patients (mean age, 39) were analyzed for a mean follow-up of 4 years (3-5.6). 33 hips also underwent bone scintigraphy (BS) at the first examination. Predictive powers of variable indexes at the initial examinations, including CE angle and abnormal OA grading (osteophyte or joint space narrowing) on radiographs, abnormal BS uptake, and cartilage abnormalities on MRI, for subsequent progression of osteoarthritis with joint space narrowing were calculated. Progression of osteoarthritis was observed in 13 hips. Positive and negative predictive value to disease progression was 60/86 percents by CE angle less than 10 degrees, 65/92 percents by abnormal OA grading, 48/100 percents by abnormal BS, and 75/96 percents by cartilage abnormality on MRI. 3D MRI allowed to detect early change of cartilage abnormality before radiographic change is evident. 3D MRI provided strongest positive predictive power to disease progression within the next few years, and may serve as one of the main indications to perform preserving surgery.

POSTER NO. P077

Natural History of Osteonecrosis of the Femoral Head with Collapse-More than Ten Years Follow Up

Chikashi Shirai, MD, *Chiba City, Japan (n)*
Yoshitada Harada, MD, Chiba City, Japan (n)
Keishi Yamashita, MD, Chiba City, Pref, Japan (*)
Hitoshi Watanabe, MD, Chiba Univ., Japan (*)
Shunji Kishida, MD, Chiba City, Japan (n)
Kazuhiro Oinuma, MD, Chiba, NI Japan (*)
Hideshige Moriya, MD, Chuo-ku,Chiba, Japan (n)

(Introduction) For younger patients with osteonecrosis of the femoral head (ONFH), several types of osteotomy were performed. However, it is more difficult to evaluate outcomes of osteotomy than those of THA. Purposes of this study were to clarify the natural history of osteonecrosis of the femoral head with collapse and to propose new indication of osteotomy. (Material and Method) Thirty-seven hips of thirty-two patients that had ONFH were observed. There were 17 hips of 14 males and 20 hips of 18 females. They had 30 hips with Steinberg stage III and 7 hips with stage IV. The average duration of follow-up was 12.5 years ranged from 10 to 24 years. Harris Hip score (HHS) was used for evaluation of hip function and the end-point of survival ship was defined the time of THA. (Result) Nine hips required THA (Group A) and 28 hips were survived even though collapse was progressed (Group B). HHS of group A was 54.8 points at the first observation and was 45 points just before THA. HHS of group B was 72.8 points at the first observation and was 71.7 points at follow-up. (Conclusion) Three forth of patients with ONFH were survived after 10 years follow-up. Group of low HHS at first required THA but group of high HHS more than 70 points had high score after 10 years without any osteotomy. We concluded that indication of osteotomy was exactly limited in patients at early stage and not expanded to patients at stage III or IV.

POSTER NO. P078

Patient Oriented Outcomes in Primary Total Hip and Knee Replacement

Carlos J Lavernia, MD, *Miami, FL*
(a,d,e – Zimmer, d – Johnson&Johnson)
Carlos E Moreyra, MD, Miami, FL
(e – Arthritis Surgery Research Foundation)
Emiliano Curia, MD, Miami, FL (n)
Victor Hugo Hernandez, Miami, FL (*)

Introduction: The Quality of Well Being (QWB) is a valid and reliable health index that has been widely utilized for measurement of quality of life for multiple medical conditions. The purpose of this study is to analyze the results of hip and knee arthroplasty using the QWB. Methods: Primary hip and knee arthroplasty patients with minimum follow-up data of two years were included in the study. Pre-operative and post-operative QWB scores available were analyzed. Statistical tests performed include paired sample T-Test and linear regression analysis for control of gender, race, and ethnicity. A $p < .05$ was considered significant. Results: Three hundred and fifty cases (288 patients) were included in the study. Of these, 286 were hips and 64 were knees. Mean follow-up was 40 months. Mean preoperative QWB score was .516 ± .004 SE, while mean postoperative QWB score was .552 ± .004 SE ($p< .001$). Linear regression analysis performed showed that both women and men underwent significant improvement in QWB scores (.039± 0.01 SE $p<.001$for women versus .031± 0.01 SE $p<.001$ for men). Conclusion: Our

results clearly demonstrate the overall positive effect of primary hip and knee arthroplasty on the quality of life of all patients. The excellent positive effects reported using conventional orthopaedic scores and x-rays continue to hold when measured with validated outcome instruments.

POSTER NO. P079

Stress Risers in the Femur Due to Gaps Between Proximal and Distal Femoral Stems

Kazuho Iesaka, MD, *New York, NY (n)*
Paul E Di Cesare, MD, New York, NY (n)
Erik Kubiak, MD, Brooklyn, NY (n)
Matthew R Bong, MD, New York, NY (n)
Denitza Blagev, New York, NY (*)
Fredrick J Kummer, PhD, New York, NY (n)

Introduction: It is generally believed that, the smaller the gap between total hip and total knee intramedullary stems, the greater the stress on the femur. This study was conducted to test this hypothesis. Methods: Finite-element models were developed simulating bending of a femoral shaft with two 14-mm stems. Femur cortical thickness was modeled to 3, 5, and 7 mm, and gap between stem tips was modeled at 5, 15, 25, 50, and 100 mm. Stem and femur were either completely fixed or loose. A femur with no stem was a control model. Mechanical testing using a Sawbones femur, two cobalt-chrome rods, Stresscoat, and strain gages verified the models' results. Results: Tensile stress on the femur with well-fixed stems never exceeded the stress of the control model, but it increased up to 20 percent with loose stems. Gap size did not affect tensile stress concentration. Tensile stresses doubled, however, when cortical thickness decreased 2 mm. Discussion: Our results show that a stem in a femoral cavity acts as a stress riser only when it is loose. The gap between two stem tips had no effect on femoral tensile stress concentrations. Cortical thickness thus appears to be a more important determinant of stress than stem-tip gap, suggesting that it is more important to use a cortical strut graft than to avoid a small gap.

POSTER NO. P080

Mid-term Results of Precoated Femoral Component in Hybrid Total Hip Arthroplasty

Hiroshi Ito, MD, *Asahikawa, Japan (n)*
Tadashi Teranishi, MD, Asahikawa, Japan (n)
Meguru Okamoto, MD, Asahikawa, Japan (n)
Takeo Matsuno, MD, Asahikawa, Japan (n)
Akio Minami, Sapporo, Japan (n)

(INTRODUCTION) The failure rate of roughened, precoated, cemented femoral components has been reported to be high. We presented mid-term follow-up results of hybrid THAs using a Harris Precoat, Precoat Plus, or CDH Precoat stem. (METHODS) Between March 1987 and October 1994, a single surgeon implanted 152 consecutive hybrid THAs (137 patients) utilizing second-generation cementing technique with posterolateral approach. Twenty patients died, 6 patients were bedridden and 6 patients were lost to follow-up. The remaining 105 patients (120 hips), 18 men and 87 women, were followed-up at an average of 10.8 years (8 to 15.5). The average age was 60 years and the average weight was 59 kg. Preoperative diagnosis was hip dysplasia in 86 hips, primary osteoarthrosis in 3, rheumatoid arthritis in 10, AVN in 7, fracture in 12, ankylosing spondylitis in 2. (RESULTS) Revisions had been performed in 6 hips _\ 1 for aseptic loosening of the acetabular component, 2 for recurrent dislocation, 2 for dislodgement of the polyethylene liner from the metal shell, and 1 for infection. No femoral component was revised for aseptic loosening. The average Harris hip score was 87 points (42 - 100) and no acetabular component or femoral component was loose at the most recent follow-up. The Kaplan-Meier survivorship of the femoral component with mechanical failure (revision for aseptic loosening) as the end point was 100%. (DISCUSSION AND CONCLUSION) A precoated femoral component utilizing second-generation cementing technique provides a good clinical function and durability of hybrid THA at mid-term follow-up.

POSTER NO. P081

Fracture Propensity of Malaligned Highly Crosslinked Polyethylene Acetabular Liners under High Load

Aaron M Bailey, *Austin, TX*
(d,e – Centerpulse Orthopaedics, Inc)
Ming Shen, PhD, Austin, TX (*)
Janet L Krevolin, MS, Austin, TX
(d,e – Centerpulse Orthopaedics, Inc)

Fracture damage at the rim of the acetabular liners used in THA has been reported in greater than 40 percent of retrieved conventional polyethylene (CPE) liners. The damage can be attributed to several factors, including material properties, implant design, and alignment. CPE is known to experience wear and oxidative embrittlement and hence, prone to fracture. Acetabular designs sometimes present stress risers at the locking mechanism with thin polyethylene cross-sections. Extreme malalignment of the shell can present adverse stress conditions to these areas. Clearly, a combination of these factors may cause rim fracture. Most modern highly crosslinked polyethylene (XPE) liners dramatically reduce wear and oxidative degradation, but some have reported lower tensile fracture strength. Will a reduction in tensile strength make XPE liners more prone to fracture damage than the CPE liners? The purpose of this study was to evaluate the fracture propensity of a particular XPE liner design. Experiments, simulating extreme malalignment in a worst-case scenario, were conducted that cyclically loaded (5xBW) the rim of the thinnest hooded liners to replicate a reported fracture in a XPE liner of another design that possesses a thin cross-section and a notched locking mechanism. The results showed neither fracture nor other adverse effects in the XPE liner. Based on the markedly improved wear resistance, rim fracture associated with wear-through is not expected from XPE. This study suggests that a reduction in tensile strength in XPE alone does not cause fracture. Rather, excessive stress due to malalignment and design deficiency may cause fracture.

POSTER NO. P082

Late Radiotherapy to Arrest the Progression of Heterotopic Ossification Following Total Hip Arthroplasty

Stephen R Kantor, MD, *La Jolla, CA (n)*
Michael Tanzer, MD, Montreal, QC Canada (n)
Louis Souhami, MD, Monteal, QC Canada (n)
Gyorgy Hegyi, MD, Montreal, QC Canada (n)

INTRODUCTION: Immediate postoperative radiotherapy has been shown to be effective for the prophylactic treatment of heterotopic ossification (HO). Ideally, one would like to treat patients who have developed HO and prevent its progression into clinically advanced stages. The purpose of this study was to determine if late radiotherapy could halt the progression of heterotopic bone formed following cementless total hip arthroplasty.

METHODS: Eight hips that developed HO six weeks or three months following were treated with 700 rads. All patients were followed clinically and radiographically for two years postoperatively. HO was evaluated using the Brooker classification. All x-rays were digitized and a computer analysis was done to determine the amount of bone that formed. A non-radiated control group of 9 identical cementless hips, all of whom had developed HO by six weeks postoperatively, was used for comparison. RESULTS: Five of the eight radiated and four of the nontreated control hips showed no progression in Brooker class over this two-year time period. Digital x-ray analysis revealed some progression occurred in all hips, and averaged only 32 percent in the radiated group compared to 86 percent in the untreated controls ($p<0.05$), This was most evident in hips with Brooker class II HO (18 percent) increase in the radiated group vs 91% increase in the controls) The untreated control hips continued to develop additional HO over the entire period while the radiation-treated hips showed no further bone formation after the intital 6 months postoperatively ($p<0.05$). DISCUSSION AND CONCLUSION: The natural history suggests that left untreated, heterotopic ossification will progress. Late radiotherapy can significantly inhibit the progression of HO both in terms of total amount of bone formation as well as the time required for HO to stop progressing.

POSTER NO. P083

The Porous Coated Anatomic Total Hip Prosthesis: An 11-13 Year Prospective Study

Louis C M Jordan, MD, *New York, NY (n)*
Joseph T Moskal, MD, Roanoke, VA (n)
Thomas E Brown, MD, Charlottesville, VA (n)

Introduction: We are reporting the clinical and radiographic results on 107 consecutive Porous Coated Anatomic total hip arthroplasties at eleven to thirteen year follow-up. Methods: One hundred thirty seven consecutive primary Porous Coated Anatomic arthroplasties were performed. Complete data was available on 107 hips in 93 patients at an average 12.4 year follow-up. Eighty-two circumferential proximally porous coated femoral stems were inserted without cement, and 25 with cement. All patients received a cementless porous ingrowth acetabular component. Results: The average Harris hip score improved from 44 to 85 at final follow up. Nine percent of patients (8/93) experienced thigh pain. Thirteen percent (14/107) of acetabular components were failures. Four porous ingrowth stems required revision. Osteolytic lesions were seen in 7.5 percent (8/107) of acetabular components. Survivorship was 83 percent at 12.4 years. Discussion and Conclusion: A poor acetabular design and the use of 32mm heads with cups < 55mm in diameter contributed to the failures in this series. The four femoral failures occurred in patients with AVN where unrecognized pathologic changes in the proximal femur may have inhibited bone ingrowth.

POSTER NO. P084

Assessment of Graft Volume and Remodeling of Bone Substitute After Hip Revision Using MD-CT

Takashi Nishii, MD, *Osaka, Japan (n)*
Nobuhiko Sugano, MD, Suita, Japan (n)
Hidenobu Miki, MD, Suita, Japan (n)
Tsuyoshi Koyoma, MD, Osaka, Japan (*)
Masaki Takao, MD, Osaka, Japan (*)
Hideki Yoshikawa, MD, Osaka, Japan (n)

There is an increasing need of bone substitutes grafting for bone loss in revision hip surgery, however, assessment of graft volume and subsequent remodeling is unreliable on plain radiographs. The current study used multi-detector CT imaging to quantify graft volume and subsequent remodeling. Ten hips in 9 patients (mean age 62) received cementless hip revision surgery with graft of beta-tricalcium phosphate (TCP) granules and calcium phosphate cement (CPC) around femoral components. One month and one year postoperatively, CT imaging was performed using an eight-detector row GE system, and axial images were reconstructed (in-plane resolution: 0.4mm, slice thickness: 1.25mm). Volume of TCP, CPC and new bone formation was calculated using Scion Image software two times by two observers. Region of TCP, CPC and new bone formation could be defined with little metallic artifacts. Intraobserver error in TCP/CPC volume was 2.5/1.7 percent, and interobserver error was 3.0/1.6 percent. One year postoperatively, TCP and CPC were decreased to 22 percent (10-53) and 67 percent (37-89) of the initial grafted volume, and new bone was formed after absorption of TCP with 45 percent (11-76) of the initial TCP volume. This is the first analysis of accurate three-dimensional quantification of grafted volume and serial remodeling of bone substitutes around artificial components, and showed active remodeling ability of TCP as compared with CPC in vivo imaging. Multi-detector CT is a promising tool for evaluation of bone stock restoration, clarification of remodeling patterns of various bone substitutes, and selection of bone substitutes in revision surgery.

POSTER NO. P085

Cementation for Femoral Head Osteonecrosis after Collapse

Mark L Wood, MD, *Chapel Hill, NC (n)*
Scott S Kelley, MD, Durham, NC (n)
Lisa Haden, RN, Chapel Hill, NC (*)

Introduction: Treatment for femoral head osteonecrosis has been less successful after progression to collapse (ARCO Stage III). The goal after collapse is to prevent additional collapse and restore femoral head sphericity. Methods: Thirty-one patients (32 hips) with Stage III osteonecrosis were treated by ORIF with methylmethacrylate cement (cementation). Patients were sub-staged preoperatively using the ARCO international classification system. Patient progress was followed using preoperative and postoperative Harris hip scores, the WOMAC Osteoarthritis Index, and Shortform-36. Radiographic evaluation was done preoperatively, intraoperatively and postoperatively. Results: Twenty-nine patients (30 hips) were available for follow-up from 24 to 66 months (average, 43 months). There were no patients with mild disease (Stage IIIA). Sixteen hips had moderate disease (Stage IIIB) with two requiring THA. Twelve of 14 hips with severe disease (Stage IIIC) required THA. Significant improvements were seen in the Harris hip score, WOMAC Osteoarthritis Index, and Shortform-36 physical health. Discussion and Conclusion: Cementation is technically simple, enables immediate improvement in pain and function, has the potential to restore and main-

tain the sphericity of the femoral head after collapse, and does not compromise subsequent total hip arthroplasty. The failure rate at short-term follow-up, while comparable with other reported techniques, does not support generalized usage. The outcome was worse for patients with advanced disease, therefore, the procedure is currently restricted to symptomatic, young patients (younger than 40 years), preferably with mild to moderate disease (degree of head involvement < 30%, collapse < 4-mm).

POSTER NO. P086

Bone Response To Titanium Foam Coatings In A Rabbit Intramedullary Rod Model

***Juan C Hermida, MD**, La Jolla, CA*
(a – Stryker Howmedica Osteonics)
Shantanu Patil, MS, La Jolla, CA (*)
Fred Dimaano BS, Rutherford, NJ (*)
Monica Hawkins, PhD, Allendale, NJ (*)
Clifford W Colwell, Jr, MD, La Jolla, CA (*)
Darryl D D'Lima, MD, La Jolla, CA (*)

Introduction: Tritanium Dimensionalized Metal (TDM, titanium foam) implants have the advantage of simulating the trabecular structure of bone to provide maximum available porous space for bone ingrowth. This report compares bone response to titanium foam surfaces with and without hydroxyapatite coatings. Methods: TDM cylinders (5 mm diameter by 25 mm length) were implanted bilaterally in 40 rabbit femurs. Twenty implants (T-HA) were coated with 20 microns of solution deposited hydroxyapatite (Peri-Apatite) while 20 implants (T) had no hydroxyapatite coating. Osseointegration was measured at 6 and 12 weeks by automated computerized histomorphometry of scanning electron microscopy images of sections taken through the implant at two levels: diaphyseal and metaphyseal. Bone ingrowth was quantified in the pores and also measured up to 1 mm beyond the surface of the implant to determine the pattern of bone growth. Results: For the T-HA surface bone ingrowth increased from 35.0 ±8.5% at 6 weeks to 41.5 ± 7.4% at 12 weeks. For the T surface bone growth was 14.1 ± 8.8% at 6 weeks and 11.4 ± 4.2% at 12 weeks. Mean bone ingrowth was significantly different between hydroxyapatite-coated and non-hydroxyapatite coated implants at both time points ($p<0.01$). Discussion and Conclusion: Osseointegration and bone ingrowth which continued to increase up to 12 weeks was higher in the hydroxyapatite-coated surface . This study supports the hypothesis that hydroxyapatite coating has an additional benefit on osseointegration. Tritanium Dimensionalized Metal surfaces may be attractive alternatives for noncemented total hip arthroplasty.

POSTER NO. P087

Isolated Liner Exchange in Revision THA: Reduced Dislocation Rate with the Direct Lateral Approach

***Jeremy Joseph O'Brien, BSc**, London, ON Canada (n)*
Robert Stephen Burnett, MD FRCSC, St Louis, MO (n)
Xunhua Yuan, Lund, Sweden (n)
K. Y. Yang, MD, London, ON Canada (n)
Steven J MacDonald, MD, London, ON Canada (n)
Richard W McCalden, MD, London, ON Canada (n)
Robert Barry Bourne, MD, London, ON Canada
(a – Smith&Nephew)
Cecil H Rorabeck, MD, London, ON Canada (n)

Introduction: Problem: Isolated liner exchange in THA for osteolysis and polyethylene wear is a revision procedure often associated with a significant dislocation rate. Purpose: To evaluate the clinical and radiographic results of isolated liner exchange in revision THA performed via the direct lateral surgical approach. Methods: A prospective study of 24 hips that underwent an isolated liner exchange revision procedure via the direct lateral approach. Accessible osteolytic lesions were curetted and bone-grafted. Disease specific (Harris Hip Score, WOMAC-Index) outcomes and radiographic analysis were recorded. Area of osteolytic lesions was calculated using a computer-assisted technique. Results: Twenty-three patients (24 hips) underwent revisions with an isolated liner exchange via the direct lateral surgical approach. Fifteen accessible osteolytic lesions were curetted and bone grafted. At a minimum follow up of 24 months (mean 48 months, range, 24-112), all osteolytic lesions had regressed. Harris Hip scores improved from 69 to 83. WOMAC indices improved from 37 to 24. NO DISLOCATIONS HAVE OCCURED. Mean osteolytic area on anteroposterior and lateral radiographs decreased from 544 to 279 mm2 and 795 to 267 mm2 respectively. Two hips (8.3 percent) required acetabular re-revision – one for accelerated polyethylene wear, another for late collapse into a recurrent osteolytic lesion. Conclusion: This is the first study to demonstrate that isolated liner exchange via the direct lateral surgical approach may reduce the dislocation rate in revision THA. Retention of well-fixed implants and bone grafting of accessible acetabular defects is a procedure that preserves bone stock and addresses osteolytic lesions at revision surgery.

POSTER NO. P088

Late Dislocations Following Primary Total Hip Arthroplasty

***Conjeevaram Maheshwer, MD**, West Lake, OH (*)*
Mihir Patel, MD, New York, NY (n)
Hoang Bang, Cleveland, OH (n)
Victor Goldberg, MD, Cleveland, OH (c – Zimmer)

Introduction: Dislocation following Total Hip Arthroplasty (THA) can be formidable problem. This study describes the causes and management of late dislocations and our experience in managing these patients. Methods: 13 patients with late dislocations after THA were reviewed for the etiology, epidemiological factors and management. Radiographs and surgical observation were used to establish component positioning. Results: There were 92 primary THA's that had dislocations between 1972 and 2000. Thirteen hips (14%) sustained late dislocations between 2 and 17 years after the primary procedure. (Average age 63 years). The average follow-up was 56 months after the first dislocation (Range: 28 months-22 years). The posterolateral approach was used for all patients in this study. All dislocations were posterior. Ten (77%) femoral components with 28-mm heads, two (15%) with 32-mm heads, and one (8%) with 22-mm head were used. In 10 patients (76%)the mechanism of dislocation was hyperflexion, Trauma in one and one patient dislocated while turning in bed. 7 hips (64%) were managed with closed reduction. Six hips (46%) required surgery to address their instability. Intraoperative findings included femoral loosening, polyethylene wear, dislocated liner, and soft tissue laxity Conclusion: The data from this study indicates that hyperflexion is the underlying cause for majority of late dislocations. Implant malposition was not a factor. Gradual stretching of the periprosthetic soft tissues may play a role in eventual dislocation. This data suggests closed reduction and bracing should be the initial management. Surgically correctable causes such as component loosening, polyethylene wear should be considered.

POSTER NO. P089 – WITHDRAWN

POSTER NO. P090

A Benchmark for Future Total Hip Arthroplasty: Results of Charnley THR at Minimum 30-Year Follow-up

John J Callaghan, MD, *Iowa City, IA (a,b,c,e – Zimmer, DePuy)*
Jesse Ellis Templeton, MD, Cleveland, OH (*)
Devon D. Goetz, MD, West Des Moines, IA (a,b,e – DePuy)
Patrick M Sullivan, MD, West Des Moines, IA (n)
Douglas R Pedersen, PhD, Iowa City, IA (n)
Richard C Johnston, MD, Iowa City, IA (c – Zimmer)

INTRODUCTION: Those who are performing total hip arthroplasty today hope that newer technology including cementless fixation and alternative bearing surfaces will produce more durable results, but benchmarks are needed to evaluate improvement. This study provides data to the surgeon and patient concerning the expected durability of total hip arthroplasty at 30 years of follow-up. METHODS: 330 Charnley total hip arthroplasties were inserted in 262 patients between 1970 and 1972. At final follow-up 27 patients with 34 hips were living. 88% of patients had a minimum 25-year radiograph. Patients were evaluated for need for revision, radiographic loosening, and wear. RESULTS: For all patients, 89% died with or are still functioning 30 years later with their original arthroplasty. For living patients, 66% are still functioning with their original arthroplasty. 24% of living patients have required an acetabular revision and 9% a femoral revision for aseptic loosening. On radiographic analysis, including those cases revised, 41% of acetabular components and 18% of femoral components are radiographically loose.The average linear wear was .1 mm/yr for the living patients. Age and male sex correlated with loosening p = .001. Functionally considering the patients' age the patients were performing well on WOMAC scoring (28 point average). DISCUSSION & CONCLUSION: As demonstrated by the results of this study many of these patients are functioning well with a total hip arthroplasty 30 years after it was performed. Two-thirds of the living patients are functioning with their original prosthesis. This can serve as a benchmark for future arthroplasty.

POSTER NO. P091 – ORS

Ultimate Compression Strength Testing Of Alumina Ceramic Femoral Heads In Revision

Nick G Dong, MD, *Allendale, NJ (*)*
Peter F Sharkey, MD, Philadelphia, PA (*)
Mark A Kester, MD, Allendale, NJ (*)
Michael Bushelow, MD, Rutheford, NJ (*)

Ceramic femoral heads have been used for several decades as bearing surfaces in THA. Ceramic bearings have been shown to significantly reduce the amount of UHMWPE wear. Additionally, when coupled with a ceramic acetabular liner, an additional decrease in the amount of wear has been demonstrated. With the advantage of superior wear characteristics, there may be a desire during revision surgery to use a ceramic femoral head. Presently, it is recommended by orthopaedic manufacturers that ceramic femoral heads not be used in these cases due to the higher potential of failure when ceramic heads are coupled with a potentially damaged trunnion. To date, there is no quantitative data available.The results of this study show that a significant reduction in the ultimate compression strength of alumina ceramic femoral heads can occur when alumina ceramic heads are placed on a previously used trunnion. The results suggest that the condition of the taper at time of revision is influenced by materials and loading conditions. Other factors may also have a significant influence on overall performance of an alumina head, including head size, head offset, trunnion material, use of sleeves, etc. In an isolated series, clinical results have shown that ceramic heads can be used during revision surgery. This study indicates that caution should be exercised when using ceramic heads in a revision scenario. Based upon the findings of this testing, the clinical significance of the reduction in the ultimate compression strength of the alumina ceramic femoral heads needs to be further investigated.

SCIENTIFIC EXHIBITS

SCIENTIFIC EXHIBIT NO. SE003

◆The Influence of Premixed Antibiotics on the Fatigue Life of Acrylic Bone Cement: Assuring Clinical Structural Integrity

Paul D. Postak, BSc, *Cleveland, OH (n)*
Adam R. Ratzel, BSc, Cleveland, OH (n)
A. Seth Greenwald, D Phil(Oxon), Cleveland, OH (n)

INTRODUCTION: The use of antibiotic-loaded bone cement is a well-accepted adjunct in the treatment of infected joint arthroplasty and is gaining further application as a method of prophylaxis. The influence of antibiotic inclusion on cement mechanical properties, specifically fatigue, determines its resistance to crack formation and the long-term in vivo structural integrity of the cement mantle. This study investigates the influence of antibiotic inclusion on the fatigue life and porosity of acrylic bone cement. METHODS: The in-vitro mechanical characteristics of four commercially available acrylic bone cements, both with and without antibiotics, were compared employing their recommended vacuum mixing system. Fatigue life was determined by diametral (splitting) tension of fully polymerized, wet specimens at body temperature under sinusoidal loading (n=10 per cement). Percent area porosity was determined by digital optical microscopy (n=10 per cement). RESULTS: The addition of antibiotics marginally reduced the mean fatigue life of all cements ($p>0.05$). Further, no statistical correlation was found between porosity and fatigue life for any individual cement. DISCUSSION AND CONCLUSION: Premixed antibiotic inclusion at the 0.5g – 1.0g level reduced the fatigue life of the bone cements studied by 4% - 6% and is unlikely to contribute to premature fatigue cracking and aseptic loosening. This information is of contemporary importance as the FDA has cleared one antibiotic cement and is actively considering others for clinical application in joint replacement.

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

SCIENTIFIC EXHIBIT NO. SE004

Critical Evaluation of Contemporary Osteogenic Stimuli: Assessment Using Canine THR Experiments

Charles R. Bragdon, BS, *Boston, MA*
(a – William H. Harris Foundation, Zimmer, Wyeth)
Murali Jasty, MD, Boston, MA (*)
Mary O'Keefe, BS, Boston, MA (n)
Harry E. Rubash, MD, Boston, MA (*)
William H. Harris, MD, Boston, MA (*)

Introduction: The development of surgically useful osteogenic agents to improve bone formation into and around orthopedic implants is advancing rapidly. The ability to evaluate these advances in a relevant in vivo model is also a critical step and is similarly advancing. This exhibit details the evolution of these stimuli and these weightbearing models, how they have been applied, and their future potential for evaluating new osteogenic agents and materials. Methods: This exhibit displays several designs of cementless total hip replacement experiments which have been developed for quantifying osteogenic stimuli into surrounding THA. Osteogenic stimuli ranging from calcium phosphate coatings, systemic alendronate therapy, BMP-2 and BSM (a calcium phosphate carrier) have been evaluated. Results: Although calcium phosphate coating on the porous surface of THR implants resulted in a 15% increase in bone ingrowth by three weeks, by six weeks, the amount of bone ingrowth between treated and control groups were equivalent. Oral alendronate had no benefit on bone ingrowth. In contrast, BMP-2 not only promoted bone formation across a bone defect (filling the defect with bone), it was the only agent that led to bony ingrowth into the porous layer deep to a defect. Still, it had no influence on bone ingrowth when the porous surface was in direct apposition to viable bone. Conclusion: This series of studies have provided valuable insight into the use of osteogenic material and has allowed us to explore their application under circumstances which closely simulate the clinical of total hip arthroplasty.

SCIENTIFIC EXHIBIT NO. SE005

Development, Validation and Multi-Centre Follow-Up of a Modern Metal-Metal Hip Resurfacing Prosthesis

Jim Nevelos, PhD, *Cirencester, UK (e – Corin Medical)*
Yasrab Ahmad, MSc, Cirencester, UK (n)
Julia Shelton, PhD, London, UK (*)
Steven Krikler, FRCS, Coventry, UK (*)
Michael Bishay, FRCS, Bath, UK (n)
Homayoun Banan, FRCS, Romford, UK (n)
David Pring, FRCS, Guernsey, UK (n)
James Richardson, FRCS, Oswestry, UK (n)
Robert Spencer, FRCS, Bristol, UK (a – Corin Medical)

Modern metal-metal hip resurfacing was introduced in 1991 with the McMinn Resurfacing Hip. First implanted in 1997, the Cormet Resurfacing Hip is a development of the McMinn hip. In addition to clinical follow-up, extensive wear testing was performed on the Cormet hip, with effects of metallurgy and bearing diameter tested under standard and severe conditions. Metal ion release is a concern with all metal-metal hips. A 5-year study has been carried out on the serum metal ion levels in patients with Cormet Resurfacing Hip replacements. Cormet is the subject of an FDA approved IDE study. Between September 1997 and August 2003, 342 primary Total Hip Resurfacings were performed in five centres. Three hundred sixteen patients were followed up with no lost to follow-up. The average age of the patient group was 53.5 years, (range: 21 to 71 years), 184 were male and 132 were female. There were 26 bilaterals and five revisions, with a revision rate of 1.5% at 5 years. The follow-up ranged from 60 months to 3 months, mean follow-up was 16 months. The average Harris Hip score at the latest follow-up review was 80.0 (range: 42 to 91). The Kaplan-Meier survivorship of Cormet was 98% at 5 years. Wear testing has shown that heat treatments do not increase wear and that wear decreases with increasing head size. Serum metal ion levels rise initially then decrease over time. This data indicates that this type of device is suitable for the young active patient with excellent medium term clinical results.

SIENTIFIC EXHIBIT NO. SE006

◆The Acetabular Augmentation Ring for the Treatment of Recurrent Dislocations After Revision Total Hip Replacement

Friedrich Bottner, MD, *Muenster, Germany (n)*
Christian Gotze, MD, Muenster, Germany (*)
Winfried Winkelmann, MD, Dusseldorf, Germany (*)
Joern Steinbeck, MD, Muenster, Germany (n)

Eighteen patients, 11 men and 7 women, with recurrent hip dislocations after revision total hip replacement received an acetabular augmentation ring. The average age at the time of surgery was 65 years (range: 44 to 78 years). The patients had an average of 5,2 prior operations including the primary total hip replacement and an average of 1,9 revision total hip replacements. The acetabular augmentation ring was implanted after an average of 4,9 dislocations and failed surgical or conservative treatment. The average follow-up period was 34,5 months (range: 22 to 52 months). During the follow-up period 6 patients experienced a dislocation (33,3%). Seven patients (38,9%) experienced minor postoperative complications, including two patients with prolonged wound healing and wound drainage, two patients with a femoral nerve palsy, one patient with a postoperative peroneal nerve palsy and one patient complained of paraesthesias of the operated lower extremity without objective neurologic findings. All neurologic deficits persisted throughout the follow-up period. Overall 10 patients (55,6%) had one or more serious complications requiring additional surgical interventions: 5 patients secondary to recurrent dislocation, 4 secondary to implant loosening requiring revision surgery and 3 secondary to deep infection. All remaining patients, who did not require further surgical interventions had a poor functional outcome (Harris Hip score: range 9,5 to 61,7).

SCIENTIFIC EXHIBIT NO. SE007

Convergence of Hip Simulator Wear Studies with Clinical Reports of Wear in Alumina-alumina Alternate THR Bearings

Ian C. Clarke, PhD, *Los Angeles, CA (a – Howmedica-Osteonics, Bioceram Inc., Smith and Nephew)*
Toshiyuki Tateiwa, MD, Los Angeles, CA (*)
Takaakishi Shishido, MD, Tokyo, Japan (*)
G. Allen Gustafson, MD, Los Angeles, CA (n)

Ceramic cups have been used for THR for over 3 decades in Europe. The FDA only gave approval to market such in the USA in 2003. So prior experience has been with long obsolete Autophor and Xenophor designs. European studies generally

showed two types of wear on femoral balls, one being a central region of mild wear and the other a peripheral region of stripe wear. Wear varied <5 microns per year up to an inexplicable 3 mm in one rare report. New Australia retrievals with 3rd generation ceramic THR has shown volumetric wear 1-3 mm3/year for early run-in period to 2 years in patients. Stripe wear was also demonstrated and corresponded to cup-rim contact in the flexed position. In the past, simulator studies did not generally investigate the micro-separation mode of the hip joint as demonstrated in fluoroscopic gait studies. Thus alumina-alumina bearings produced ultra low wear of the order <0.05 mm3 per million cycles of the simulator machine and stripe wear was not duplicated. This was 1,000-fold less wear than with UHMWPE. With the latest micro-separation kinematics, the simulators can now duplicate the stripe wear seen in-vivo and this has raised the run-in wear rates by 4-fold and the steady state wear by up to 30-fold. This test mode now gives reasonable agreement with the Australian retrieval data. Such short-term 'worst-case' performance was still 100-fold less than with UHMWPE cups. It is also likely that the micro-separation test mode is relevant for metal-metal and metal-UHMWPE bearings.

SCIENTIFIC EXHIBIT NO. SE008

An Algorithmic Approach to the Acetabulum During Revision Arthroplasty of the Hip

Wayne G. Paprosky, MD, Chicago, IL (c – Zimmer)
***Michael R. O'Rourke, MD,** Iowa City, IA (n)*
Scott Sporer, MD, Chicago, IL (n)

The prevalence and complexity of hip revisions is rising. Our purpose is to provide an algorithm to make appropriate surgical management decisions and illustrate techniques for revision acetabular arthroplasty. Between January 1982 and January 2001 the senior author performed 1353 hip revisions. The acetabulum was revised in 893 of these revisions. We used structural allograft in 137 acetabular reconstructions including 31 acetabular transplants. Classification of the acetabular deficiency is based on the radiographic appearance including superior migration of the hip center, ischial osteolysis, integrity of the Kohlers's line, and destruction of the teardrop. The radiographic classification allows prediction of remaining bone for reconstruction. Excellent long-term results can be expected with the use of hemispherical ingrowth cups for the treatment of the type I and type II acetabulum. The type IIIA defects (30-50% host bone contact) have a successful long-term outcome when treated with ingrowth cups and structural grafts. The type IIIB acetabulum requires more extensive grafting (acetabular transplant) with supplemental support using a cage. Using trial components is critically important when making intraoperative decisions. This exhibit outlines the technical aspects of reconstructing type III defects including the use of trials, determination of intrinsic stability, restoration of hip mechanics, placement of structural allografts, and the use of cages as well as explores alternatives to bone grafts for the complex acetabular reconstruction.

SCIENTIFIC EXHIBIT NO. SE009

Use of Constrained Polyethylene Acetabular Component Liners in Revision Total Hip Arthroplasty: Long-Term Follow-Up in 38 Cases

***Richard Smith, BS,** Saint Paul, MN (a – DePuy, a Johnson & Johnson Co.)*
Jack M. Bert, MD, Saint Paul, MN (n)

Thirty eight patients with multiple recurrent dislocation subsequent to total hip arthroplasty (THA) were treated with a Joint Medical Product (Depuy) constrained liner using the Supercup acetabular shell over a 13-year period. Thirty four patients were available for follow-up. Two were deceased and two were unable to be located. The follow-up range was 1.2 to 13.4 years with a mean follow-up of 7.3 years. The mean hip flexion in this patient group was 92 degrees. Only one patient had liner failure after a traumatic episode 1-year postoperative requiring liner and constraining ring exchange due to fracture of the polyethylene. This patient has had no further complications with the procedure. There were no acetabular shell failures or pull outs. There were no femoral head failures or pull offs. The infection rate was 0%. Of the 34 patients available for review, all patients continue to be satisfied with their results. None of the patients complain of a sensation of instability or fear of subluxation/dislocation noted preoperatively. All 34 patients note some degree of limitation of hip flexion but this has not inhibited their work activity or activities of daily living. Constrained acetabular component revision for recurrent dislocation of THA appears successful long term with minimal morbidity. Success rates vary using constrained acetabular systems which may be dependent upon the unique design characteristics associated with each specific component type.

SCIENTIFIC EXHIBIT NO. SE010

Total Femoral Arthroplasty for the Salvage of End-Stage Prosthetic Disease

***Keith R. Berend, MD,** Columbus, OH (a, e – Biomet, Inc.)*
Adolph V. Lombardi, Jr, MD, FACS, Columbus, OH (e – Biomet, Inc.)
Thomas H. Mallory, MD, FACS, Columbus, OH (e – Biomet, Inc.)
Joanne B. Adams, BFA, Columbus, OH (a – Biomet, Inc.)
Kathleen L. Dodds, BS, RN, Columbus, OH (a – Biomet, Inc.)

The purpose of this study is to report the indications, complications, and functional outcomes in patients who underwent total femoral arthroplasty for the salvage of the severely compromised femur. These indications include numerous revision total hip or knee arthroplasties, failed periprosthetic fractures, or recurrent infection treated with multiple radical debridement surgeries. Fifty-nine patients were identified in whom total femoral arthroplasty was done using a constrained acetabular component, a proximal femoral replacement, a diaphyseal segment, and a distal femoral replacement of hinged or constrained design. Average age at surgery was 73.7 years. At an average 4.8-years follow-up, adequate pain relief was achieved with Harris hip pain scores averaging 33.8 of 44 points, and knee pain scores averaging 42.8 of 50 points. Good function was achieved with 98% able to ambulate and 43% using no assistive device or a cane alone. There were 18 complications or subsequent surgeries. Infection and dislocation occurred in eight patients

and seven patients respectively. Total femoral arthroplasty for salvage of the severely compromised femur provides acceptable results even in the most rare and difficult of cases.

SCIENTIFIC EXHIBIT NO. SE012

Anterior Approach Revision Total Hip Arthroplasty: Beyond the Minimally Invasive Technique

Robert E. Kennon, MD, *New Haven, CT (n)*
John M. Keggi, MD, Waterbury, CT (n)
Rahul V. Shah, MD, New Haven, CT (*)
Laurine Zatorski, RN, Waterbury, CT (n)
Kristaps J. Keggi, MD, Waterbury, CT (n)

INTRODUCTION: Revision total hip arthroplasty presents a greater challenge than primary procedures regardless of the approach used. The same direct anterior approach developed by the senior author for primary THA via mini-incisions can be readily extended proximally and distally for use in complex revision surgeries, including acetabular cages, stem revisions, and even total femur replacements. METHODS: The advantages and disadvantages of the technique are described fully along with a detailed description of the surgical technique used between 1972 and 2003. This review examines retrospective data on the subset of these cases that comprised all consecutive revision total hips performed by the senior author in the past 10 years, including the operative time, blood loss, and reported complications. RESULTS AND CONCLUSIONS: This versatile approach has been used in over 7000 total hip arthroplasties performed at our institution over the past thirty years by the senior authors, including many revision cases. The results and follow-up of consecutive revision THA by the senior author were drawn from our extensive institutional database. This approach affords simple, direct access to the acetabulum and entire femur. It provides relatively short operative times, relatively small blood loss, and few complications both in the perioperative period and over a long period of follow-up.

SCIENTIFIC EXHIBIT NO. SE013

Clinical Validation of a Structural Porous Biomaterial for Adult Reconstruction

J. Dennis Bobyn, PhD, *Montreal, QC, Canada (a – Implex, e – Zimmer)*
David Lewallen, MD, Rochester, MN (a, b ,c – Zimmer, a, c - Implex)
Arlen Hanssen, MD, Rochester, MN (a – Implex)
Thomas O'Keefe, MD, Ann Arbor, MI (*)
Randy Lewis, MD, Washington, DC (a, d – Implex, e – Zimmer)
Anthony Unger, MD, Washington, DC (e – Zimmer)
Michael Christie, MD, Nashville, TN (*)
Sam Nasser, MD, Detroit, MI (n)
Michael Tanzer, MD, Montreal, QC, Canada (a – Zimmer)

There has been a longstanding need for a structural biomaterial that can serve as a bone graft substitute or implant construct and achieve effective fixation by bone ingrowth. A porous tantalum material was developed to address this problem. The purpose of this exhibit is to describe its properties and the clinical application and results in various reconstructive procedures. Porous tantalum was used to manufacture primary and revision acetabular cups, acetabular augments, tibial plateaus, patellar augments, and structural devices for the treatment of osteonecrosis. Follow-up includes prospective clinical and radiographic evaluation of: 710 primary cups, 2-5 years; 402 revision cups, 2-5 years; 114 tibial plateaus, 2 years; 38 patellar augments/replacements, 2-3 years; 54 osteonecrosis implants, 2 years. All reconstructions have shown excellent stability and functionality, regardless of type. There have been no mechanical failures of the porous tantalum biomaterial. Acetabular augments have substituted well for bone graft, osteonecrosis implants have improved outcomes, and patellar implants have solved difficult patellar deficient/absent cases. No acetabular cups, tibial plateaus, or osteonecrosis devices were revised for aseptic loosening. Radiographically, the interfaces showed positive signs of bone ingrowth and frequent filling of initial gaps, if present. Histologic analyses of implants revised for malposition, dislocation or infection have confirmed bone ingrowth.

SCIENTIFIC EXHIBIT NO. SE014

Factors Influencing Cerclage Cable Tension Loss During Surgery

Fares Sami Haddad, FRCS, *London, UK (a – Smith & Nephew)*
Robert L. Barrack, MD, New Orleans, LA (e – Smith & Nephew)
Michael D. Ries, MD, San Francisco, CA (c – Smith & Nephew)
Wayne Allen, BS, Cordova, TN (e – Smith & Nephew)
Bob Jones, BS, Cordova, TN (a – Smith & Nephew)
Stanley Tsai, MS, Cordova, TN (e – Smith & Nephew)
Abraham Salehi, Memphis, TN (a – Smith & Nephew)

Introduction: Cerclage cables are commonly used in the management of periprosthetic femoral fractures, and for the fixation of trochanteric osteotomies. For adequate fixation and bone healing, tension in the cables must be maintained to minimize micromotion between the fragments. However, loosening of cables has been observed during surgery, and may be caused by the viscoelastic properties of bone or by mechanical loosening of the cables. Methods: Experiments were conducted on three preserved human cadaveric femurs to continuously monitor cable tension prior to clamp fixation through one hour following clamp fixation using data acquisition and tension sensors. Additionally, testing was performed on bovine femurs to examine technique factors that may lead to tension loss. Results: Cable tension measured immediately after clamp fixation was >50% less than tension measured just prior to clamp fixation. This indicates that cable tension loss is immediate and significant, and is not a result of bone relaxation over time as expected. There was minimal tension loss due to bone relaxation over a period of one hour following clamp fixation. Subsequent testing on bovine femurs revealed that implantation technique factors may cause tension loss immediately following clamp fixation. Conclusions: Cable loosening contributes to poor fixation and delayed fracture healing/non-union. The observed tension loss appears to be immediate, significant, and caused by technique and implant/instrumentation design rather than relaxation of the underlying bone. By regulating these factors, cable tension may be maintained during implantation.

SCIENTIFIC EXHIBIT NO. SE015

Ten-Year Radiographic Results of Thin-Layer Femoral Cement Technique for Primary Total Hip Arthroplasty

William R. Kennedy, MD, *Sarasota, FL*
(a – Zimmer, b – Lima Lto)
Ronald P. White, MD, Sarasota, FL (a – Zimmer)
Thomas A. Gruen, MS, Wesley Chapel, FL (*)
Robert W. Eberle, PhD, Apex, NC (n)

PURPOSE: We report the prospective results of a thin-layer femoral cement technique for primary total hip arthroplasty. MATERIALS AND METHODS: A prospective study was conducted on 114 hips in 107 patients with using a thin-layer femoral cement technique for primary THA. Patient serial radiographs were independently evaluated. Serial radiographs were classified based on cement grade, cement voids, evidence of positive or negative remodelling, femoral osteolysis and cement debonding. RESULTS: The average patient age was 73 years (± 5 years, range: 62 years – 84 years).There was one patient death not related to the primary THA. The average time to follow-up was 10 years (± 2 years, range: 8 years – 13 years). At the most recent follow-up, cement mantel grade was A (12%), B-1 (17%), B-2 (11%), C-1 (0%), C-2 (31%), and D (30%). Femoral osteolysis was seen in 18 hips and was confined to zones I or VII. Femoral remodelling was generally observed in the proximal femoral zones (positive remodelling: 13 hips, negative femoral remodelling: 50 hips). There were cement voids in 31 of 114 hips. At time of latest review there were no clinical failures. CONCLUSION: A thin-layer cement mantel and, at times, incomplete, may allow direct load bearing between the femoral component and host bone thus not relying on the complete cement mantel for stress transfer. Two-thirds of the patients studied had cement mantel grades C-2 and D, yet no evidence of progressive cement mantel failure resulting in no clinical failures in this patient cohort.

SCIENTIFIC EXHIBIT NO. SE016

Strength and Modularity: Engineering for Successful and Durable Modular Femoral Components for Revision THA

Ronald Sekel, MD, *Kogarah NSW, Australia*
(a ,d, e – Portland Orthopaedics, b, c – NIL)
Peta Wingrove, PhD, Double Bay, Australia
(e – Portland Orhtopaedics)
Debi Ronen, MD, Double Bay, Australia (*)
Robert W. Eberle, PhD, Apex, NC (n)

INTRODUCTION: Recently, much attention has been paid to the effect of modular femoral component design and reported failures. The purpose of this scientific exhibit is to review and recommend the engineering principles for successful femoral component modularity for revision THA in the face of significant proximal femoral host bone deficiencies. MATERIALS AND METHODS: Principles of lever arm mechanics were investigated and the effect of various positioned Morse tapers (mid stem to proximal placement). The effect of deflection and resultant crack propagation were calculated and reported. Reviews were performed at various potting levels and various taper junction positions with common implant materials (CoCr and Ti Alloy). RESULTS: Modelled tests yielded calculated results showing increased deflection properties between materials, and subsequent fatigue failure at the Morse taper junction. The increased strength of material of CoCr in conjunction with component design has led to a recommendation of Morse taper placement. This design allows for adjustability in 4-vectors (stem length, offset,: In lieu neck version and neck length) without compromising the restoration of normal hip mechanics. DISCUSSION AND CONCLUSION of current reported failures of mid-stem modular junction femoral components, we propose specific parameters for successful femoral modularity for revision THA in the face of proximal femoral defects.

SCIENTIFIC EXHIBIT NO. SE017

Collared Versus Collarless Porous-Coated Titanium Femoral Components in Primary Cementless Total Hip Arthroplasty

Aaron A. Hofmann, MD, *Salt Lake City, UT*
(e – Centerpulse/Zimmer Ortho)
Marcelo Camargo, MD, Salt Lake City, UT (n)
Amie M. Tanner, BS, Salt Lake City, UT (n)
Michael P. Bolognesi, MD, Salt Lake City, UT (n)
Tyler D. Goldberg, MD, Salt Lake City, UT (n)
Katy M. Stirland, AS, Salt Lake City, UT (*)

Introduction: The benefit of collared or collarless implants over the other in cementless total hip arthroplasty remains controversial. This paper reports the clinical and radiographic outcomes of collared and collarless versions of an otherwise identical femoral component in total hip arthroplasty. Methods: One-hundred consecutive patients undergoing primary cementless THA were implanted with either collared or collarless versions of a porous-coated femoral component. The patients were randomized based on the last digit of their social security number. The collared group contained 33 males and 22 females with an average age of 57 (range: 18 to 79). The collarless group contained 22 males and 23 females with an average age of 50 (range: 25 to 81). Both groups had an average follow-up of 133 months (96-158). The preoperative diagnoses were comparable in both groups. All patients were evaluated clinically with Harris hip scores and radiographically for collar/calcar contact, proximal bone loss, subsidence, and osteolysis. Results: The HHS for the collared group increased from 45 preoperatively to 88 postoperatively at an average follow-up of 133 months. The collarless group increased from 43 to 90. There was no difference in radiolucent lines, proximal bone resorption, subsidence, or osteolysis between the two groups. There were no femoral component revisions. Discussion and Conclusion: These results obtained from this prospective randomized study reveal that there is no significant difference between collared or collarless porous-coated titanium femoral components of the same design in primary total hip arthroplasty.

SCIENTIFIC EXHIBIT NO. SE018

Ten-Year Experience Using an Articulating Antibiotic Cement Hip Spacer for the Treatment of Chronically Infected Total Hip

Thomas M. Cook, DO, *Salt Lake City, UT (n)*
Aaron A. Hofmann, MD, Salt Lake City, UT (*)
Steven Lyons, MD, Salt Lake City, UT (*)
Amie M. Tanner, BS, Salt Lake City, UT (n)
Marcelo Camargo, MD, Salt Lake City, UT (n)
Tyler D. Goldberg, MD, Salt Lake City, UT (n)

Introduction: Infection remains one of the most devastating complications following total hip arthroplasty. The goal of this clinical study was to demonstrate that the use of an articulating antibiotic cement hip spacer maintains soft-tissue length, hip function, while eradicating infection; also the use of uncemented technique, during second stage reconstruction, was not associ-

ated with a higher rate of re-infection. Methods: Between June 1991 and December 2001, all patients treated at our center for chronic infection of a primary total hip arthroplasty, were retrospectively reviewed. Thirty-five of 42 patients underwent two-stage reimplantation using an articulating antibiotic hip spacer during the first stage, and noncemented implants during second stage reimplantation. All patients underwent comprehensive preoperative clinical and radiographic evaluation for infection, prior to two-stage reconstruction. Results: Thirty-three patients (94%) remain free of infection with an average follow-up of 57 +38 months (range: 2 to 138 months) and an average postoperative Harris Hip score of 90 +6 (range: 81 to 99), which was an improvement from an average of 52 +9 (range: 36 to 68) preoperatively. Two patients (6%) had recurrence of infection, and elected not to have a repeat two-stage revision. Conclusion: Two-stage reconstruction with an articulating antibiotic hip spacer, for the treatment of infected primary total hip arthroplasty was considered effective for the maintenance of soft-tissue tension, hip function, and eradication of chronic infection.

SCIENTIFIC EXHIBIT NO. SE019

Treatment Protocol for Periprosthetic Fractures Around the Hip

William J. Hozack, MD, *Philadelphia, PA (n)*
James J. Purtill, MD, Haddonfield, NJ (n)
Venkat Rapuri, MD, Philadelphia, PA (n)
Javad Parvizi, MD, Philadelphia, PA (n)

Introduction: With improving longevity of the population and the rise in the number of total hip arthroplasties being performed, there has been an increase in the number of periprosthetic fractures. They continue to present a formidable challenge to the reconstruction surgeons. Methods: Using a computerized database all patients presenting with periprosthetic fracture around the hip were identified. The clinical and radiographic records of all the patients were reviewed in detail. The fracture was categorized according to the Vancouver classification. The radiographic and clinical outcome of the patients was evaluated using Harris hip scores and SF-36. Results: There were 139 patients presenting with periprosthetic fracture between 1995 to 2000. They were categorized as Vancouver-A (8), B1 (23), B2 (67), and C (43). The treatment consisted of revision of the femoral stem with or without cortical bone grafting, open reduction and internal fixation using various designs of plating system or intramedullay nail, or a combination of these. Bone graft substitute was also used in some cases. This study will present the outcome of each surgical intervention correlating the results with the type of fracture and various other factors in order to identify factors responsible for failure. Discussion:There are various types of classification for periprosthetic fractures. Vancouver classification is simple, reproducible, and has a relatively low interobserver variability. Using the latter classification we are recommending a treatment protocol for periprosthetic fractures around the hip.

SCIENTIFIC EXHIBIT NO. SE021

◆Metal-on-Metal Hybrid Surface Arthroplasty of the Hip: Clinical Results and Risk Factors for Failure

Harlan C. Amstutz, MD, *Los Angeles, CA*
(a, e – Wright Medical Technology)
Paul E. Beaule, MD, Los Angeles, CA
(a – Los Orthopaedic, b – Wright Medical Technology)
Michael J. LeDuff, MA, Glendale, CA (n)
Frederick Dorey, PhD, Los Angeles, CA (n)
Patricia A. Campbell, Los Angeles, CA
(a – Wright Medical Technology)
Thomas A. Gruen, MS, Wesley Chapel, FL (*)

Introduction: This exhibit on metal on metal surface arthroplasty of the hip (MMSA) includes the study of tribology, biocompatibility (local, allergic sensitivity, systemic), evolution of the design, surgical technique, and medium term results with an emphasis on determining risk factors and criteria for patient selection. Methods and Materials: 400 hips in 355 patients were implanted with a hybrid MMSA at our institution. Patients had an average age of 48 years; 73% were male. Data analysis included femoral head cysts, activity, patient weight, previous hip surgery, femoral component sizes. Failed components were retrieved, sectioned, and analyzed histologically. A surface arthroplasty risk index (SARI) was developed for patient selection. Results: Mean follow-up was 4.6 years (3.2-7.2). Clinical results are excellent. Revisions included 3 neck fractures (0.75%), 9 femoral loosenings (2.25%), 1 postop acetabular component protrusio (0.25%), 1 sepsis (0.25%), and 1case of recurrent subluxation (0.25%). Four-year survivorship was 94.4%. The most important risk factors for femoral loosening were large cyst formation (p=0.029), height (p=0.032), female gender (p=0.005), and smaller component size in male patients (p=0.005). Patients with a SARI >3 were 4.2 times more at risk of early failure with a survivorship of 89% compared to 97% if SARI<3 (p=0.001). No metallosis was observed in retrieved specimens and wear was not measurable by CMM. Conclusion: Bone preparation and fixation are paramount to prevent femoral failures. Cementation of the metaphyseal stem and reduction of impact activities has improved the outlook for young patients with risk factors.

SCIENTIFIC EXHIBIT NO. SE022

E-Templating: Digital Preop Planning in THA

James V. Bono, MD, *Boston, MA (d, e – Galen)*

Digital templating is the wave of the future for planning Total Hip Arthroplasty (THA) as well as many other surgical procedures. Templating electronically is more accurate and efficient than the conventional technique of using wet film x-ray images. Several problems of manual templating are solved by the digital templating process. The issue of scaling is solved be calibrating the image using a marker of known size. This eliminates guess work and avoids common distortions experienced when templating manually. Once the image is calibrated a templating wizard can accurately measure anatomy and accurately recommend the proper template for the patient. The templates are manufacturer specific and can be changed or manipulated until the surgeon is satisfied. This process can also be done manually without the use of the templating wizard. Once a template is chosen the study can be printed on paper or film or it can be archived electronically becoming a part of the patient's permanent file. For these reasons Digital Templating will revolutionize

the way Orthopaedic Surgeons lan for THA by cost efficiently templating more quickly and accurately than conventional planning methods.

SCIENTIFIC EXHIBIT NO. SE023

Modular Neck Primary Prosthesis: Experimental and Clinical Outcomes

Francesco Traina, MD, *Bologna, Italy (n)*
Massimiliano Baleani, M Eng, MSc, Bologna, Italy (n)
Marco Viceconti, M Eng, PhD, Bologna, Italy (n)
Aldo Toni, MD, Bologna, Italy (n)

Introduction: Modular acetabular designs are widespread used in primary THA for their versatility while little experience is reported with modular femoral designs. Stem modularity could be useful when the anatomy is overthrown and for mini-incision approaches, providing an increased adaptability without any need for a large inventory or expensive custom made prostheses. The aim of this study is to report the preclinical validation and clinical experience with modular neck primary prosthesis. Methods: The fretting-corrosion behavior of the neck-stem coupling and the amount of particulate released under simulated physiological activities were investigated. In vitro tests were performed in Ringer's solution loading the stem up to 20 millions cycles (i.e. 20 yrs) according to ISO 7206. From January 1995 to December 2001, 864 primary surgeries were performed with a modular stem. There were 458 women and 406 men; the mean age was 55 years (16-81 years). The main preoperative diagnosis was primary arthritis (58.1%), the second CHD (22.2%). The stem survival was estimated by the Kaplan-Meier method. Results: Evidence of primary corrosion was not found, conversely areas showing fretting damage were seen. The amount of fretted material was estimated in less than 1mg/year. Clinically 3 stems were revised, 2 for recurrent dislocation, 1 for stem subsidence, none for mechanical failure. At 6 years the estimated stem survival is 99.4%. Discussion: Modular stems have shown excellent clinical and mechanical behavior. The amount of fretting debris product is negligible taking that a stable prosthesis is likely to produce more than 10mg/year of metal debris.

PAPERS

PAPER NO. 001

Volume and Outcomes of Primary and Revision Total Knee Arthroplasty

Nizar Mahomed, MD, *Toronto, ON Canada (n)*
Jeffrey N Katz, MD, Boston, MA (n)
Jane Barrett, Lebanon, NH (n)
John A Baron, MD, MS, Lebanon, NH (n)
John Wright, MD, Boston, MA (n)
Elena Losina, MD, Boston, MA (*)

Introduction: For several major surgical procedures, the annual caseload handled by hospitals and surgeons has been inversely associated with rates of perioperative mortality and complications. However, the relationship between hospital and surgeon volume and perioperative outcomes following total knee replacement (TKR) has received little study. The purpose of the study was: 1) To evaluate the distribution of TKR by surgeon and hospital volume in the Medicare population. 2) To assess the relationship between volume and post-operative mortality and complications. Methods: We analyzed claims data for all patients in the Medicare population who had elective primary or revision TKR from January 2000 through August 2000. Hospital and surgeon volumes were defined as the number of primary plus revision TKR performed by the hospital and surgeon on Medicare enrollees during calendar year 2000. We examined the associations between annual hospital and surgeon volumes of TKR and the rates of mortality and complications (infection, pulmonary embolus, myocardial infarction, pneumonia) in the first 90 postoperative days. The analyses were adjusted for age, gender, comorbidity, income and arthritis diagnosis. Analyses of hospital volume were adjusted for surgeon volume, and vice versa. Results: Patients undergoing primary TKR in hospitals with higher annual volume had lower risks of mortality OR 0.69 (95% CI 0.50, 0.95), pneumonia OR 0.65 (0.51, 0.83) and deep wound infection OR 0.61 (0.38, 0.99) as compared with patients having primary TKR in hospitals with lower annual volume. Patients having primary TKR by surgeons with high volumes had lower risks of pneumonia OR 0.72 (0.58, 0.89) and deep infection OR 0.62 (0.42, 0.93) as compared with patients of surgeons with low volumes. Patients undergoing revision TKR in the highest volume hospitals had lower rates of acute myocardial infarction OR 0.25 (0.10, 0.63) and pneumonia OR 0.36 (0.16, 0.82) as compared with patients having surgery in the lowest volume hospitals. Discussion and Conclusion: Greater hospital and surgeon volumes of primary TKR are associated with lower risks of select perioperative adverse events. Patients and clinicians should incorporate these findings and these data should be integrated into the policy debate about the advantages and drawbacks of regionalizing total joint replacement to high volume centers.

PAPER NO. 002

Implementation and Application of a Community Joint Registry: A Ten-Year History

Terence J Gioe, MD, *Saint Paul, MN*
(a – DePuy, Johnson & Johnson)
Kathleen Killeen, OT, Saint Paul, MN (n)
Susan Clay Mehle, BS, Saint Paul, MN (n)
Karen Scheltema, MD, Saint Paul, MN (n)
Katherine Grimm, MPH, Saint Paul, MN (n)

Background: Typical total joint populations studied for revision rates often come from a single academic center or group of centers, a situation that infrequently reflects the experience of the majority of primary or revision joint patients. Community or regional implant registries can accurately portray the experience of a surgeon within his/her immediate peer group, and provide the advantage of a larger population base for statistical analysis. Methods: In 1991, hospital administrators and surgeons in a community hospital system recognized the need to track and trend implant utilization, costs, and failures. A custom database allowed automation as a registry with access to implant, explant, surgeon, patient, hospital, cost, charge, and reason for revision data, permitting analysis of use and failure rate of implants utilized by over 40 orthopaedic surgeons in three community hospitals. Implant catalog number was recorded and imported electronically into the registry database, where it was merged with the patient/hospital file, capturing demographic information. On a biannual basis, death data were obtained from a government agency and also merged into the database. Medical records were reviewed by orthopaedic surgeons to identify and classify reasons for failure among the implants revised. Results: Over 11,200 implants are in the database, and analysis of this population has allowed us to identify: 1) problems with a particular design of acetabular component 2) a higher rate of UKA revision compared to TKA 3) a greater incidence of revision for unresurfaced patellae vs. resurfacing, among numerous examples. Discussion and Conclusion: This study presents further evidence of the value of, and ongoing need for, total joint registries. It represents a strong alternative in our present healthcare model to the data and labor-intensive registries utilized at other sites. Our model of community registry is estimated to cost $20,000 annually, or about $17 per procedure. The limitations of such an implant/explant registry are well defined; revision is a relatively crude, but easily obtainable endpoint. We believe that the standard data captured in our database should be recorded by every surgeon or hospital system performing joint arthroplasty.

PAPER NO. 003

Perioperative Complications Between Simultaneous Bilateral Versus Unilateral Total Knee Arthroplasty

Scott M Sporer, MD, *Wheaton, IL (n)*
Daniel Bullock, Lebanon, NH (n)
Thomas G Shireffs, Lebanon, NH (n)

Introduction: Previous studies have reported an increased rate of perioperative complications and mortality following simultaneous bilateral TKA. The purpose of this study was to evaluate the perioperative complications and mortality associated with simultaneous bilateral TKA compared to unilateral TKA. Methods: All bilateral and unilateral TKAs performed between January 1994 and June 2000 were retrospectively reviewed. Patient's demographic information was recorded along with their preoperative comorbidities.

Perioperative complications including infection, deep venous thrombosis, pulmonary embolism, cardiovascular ischemia and neurologic insult were evaluated along with the 30-day and one-year mortality rates. Statistical power was 80%, with a two sided type I error of 0.05. Results: A total of 514 unilateral TKAs (514 knees) and 255 bilateral TKAs (510 knees) were reviewed. Patient's baseline demographics and preoperative comorbidities were similar between cohorts. The intraoperative blood loss, tourniquet time, need for blood transfusion and length of hospitalization was greater in the bilateral cohort. Rates of myocardial infarction, postoperative confusion, and the need for intensive monitoring, was also slightly greater in the bilateral cohort. However, the 30-day and one-year mortality rates along with the risk of pulmonary embolism, infection and deep venous thrombosis were unchanged. Conclusions: The incidence of perioperative complications is greater with bilateral TKA compared with unilateral TKA. However, the mortality rates between these cohorts are similar. Bilateral simultaneous TKA should not be abandoned due strictly to concerns of increased perioperative complications since the morbidity and mortality from this procedure is not double that from unilateral TKA.B

PAPER NO. 004

Epidemiology of Primary and Revision Total Knee Replacement in the US Medicare Population

Nizar Mahomed, MD, *Toronto, ON Canada (n)*
Jeffrey N Katz, MD, Boston, MA (n)
Jane Barrett, Lebanon, NH (n)
John A Baron, MD, MS, Lebanon, NH (n)
John Wright, MD, Boston, MA (n)
Elena Losina, MD, Boston, MA (n)

Introduction: Although total knee replacement (TKR) is one of the most frequently performed surgical procedures in the US, there is limited data on its epidemiology. The purpose of the study was to describe the rates of primary and revision TKR and select 90-day outcomes in persons 65 years or older residing in the US. Methods: Using Medicare hospital (Part A) and surgeon (Part B) claims, we identified unilateral primary and revision TKR in the year 2000. Annual incidence rates were computed. Poisson regression was used to assess the relationship between demographic characteristics and incidence rates. Proportional hazards models were used to examine the relationship between demographic factors and 90-day postoperative complications including death, readmission for further knee surgery, manipulation under anaesthesia (MUA), pulmonary embolus (PE), deep wound infection and acute myocardial infarction (MI). Results: The rates for unilateral primary and revision TKR increased with age and peaked between 75-79 years. Women were more likely than men to undergo primary TKR OR 1.44 (95 percent CI 1.40, 1.47) or revision OR 1.11 (1.06,1.17). Blacks were less likely than whites to have primary TKR OR 0.73 (0.69, 0.77) or revision OR 0.89 (0.81, 0.98). Those with low income (receiving Medicaid) were less likely to have primary TKR OR 0.77 (0.74, 0.81) or revision OR 0.91 (0.84, 0.99). Increasing age was associated with greater risk of mortality in both primary and revision TKR. For primary TKR women had lower risks for mortality, readmission, wound infection and AMI compared to men. For revision TKR women had lower risks for readmission, wound infection and AMI. For primary TKR blacks were at higher risk for mortality, wound infection and MUA. In primary TKR those with low incomes were at higher risk for mortality, readmission, PE, wound infection and AMI. Discussion and Conclusion: Women have higher rates of TKR compared with men. Overall the rates of 90-day postoperative complications following TKR are low. Those with low incomes and of black race undergo TKR less frequently and in general have higher risk for adverse outcomes following primary TKR.

PAPER NO. 005

Response Bias: Effect on Outcomes in Mail Surveys after Total Knee Arthroplasty

Jane Kim, MD, *Philadelphia, PA (*)*
Jess H Lonner, MD, Philadelphia, PA (*)
Charles Nelson, MD, Philadelphia, PA (*)
Paul A Lotke, MD, Philadelphia, PA (*)

Introduction: Mail survey questionnaires are increasingly being used for follow-up evaluation of patients to gauge satisfaction and performance after total joint arthroplasty. A variety of possible questionnaire response biases exist. This paper evaluates response behavior in a mail survey sent to patients following total knee arthroplasty. Methods: 472 patients who underwent primary total knee arthroplasty from 1996 to 1998 were mailed a ten-question survey that evaluated patients in satisfaction, general health, and Knee Society Function and clinical scores. The 83% who responded were stratified as early, late, and repeat responders. The remaining 17% who failed to respond after two mailings were considered "non-responders". 100% of the non-responders were eventually contacted. These groups were analyzed and compared at the preoperative visit, most recent office visit, and by the mail survey. Results: In the mail survey, the satisfaction ratings were highest in patients who responded earliest and poorest among the non-responders ($p<0.001$). Similarly, the mean Knee Society knee score was significantly greater in early responders, (82.7 ± 19.0), compared to non-responders, (66.9 ± 16.0); the mean Function score was significantly greater in early responders, (68.8 ± 24.1), compared to non-responders, (48.4 ±12.5); and the mean pain score was significantly greater in early responders, (39.8 ± 13.9), compared to non-responders, (27.0 ± 9.7) (all $p<0.0001$). In the change from baseline to the mail survey, the mean Knee Society knee score was significantly increased in early responders, (46.12 ± 25.71), compared to non-responders, (28.45 ± 23.62); the mean Function score was significantly increased in early responders, (18.87 ± 22.52), compared to non-responders, (5.34 ± 20.05); and the mean pain score significantly increased in early responders, (23.57 ± 17.76), compared to non-responders, (10.67 ± 12.93) (all $p<0.0001$). Discussion and Conclusion: In mail survey follow-up, non-responders are unique and have significantly poorer outcomes compared to responders. This potential response bias should be considered in all follow-up analyses. While this may be difficult in a very large series of patients, the division of the study cohort into more manageable segments is advised to attain 100% response rates. Therefore, the assessment of patients who are lost to follow-up is an important and necessary component to accurately analyze outcomes after treatment.

PAPER NO. 006

Analysis of Early Revision in a Community Knee Implant Registry

Terence J Gioe, MD, *Saint Paul, MN*
(a – DePuy, Johnson & Johnson)
Kathleen Killeen, OT, Saint Paul, MN (n)
Susan Clay Mehle, BS, Saint Paul, MN (n)
Karen Scheltema, MD, Saint Paul, MN (n)
Katherine Grimm, MPH, Saint Paul, MN (n)

Background: This study evaluates early revision in 5760 primary knee arthroplasties evaluated prospectively in a community joint implant registry. Methods: Since 1991, 5,760 knee arthroplasty procedures performed by 53 surgeons have been registered in a community joint implant registry and were reviewed concerning initial revision performed within the health care system. We esti-

mated a very low percentage of revision performed outside the health care system, and those cases were not included. The 168 revisions performed represented 2.9% of the knee arthroplasties between 9/1991 and 12/2002. Survival was defined as the absence of revision surgery. Death was considered a censored event. Results: Cumulative survival rates for the different TKA configurations were: cemented TKA with all-polyethylene tibia (APT) – 99.2% (98.2%, 100%); cemented TKA with metal-backed tibia (MBT) – 96.3% (95.3%, 97.3%); hybrid TKA – 89.3% (83.9%, 94.6%); and unicondylar knee (UKA) – 87.2% (82.8%, 91.6%). Follow-up tests using cemented TKA with MBT as the reference group were conducted and odds ratios were calculated. Cemented TKA with MBT had significantly better survival than hybrid TKA (p=.031, OR=1.56), ingrowth TKA (p=.005, OR=2.31), and UKA (p<.001, OR=3.06). Cemented TKA with MBT did not have significantly better survival than cemented TKA with APT (p=.220, OR=.412). Gender was not significantly related to survival (p=.680). Age was significantly related to survival, with older patients' knees surviving longer (p<.001). Aseptic loosening or wear was the cause of revision in 40.8% of TKA and 46.6% of UKA, while progression of arthritis necessitated UKA revision in 51.2%. Conclusion: This study presents further evidence of the value of, and ongoing need for, total joint registries. Cemented TKA with APT and with MBT showed greater than 95% ten-year cumulative survival. Hybrid TKA, ingrowth TKA and UKA fared less well.

PAPER NO. 007

Effect of Comorbidities on Outcomes of Major Joint Replacement Surgeries Based on 959,839 Cases

Nitin Jain, MD, MSPH, *Carrboro, NC (n)*
Laurence D Higgins, MD, Durham, NC (n)
Ricardo Pietrobon, MD, Durham, NC (n)
Thomas K Bond, MD, New Orleans, LA (n)
Ulrich Guller, MD, Durham, NC (*)
Anoop Shankar, Madison, WI (*)
Shamsah Kazani, MD, Buffalo, NY (n)

Introduction: Hypertension, diabetes and obesity are frequently encountered comorbidities in patients undergoing orthopaedic surgery. The objective of this study was to determine the effect of these comorbidities on outcomes in patients undergoing total joint replacement surgeries. We hypothesize that patients with hypertension, diabetes or obesity have worse outcomes after shoulder, knee and hip joint replacement as defined by higher rate of post-operative complications and non-routine disposition of patient on discharge. Methods: The combined Nationwide Inpatient Sample databases for the years 1988 through 2000 with a total of 959,839 cases undergoing shoulder, knee or hip arthroplasty were used for the present analysis. Logistic regression was used to estimate the association between outcomes and each of the comorbidities after adjusting for age, race, household income, sex, hospital volume per year, geographic location of hospital, and teaching status and location of hospital. Results: Post-operative complications were significantly more likely to occur in patients with hypertension, diabetes or obesity as compared to patients without these disorders (post-operative complications rate 2.8% as compared to 2.6% for HT, 2.9% as compared to 2.6% for DM, and 3.7% as compared to 2.6% for obesity, all p-values less than or equal to 0.01). The likelihood of non-routine disposition of patient on discharge after surgery was increased in patients with hypertension, diabetes or obesity (non-routine disposition of patient on discharge rate 68.9% as compared to 62.4% for HT, 70.1% as compared to 64.5% for DM, and 68.9% as compared to 65.1% for obesity, all p-values less than or equal to 0.01). Similar negative effects were observed in patients with combination of comorbidities. Conclusion: Hypertension, diabetes and obesity are important predictors of poor outcomes in patients undergoing major joint replacement surgeries. Information about these comorbidities is easily available from patient records, and can be used for counseling such patients to better assess operative risks and benefits while considering major joint replacement surgery.

PAPER NO. 008

Prospective Analysis of 1000 Patients with Hydroxyapatite-Coated Total Knee Replacements

Mervyn J Cross, MD, *Crows Nest, Australia*
(c – Osteo AG Switzerland)
Erin Nicholas Parrish, MHS C, Crows Nest, Australia (n)

Introduction: Use of bioceramic coatings to enhance fixation of joint arthroplasties is a relatively new concept that has yet to prove long term, reliable results in knee arthroplasty. The purpose of this study was to prospectively report on the medium to long-term outcomes of an uncemented, hydroxyapatite (HA) coated total knee replacement (TKR). Methods: Between 1992 and 2001 all patients requiring primary TKR were treated with an uncemented, HA-coated, PCL retaining prosthesis implanted by the senior author. Regular postoperative clinical follow up was conducted using the Knee Society score. Results: One thousand patients with a mean age of 68 years underwent TKR mainly for OA (94%). Mean follow up was 6.6 years (range 2.5-11.3 years). There were 571 unilateral and 858 bilateral replacements. Mean preoperative score was 96. At 5 and 10 years scores improved to 182 and 180 respectively. There have been 7 (0.5%) cases requiring revision, primarily for septic loosening (4 cases). There have been 17 deep infections (1.2%), 25 proven pulmonary emboli (1.7%) and 5 periprosthetic fractures (0.3%). There has been 1 (0.07%) case of aseptic loosening which required revision. Discussion and Conclusion: These results reveal the use of HA in uncemented TKR produces reliable fixation that is comparable to other methods of fixation as demonstrated with minimal revision rate and incidence of loosening. The clinical results produce an excellent range of movement with good medical and functional outcomes in the medium to long-term follow-up.

PAPER NO. 009

Mode and Frequency of Failure Necessitating TKAR: A Fifteen-Center Prospective Cohort Study

Khaled J Saleh, MD, *Minneapolis, MN*
(a – Stryker Howmedica Osteonics)
Kristin A Schwartz, St Paul, MN (n)

Introduction: There are few studies that prospectively report the mode and frequency of failure leading to revision knee arthroplasty. The purpose of this study was to prospectively identify these factors. Methods: The North American Knee Arthroplasty Revision Study (NAKAR) is a multicenter prospective observational cohort study being conducted at fifteen sites. The primary objective of the study is to document functional outcome following revision knee arthroplasty procedures. Baseline data was collected using self-report questionnaires on 187 consecutive subjects inducted over a six-month period. Surgeons documented physical exam and radiograghic data preoperatively to capture baseline characteristics prior to revision surgery. Results: The mean age of participants in need of revision was 68.6 years. Females comprised 51% of the cohort. 83% of the study subjects

in need of TKAR were aseptic and 17% were septic. Of the septic failures, over half (63%) underwent a two stage exchange. The most common responses for failure were extensor mechanism instability 33%, polyethylene wear 27%, failed tibial component 26%, femoral bone lysis 24%, tibial bone lysis 24%, failed polyethylene insert 21% and failed femoral component 21%. The average length of time between the first implantation and TKAR was 7.9 years. Conclusion: Majority of subjects in need of TKAR were aseptic. Aseptic loosening secondary to osteolysis in this multicenter series is significantly higher then that previously reported in the literature. The majority of septic cases were treated with two-stage exchange. There are several different reasons for TKAR, most notably was extensor mechanism instability.

PAPER NO. 010

Patellar Resurfacing/Nonresurfacing in Total Knee Arthroplasty: A Randomized Trial at Minimum 10 yrs

Robert Stephen Burnett, MD FRCSC, *St Louis, MO (n)*
Chris Haydon, London, Canada(n)
Husam Elkassem, BS, London, Canada (n)
Cecil H Rorabeck, MD, London, Canada
(a, c – DePuy, Johnson & Johnson)
Robert Barry Bourne, MD, London, Canada (n)

Introduction. Problem: Patellar resurfacing in TKA remains controversial. Purpose: To evaluate the results of resurfacing/non-resurfacing of the patella in a randomized controlled clinical trial at a minimum of 10-years. Methods One hundred knees (90 patients) with osteoarthritis were enrolled in a prospective randomized controlled double-blinded trial using the same posterior cruciate retaining total knee replacement. Patients were randomized to resurfacing or nonresurfacing of the patella. Evaluations were performed preoperatively and yearly to a minimum 10 years (range, 10.1-11.5 years) postoperatively. Disease specific (Knee Society Clinical Rating System, WOMAC), general health (SF-12), functional (stair climbing, knee flexion/extension torques) outcomes were measured. Patient satisfaction, anterior knee pain, and patellofemoral questionnaires were completed. Intraoperative grading of the articular cartilage was performed. Results No patients were lost to follow-up; 46 knees remained alive. Nine revisions (10percent) were performed: 7 (15 percent) in the nonresurfaced and 2 (5percent) in the resurfaced group. Three knees in the nonresurfaced group were revised to a resurfaced patella for anterior knee pain. One resurfaced patella was complicated by AVN and fracture, requiring revision. No significant difference was found between the groups regarding revision rates, KSCR score, WOMAC, SF-12, functional, satisfaction, anterior knee pain, patellofemoral, and radiographic outcomes. Intraoperative cartilage quality was not a predictor of outcome. Conclusions his study represents the longest follow up to date of a randomized controlled clinical trial to examine patellar resurfacing in TKA. The results showed no significant difference between the groups for all outcome measures at a minimum of 10-years.

PAPER NO. 051

Viscosupplementation: Evidence for a Mechanism of Action

David D Waddell, MD, *Shreveport, LA*
(a – Genzyme Biosurgery, e - Wyeth)
Oleg V Kolomytkin, PhD, Shreveport, LA (n)
Andrew A Marino, Shreveport, LA (*)
Kalia K Sadasivan, MD, Shreveport, LA (n)
James A Albright, MD, Shreveport, LA (n)

INTRODUCTION: Viscosupplementation is approved for treating pain due to osteoarthritis (OA). One possible mechanism is the reduction in expression of cartilage-destroying enzymes (metalloproteinases (MMPs)), which are produced in response to proinflammatory cytokines such as IL-1. We hypothesized that hyaluronan (HA), the substance used in viscosupplementation, reduced MMP activity of synovial cells in OA patients induced by IL-1. METHODS: Surgical biopsies (0.12 square cm, +/-15 percent) were obtained from 20 patients undergoing total-knee replacement for OA. The biopsies were cultured for 24 hrs in serumless medium in the presence or absence of IL-1 (100 pg/ml) and HA (8 mg/ml), and the MMP activity of the supernatant (principally collagenase) was measured using a film of collagen as the substrate. The three HA products approved by FDA for viscosupplementation and one additional HA were studied. The HA's and their respective molecular weights were: Synvisc (6 MDa); Supartz (0.6-1.1 MDa); Hyalgan (0.5 MDa); 0.2 MDa HA (Lifecore). The effect of HA on the IL-1-induced MMP production was evaluated using the unpaired t-test; enzyme activities are expressed in units of mg of substrate digested per hour per square meter. RESULTS: The synovial biopsies produced a constitutive MMP activity of 2.7+/-1.2, which was increased 16-fold (to 44.7+/-4.8) in response to treatment with IL-1. When 0.2 MDa HA was added together with the cytokine, the MMP activity was unaffected (45.0+/-5.5). The MMP activities measured in the presence of IL-1 and viscosupplementation HA's were: 27.9+/-5.7, Hyalgan; 7.8+/-4.3, Supartz; 3.6+/-1.1, Synvisc ($P<0.05$ compared with IL-1 alone for all 3 HA's). Fat biopsies produced only a negligible amount of MMP activity, indicating that the enzymatic activity in the synovial biopsies was produced by synovial cells. CONCLUSION: Viscosupplementation HA's blocked the IL-1-induced MMP activity produced by synovial cells in a process that depended on HA molecular weight; maximum inhibition occurred at the highest molecular weight (6.1 MDa). It is not possible to reach conclusions regarding the relative abilities of the HA's to inhibit cytokine-induced MMP activity when the HA's are used at the FDA-approved concentrations (10 mg/ml, except 8 mg/ml for Synvisc). Even so, the results established that the viscosupplementation HA's can inhibit cytokine-induced MMP activity, as hypothesized, suggesting that the mode of action of HA might be due to reduced MMP activity with concomitant reduction in inflammatory-mediated pain.

PAPER NO. 052

Chondral Debridement using Arthroscopic Plasma-Mediated Electrosurgery: A 2-year Multicenter Study

Frank A Pettrone, MD, *Arlington, VA*
(a - Arthrocare Coorporation)
Francois S Antounian, MD, San Francisco, CA
(b - Arthrocare Coorporation)
Jonathan Greenleaf, MD, Tualatin, OR (n)
Champ L Baker Jr, MD, Columbus, GA (n)

Background: Functional problems and pain associated with chondral defects in the knee are a common orthopedic complaint. Safety and clinical outcomes were evaluated in subjects with symptomatic chondral defects who received routine debridement via bipolar electrosurgery (bES). Methods: Eight clinical sites prospectively tracked clinical sequelae and collected joint specific function measures, pain status, and frequency of participation in sports activity from subjects at regular intervals over the 2-year postoperative follow-up period after debridement. Subjects (n=101) had knee pathology requiring arthroscopic surgery and concomitant partial-thickness Outerbridge grade II or III chondral defect(s). Magnetic resonance imaging (MRI) photography was obtained more than 1 year postoperatively in a subset of the study sample (n=23). Results: Two years after debridement, 74 percent of subjects reported normal knee condition and rare to no knee function symptoms (confidence interval (CI) = 64, 84) compared to 11 percent (CI = 5, 17) at baseline. This proportion was consistent from postoperative 12 weeks. Improvement in knee function corresponded to reduction or elimination of pain. At 2 years, 66 percent (CI = 54, 78) of subjects reported more frequent participation in sports activity than at baseline. No unexpected adverse clinical sequelae were observed. Subjects eventually lost to follow-up had similar results at most recent follow-up to those who had successful outcome at 2 years. Conclusions: Bipolar electrosurgery for chondral debridement is a safe and effective method for treating functional symptoms and pain associated with moderate grade chondral defects in the knee.

PAPER NO. 053

Unispacer Arthroplasty of the Knee

Domenick J Sisto, MD, *Sherman Oaks, CA (n)*

Introduction: The purpose of this study is to report on my experience with the use of a unispacer arthroplasty for the treatment of isolated medial compartment arthritis of the knee. Methods: Between April 2002 and November 2002, 37 unispacer arthroplasties were performed in thiry four patients for the treatment of arthritis that primarily involved the medial compartment of the knee. The Ahlbach radiographic evaluation scale was used to grade the severity of arthritis; the mean score was 2.6 points (range 2-3 points) for the medial compartment and 0.5 point (range 0-1 point) for both the lateral and patello-femoral compartments. The patients included eighteen women (one bilateral) and sixteen men (two bilateral) who had a mean age of 55 years (range 42 to 75 years). Twelve of the patients had previous arthroscopic meniscectomies of the knee. The mean pre-operative knee society objective score was 62 points (range 40 to 76 points). Results: At a mean duration of follow-up of eight months (range, 6 to 11 months), there were no excellent, ten good, fifteen fair and twelve poor results. The mean knee society objective score was 72 points (range 45-88 points). The twelve poor results included six patients with dislocations of the unispacer. All twelve were revised to a total knee arthroplasty. Conclusion: Unispacer arthroplasty is not recommended for the treatment of medial compartment degenerative arthritis of the knee.

PAPER NO. 054

Unicompartmental Arthroplasty - Long Term Success in Middle-Age and Obese Patients

Owen B Tabor Jr, MD, *Memphis, TN (n)*

Introduction: This study was performed to determine whether unicompartmental arthroplasty (UKA) is a viable long term solution to isolated single compartment knee arthritis, and specifically to address the results in middle age and obese patients. Methods: Five to 20 year follow up data were obtained from 93 consecutive UKAs performed in 76 patients for isolated medial compartment knee arthritis. The Knee Society scoring system was used. Radiographs were evaluated for component loosening and progression of disease in unoperated compartments. Survivorship analysis was performed. Results were stratified based on age over or under 60 at the time of surgery, gender, and body habitus with obesity defined as body mass index > 30. Results: One patient was lost to follow-up. Four patients (5 knees) died with functioning UKAs prior to 5 year follow up. Twelve UKAs failed in 10 patients at an average of 74 months. All failures were successfully revised using primary total knee implants. Survivorship was 93.1 % (95% CI - 87.4-98.9%) at 5 years, 89.2 % (80.7-97.7) at 10 years, 85.2% (71.3-99.2) at 15 years, and 82.2 (56.2-108.4) at 20 years. Average knee society score was 90.5 and the average functional score was 76.7 at last follow up. Knee Society scores were similar when stratified based on gender, age at surgery, and body habitus. There was no difference in survival at any interval based on age over or under 60 at the time of surgery. Obese patients had better survival at all intervals than non-obese patients, reaching statistical significance at 20 years. Females had significantly better survival than males at 10, 15 and 20 years. Discussion/conclusion: This study confirms continued good functional outcome and survivorship for UKA up to 20 years. Age under 60 and obesity do not appear to be contraindications to UKA..

PAPER NO. 055

◆A Clinical Assessment of Hydroxyapatite-coated Unicompartmental Knee Arthroplasty

Michael T Manley, PhD, *Ridgewood, NJ*
(a, d, e – HowMedica Osteonics)
Jean-Alain Epinette, MD, Bruay-Labuissiere, France
(a, c – Stryker - HowMedica Osteonics)

Introduction Long-term fixation of unicompartmental knee arthroplasty has proven to be a difficult clinical problem. In 1990, we began an evaluation in France of hydroxyapatite - coated unicompartmental knee tibial components. The intention of this study was to measure the survivorship rate and compare it to controls from the literature. Methods consecutive series of 113 "Unix" tibial components was implanted in 110 patients. The average incision length was 5 centimeters. All components were fixed with screws. Assessment was by radiographic review using the International Knee Society (IKS) scoring system. Mean follow-up was 6.93 years (range, 5-13 years). Results Average range of motion at most recent follow-up was 127.5 degrees (range, 60 to 160 degrees). The average IKS score was 95.6 (range, 67 to 100). Radiographic evaluation showed one knee with reactive lines under the tibial plateau. No other instances of interface loosening were observed. Survivorship (aseptic loosening) was 99.5 percent plus or minus 0.009. Discussion and Conclusion Our study demonstrates that patients with UKA HA-coated tibial components, implanted

through a small incision, remain active and essentially pain-free at ten years follow-up. Polyethylene wear has not been a problem. Radiographically, all implants remain stable. The patients in this group remain satisfied with the outcomes of their UKA procedures.

PAPER NO. 056

◆Long-term Results of the Oxford Mobile Bearing Unicompartmental Knee Replacement

Roger H Emerson, Jr, MD, *Plano, TX (a, b, c – Biomet Inc)*
Linda Higgins, PhD, Plano, TX (n)

Mobile-bearing unicompartmental implants have the promise of enhanced survivorship due to favorable polyethylene wear features of this type of design. The authors report on a series of 59 medial Oxford unicompartmental implants done from 1989-1993 with a minimal follow-up of 10 years (range 10-14 years). 50 of 59 knees were available for follow-up (85%). These were part of an IDE study. The goal of the report is to focus on survivorship analysis and the modes of failure. Results have shown good overall clinical scores and patient satisfaction. There have been no bearing dislocations, but one bearing had to be replaced because of bone impingement in full extension. There was one femoral loosening, one revision due to the acute onset of rheumatoid arthritis and 3 revisions due to progression of arthritis in the lateral compartment. One tibial insert was revised. There are no impending failures in the series at the time of review. Overall survivorship at 14 years based on revision for any reason is 85.9%. For revisions due to implant loosening the survivorship was 98.2%. For revision due to polyethylene wear the survivorship was 98.2%. For revision due to arthritis progression the survivorship was 92.1%. In all of theses progression cases the implant showed no excessive polyethylene wear and no loosening. The lateral progression correlated with an increased valgus alignment compared to surviving implants. Over-correction of knees with unicompartmental implants should be avoided.

PAPER NO. 057

Creep and Wear of Full Polyethylene Retrieved Unicompartmental Tibial Components

Philippe Hernigou, PhD, *Creteil, France (n)*
Gerard Deschamps, MD, Dracy Le Fort, France (c – Tornier SA)

Introduction: This study evaluated the creep and true wear in 55 medial unicompartmental implants that had a flat articular surface at the time of implantation. Materials and methods: All the full polyethylene components had the same design and were retrieved from 11 to 244 months after their implantation. The postoperative varus deformity had been measured on weight-bearing radiographs of the whole limb (hip-knee-ankle angle). The retrieved implants were placed in a coordinate measuring machine.Using this system, a three dimensional scaled image was used to calculate the total penetration of the femoral implant in relation with true wear and creep. To separate plastic deformation from true wear, the volume of true wear was calculated by wheighing the tibial components and comparing the results with non implanted components . Difference between the penetration determined by the coordinate machine and penetration determined by wheighing was considered to be in relation with creep. Results: Total linear penetration rates ranged from 0.2 to 2.6 mm/year (mean 0.25 mm/year). Linear penetration rates in relation with wear ranged from 0.1 to 1.4 mm/year (mean 0.13 mm/year), and penetration in relation with creep ranged from 0.1 to 1.9 mm/year (mean 0.12 mm/year). The linear penetration of the femoral condyle in relation with true wear was negatively correlated with length implantation. The linear penetration in relation with creep was higher in the first two years after the implantation versus the subsequent years. Using multiple linear regression analyses to remove the confounding effects of age, weight, gender and thickness of the implant, we found that an increase of the postoperative varus deformity was in relation with an increase of creep ($p = 0.03$) but not with an increase of true wear ($p = 0.25$). Thinner implants were in relation with an increase of creep ($p = 0.02$) but not in relation with an increase of true wear ($p = 0.08$). Increase in age was in relation with decrease of wear ($p = 0.04$) and increase of weight was in relation with increase in creep ($p = 0.03$). Discussion: Creep had a high influence on the penetration rate of the femoral condyle in full polyethylene implants. There is a risk of increase penetration and decrease remaining thickness of the tibial plateau when the implant is too thin, the knee malaligned and the patient heavy, all these factors increasing the creep deformation.

PAPER NO. 058

◆Ten-Year In Vivo Wear of a Fully Congruent Mobile Bearing Unicompartmental Knee Arthroplasty

Andrew Price, FRCS, *Melbourne Victoria, Australia (a, b - Biomet Inc)*
Andrew Liam Short, MD, Oxford, United Kingdom (*)
Catherine Kellett, FRCS, Stanton St John, OXFORD United Kingdom (*)
Hemant G Pandit, FRCS, Oxford, United Kingdom (*)
Harinderjit Gill, PHD, Oxford, United Kingdom (*)
David W Murray, MD, Oxford, United Kingdom (*)

Aim: To investigate the in-vivo 10-year linear polyethylene wear of a fully congruent mobile bearing unicompartmental knee arthroplasty (UKA). The device studied was the Oxford UKA.Methodology: Seven patients with unilateral fully congruent mobile bearing devices (Study Group) that had all been implanted at least 10 years previously were recruited. In addition eight patients with the same device (Control Group) were examined within 3 weeks of surgery. RSA stereo x-ray pairs of the operated knee were taken at 0 and 30 degrees of knee flexion. The RSA system gave the position and orientation of each femoral and tibial component, from which the bearing position was inferred. Linear wear was calculated as the maximum penetration of the femoral component into the original surface of the bearing. Error was determined from the control group and by comparing the measurements at different flexion angles. Results: The control group showed no measurable wear. The study group had an average linear penetration of 0.25mm at a mean follow-up of 10.9 years. The mean error was 0.01mm with a standard deviation of 0.09mm. The linear wear rate was 0.02mm/year. Discussion: Polyethylene particulate wear debris is implicated in the aetiology of component loosening and implant failure following knee arthroplasty. This device has a spherical femoral component and a fully congruous meniscal bearing to increase contact area and theoretically reduce the potential for polyethylene wear. The results from this in-vivo study confirm that the device has low 10-year linear wear in clinical practice.

PAPER NO. 059

Determinants of Patient Satisfaction and Outcome After Medial Opening Wedge High Tibial Osteotomy

Bruce Miller, MD, *Ann Arbor, MI (a – EBI)*
Thomas A. Joseph, MD, Vail, CO (a – EBI)
Elizabeth M Barry, Vail, CO (a – EBI)
Valerie Rich, MD, Vail, CO (*)
William I Sterett, MD, Vail, CO (n)

Objective: The purpose of this study was to measure satisfaction and functional outcome of patients treated with medial opening wedge high tibial osteotomy for the degenerative varus knee, and to correlate these with a number of preoperative and postoperative variables. Methods: Our clinical database was reviewed to identify patients with minimum two-year follow-up. Data were collected prospectively and analyzed retrospectively. Correlative and multivariate analyses were performed. Results: Medial opening wedge osteotomy was performed in 61 patients with an average age of 52.2 years. Thirty patients were treated with plate fixation, and 31 with distraction osteogenesis and external fixation. The average correction was 15.5 mm. Mean satisfaction score was 7.6 (1=not satisfied, 10=very satisfied). The mean preoperative Lysholm score of 49.9 improved postoperatively to 75.4 (P<0.001). There was no significant correlation between satisfaction and age, gender, fixation technique, or magnitude of correction. Nineteen patients had Outerbridge grade III or IV patello-femoral lesions at surgery. There was a statistically significant positive correlation between satisfaction and patello-femoral arthrosis (P<0.039), as well as between satisfaction and postoperative Lysholm score (P<0.001). Females showed a significantly higher improvement in Lysholm scores than males (P<0.029). The independent multivariate predictor of patient satisfaction was the postoperative Lysholm score. Conclusion: Medial opening wedge high tibial osteotomy in the active patient with varus degenerative joint disease produces high patient satisfaction and improved functional outcome scores. Patient satisfaction was independent of age, gender, or magnitude of correction. A greater change in Lysholm scores was seen in female patients. The presence of patello-femoral arthrosis should not be considered a contraindication to medial opening wedge tibial osteotomy.

PAPER NO. 060

◆Ximelagatran Provides Greater Prevention of VTE After Total Knee Replacement Than Warfarin

Clifford W Colwell Jr, MD, *La Jolla, CA*
(a – AstraZeneca, Aventis, Sanofi-Synthelabo, Wyeth-Ayerst)
Scott D Berkowitz, MD, Wilmington, DE
(e – AstraZeneca)
Phillip C. Comp, MD, Oklahoma City, OK
(a, b – AstraZeneca, Aventis, Sanofi-Synthelabo)
Jay R Lieberman, MD, Los Angeles, CA (b – AstraZeneca)
Jeffery G Ginsberg, MD, Hamilton, Canada
(a, e – AstraZeneca)
Guy D Paiement, MD, Mission Viejo, CA
(a – AstraZeneca)
Gary R Peters, MD, Wayne, PA (e – AstraZeneca)
Anne W Roth, Wilmington, DE (e – AstraZeneca)

Introduction: Even with dose adjustment, warfarin is associated with total DVT rates in TKR of 36-55 percent, proximal DVT rates of 7-12 percent, and requires routine coagulation monitoring. Ximelagatran (Exanta™), a novel oral direct thrombin inhibitor, selectively inhibits free and clot-bound thrombin and requires no coagulation monitoring. Objective: To optimize the dose of ximelagatran and compare the efficacy and safety of ximelagatran with warfarin for prevention of VTE in TKR patients. Methods: Multicenter clinical trial of fixed-dose ximelagatran 24 or 36 mg bid initiated the morning after surgery, or warfarin (target INR 2.5; range 1.8-3.0) initiated the evening of surgery and matched placebo continued for 7-12 days. Measurements: Efficacy was confirmed by incidence of VTE, by postop Day 12, confirmed by mandatory bilateral venography or, if symptomatic by objective means; all-cause mortality; and safety by incidence of major or any (major and minor) bleeding. An independent central adjudication committee interpreted VTE and bleeding. Results: 2301 patients randomized; 2285 received 1 dose of study drug (safety population), and 1851 had adequate venography or symptomatic VTE (evaluable population). The efficacy of ximelagatran 36 mg po bid was superior (20.3 percent vs. 27.6 percent, P equals 0.003) to warfarin for total VTE. No statistically significant differences occurred for proximal DVTs, PEs, or death, nor for major or any bleeding, or wound drainage or appearance. Conclusions: Ximelagatran 36 mg po bid started the day after TKR for VTE prophylaxis provides superior efficacy and no increase in bleeding compared with warfarin and requires no coagulation monitoring or dose adjustment.

PAPER NO. 171

Component Revision for Stiffness after Primary Total Knee Arthroplasty

George John Haidukewych, MD, *Rochester, MN (n)*
David J Jacofsky, MD, Rochester, MN (n)
Mark W Pagnano, MD, Rochester, MN (*)

Purpose: Stiffness remains a common and frustrating complication after total knee arthroplasty. The poor results of open arthrolysis and polyethylene "down-sizing" have been previously reported. The purpose of this study was to retrospectively review the results of formal revision of well fixed components for stiffness after primary total knee arthroplasty to learn more about the results, outcomes, and complications of the procedure. Materials and Methods: Between 1990 and 2001, 16 revision total knee arthroplasties were performed in 15 patients with a mean age of 68 years (44-84 years) for a diagnosis of stiffness. Only primary total knee arthroplasties were studied, and in all cases, all components were well fixed. Isolated polyethylene exchanges were excluded. All knees were revised to a cemented posterior stabilized design. Patients were followed until death, revision, or a minimum of two years. One patient died before 2-year follow-up. Mean follow-up for the remaining 14 patients was 41 months. Function and radiographs were evaluated using the Knee Society criteria. Results: 11 of 15 patients (73%) were satisfied with the results of the procedure. The mean Knee Society pain score improved from 28 (0-54) preoperatively to 65 (17-94) postoperatively. The mean Knee Society function score improved from 45 (0-80) preoperatively to 58 (28-90) postoperatively. The mean arc of motion improved from 40 degrees preoperatively to 73 degrees postoperatively. All components were well fixed at follow-up. Three knees (18%) required manipulation postoperatively due to recurrent stiffness. Discussion and Conclusion: The results of revision of a well-fixed stiff primary total knee arthroplasty were mixed in our hands. Although the majority of patients experienced improvement in pain and function, many remained unsatisfied with the procedure. The patient and the treating surgeon should be cognizant of the modest improvements in pain, function, and range of motion with revision in this setting.

PAPER NO. 172

Osteolysis Around Total Knee Arthroplasty Diagnosed by Multi-Detector Computed Tomography

Timothy G Reish, MD, *Columbus, OH (n)*
Giles R Scuderi, MD, New York, NY (a, c, e – Zimmer)
W Norman Scott, MD, New York, NY (c – Zimmer)
Fred D Cushner, MD, New York, NY (n)
Kevin Math, MD, New York, NY (n)

Purpose: The purpose of this study was to determine the accuracy of plain radiography in detecting osteolytic lesions around total knee arthroplasty compared to multi-detector computed tomography, MDCT. Methods: 26 patients were retrospectively reviewed who had diagnoses of osteolysis by MDCT scanning. The results of these scans were compared with the xrays performed on the same patients prior to the CT. All studies were read in a blinded fashion by a fellowship trained musculoskeletal radiologist and the orthopaedic surgeon. The number, size, and location of the lesions were compared. Results: The average age was 69 years. 23 prostheses were PS and 3 were CR. Xray detected osteolytic lesions in 8 of 26 knees. The MDCT scanning technique located 40 individual lesions in 26 knees. There were 3 femoral lesions, 33 tibial lesions, 3 patellar lesions and 1 lesion adjacent to the tibial stem. Xray diagnosis was made in 6 of 33 tibial lesions, 2 of 3 femoral lesions, and 0 of 3 patellar or stem lesions. Conclusions: Xray was able to detect 20 percent of the osteolytic lesions present in this cohort of patients. MDCT allows the surgeon a diagnostic and preoperative planning tools for revision surgery due to osteolysis. It is our contention that xray is an inadequate means by which to diagnose osteolysis around total knee arthroplasty.

PAPER NO. 173

Factors Influencing Wear and Osteolysis in PFC Modular Total Knees

Thomas K Fehring, MD, *Charlotte, NC*
(a, e – DePuy, Johnson & Johnson)
Jeffrey A Murphy, MS, Warsaw, IN
(a, e – DePuy Orthopeadics)
T David Hayes, MD, Vancouver, WA (*)
Donald W Roberts, MD, Vancouver, WA (a – DePuy)
Donald L Pomeroy, MD, Louisville, KY (*)
William L Griffin, MD, Charlotte, NC
(a, b, c, e – DePuy, Johnson & Johnson)

Introduction: The purpose of this study was to determine the factors influencing wear related problems in one total knee system. Methods: 2091 TKA's were performed using the PFC modular system at 3 centers. Radiographic analysis was performed by an independent radiologist. Manufacturing data was obtained for 2084 of 2091 (99%) implants. Patients with major osteolysis or a wear related revision were considered a positive event. Survival analysis was conducted using the Kaplan-Meier method. Cox proportional hazards analysis was conducted to determine which manufacturing or patient variables were related to positive events. Results: Since osteolysis rarely occurs without a substantial in-service life we chose to create a subset of cases with at least 5 year follow-up to report the prevalence of wear related failure. The prevalence of wear related failure with this implant was 8.4% (108 of 1287). The 13 year survivorship for all patients was 82.6% (95% C.I. = 78 to 86.8%). Five variables were statistically significant - age and gender of the patient, polyethylene sheet processor, finishing method and shelf age in years. Conclusion: We were unable to identify one single factor as the defining reason for these wear related failures. The multiple changes in manufacturing methods during the life of this implant precluded such a determination. The reason for these wear related failures are probably multifactorial. This study emphasizes the potential deleterious effects that small changes in the manufacturing process may have on the outcome of a prosthesis with an initially favorable survivorship. Careful consideration of these effects must be made before any change in the manufacturing process of a successful implant is entertained.

PAPER NO. 174

Early Failure of Cementless Mobile Bearing TKA

Robert L Barrack, MD, *New Orleans, LA (n)*
Shawn J Nakamura, MD, Austin, MN (n)
Alexander J Bertot, MD, Miami, FL (n)
Michael Wayne Wolfe, MD, Salem, VA (n)

A consecutive series of 82 cementless mobile bearing total knee arthroplasties performed was studied. The indications for surgery in all cases was osteoarthritis with only mild or moderate deformity. Evaluation consisted of a Knee Society clinical score (KSCS) and radiographic evaluation pre-operatively and at annual follow-up. Minimum two year follow-up was obtained in 73 of 82 knees (89%). Results were compared to those of a subsequent consecutive series of 76 knees (66 with 2 yr follow-up) performed with a mobile-bearing TKA with cemented components with the same indications, implant, technique, and length of follow-up. Six of 73 cementless mobile-bearing TKA's (8%) underwent tibial component revision for symptomatic subsidence and failure of ingrowth compared to 0/66 revisions in the cemented group ($p < .05$). Patients with cementless mobile bearing TKA also had a significantly lower KSCS (161 vs 184, $p < .05$), significantly higher incidence of pain rated more than mild (23% vs 7%, $p < .01$) and a trend toward less arc of motion (1060 vs 1150, $p < 0.2$). .

PAPER NO. 175

Stiffness after Total Knee Arthroplasty: Prevalence and Outcomes after Revision Surgery

Jane Kim, MD, *Philadelphia, PA (n)*
Paul A Lotke, MD, Philadelphia, PA (e – Johnson & Johnson, Stryker)
Charles Nelson, MD, Philadelphia, PA
(c – Exactech, e – Zimmer)

Introduction: Stiffness after total knee arthroplasty is an uncommon, yet disabling complication. The prevalence of the stiff total knee has not been well defined in the literature. In addition, the outcomes after revision of a stiff total knee arthoplasty have not been evaluated in a large series of patients. The purpose of this study is to define the prevalence of stiff knees after primary total knee arthroplasty, and to evaluate the success of managing the complication with revision surgery. Methods: We defined a stiff total knee as one having a flexion contracture of at least 15_ and/or less than 75_ of flexion. Two groups were evaluated. In order to determine the prevalence of stiffness, one thousand consecutive primary total knee replacements were reviewed in the first group. In the second group, fifty-six primary total knees (fifty-two patients) which had undergone revision surgery for stiffness were assessed. They were evaluated with Knee Society clinical scores at the preoperative visit, the first follow-up visit, and the final follow-up visit. Results: In the series of one thousand consecutive primary total knee replacements at

our institution, the prevalence of stiffness was 1.3%, at an average follow-up of thirty-two months (range, twenty-one months to five years). In our second study group, fifty-six stiff total knees had revision surgery at a mean of eighteen months (range, nine months to five years) from index surgery. These patients had an average follow-up of forty-three months (range, twenty-four months to ten years). The mean pain scores improved from 15 points, preoperatively, to 46.9 points, postoperatively; mean Knee Society scores improved from 38.5 points to 86.7 points, postoperatively; and function scores improved from 40 points to 58.4 points, postoperatively. The mean flexion contracture decreased from 11.3_ to 3.2_ , postoperatively. The mean flexion improved from 65.8_ to 85.4_ and the mean arc of motion improved from 54.6_ to 82.2_ , postoperatively. Discussion and Conclusion: The prevalence of the stiff total knee was relatively low and was only 1.3% of 1000 knees. Revision total knee arthroplasty was a satisfactory treatment option for the stiff total knee as these patients had improved range of motion and Knee Society scores after revision. However, our findings suggest that the benefits are modest and do not approach the expected results for primary total knees. Nonetheless, the increased range of motion is important to these patients because any degree of improvement is of valuable benefit to their function.

PAPER NO. 176

Results of Resurfacing a Native Patella in Patients with a Painful Total Knee Arthroplasty

Monti Khatod, MD, *Santa Monica, CA (n)*
Benjamin E Bierbaum, MD, Boston, MA (*)
Michael J Codsi, MD, Watertown, MA (n)

Patellar resurfacing remains a controversial topic. No studies currently exist exclusively evaluating the outcome of non-resurfaced patients undergoing subsequent resurfacing. We hypothesize that subsequent resurfacing outcomes are inferior to primary patellar resurfacing outcomes. We retrospectively reviewed 24 patients with 28 knees that underwent knee replacement surgery but did not have their patellas resurfaced. These patients subsequently presented for anterior knee pain and underwent patellar resurfacing. At average 2.9 year follow-up from their revision surgery, mean Knee Society Score is 138; mean score for pain is 45; mean score for function is 68. These values are lower than those reported for primary total knee patients in the literature. Range of motion increased from an average of 102 degrees to 106 degrees after revision. This was not statistically significant. Mean post-operative patellar tilt was 0 degrees. Only 52% of patients would chose to undergo the subsequent resurfacing given their current outcome.On a scale of 100 mean patient satisfaction is 70 with only 35% of patients responding with scores of 90 or greater. These findings are in concordance with anecdotal findings of subsequent patellar resurfacing outcomes reported in large randomized trials.We conclude that subsequent patellar resurfacing does not have equivalent outcomes as primary resurfacing when compared with historical controls. This information will hopefully aid the surgeon-patient decision making process on whether or not to resurface the patella during total knee arthroplasty.

PAPER NO. 177

Isolated Patella Revision Following Total Knee Arthroplasty

J Bohannon Mason, MD, *Charlotte, NC*
(e – DePuy, Johnson & Johnson)
Susan Marie Odum, MED, Charlotte, NC (n)
Thomas K Fehring, MD, Charlotte, NC (a, e – DePuy)
Thomas H McCoy, MD, Charlotte, NC (n)
William L Griffin, MD, Charlotte, NC
(a, b, c, e – DePuy, Johnson & Johnson)
Matthew Squire, Charlotte, NC (*)

Introduction: Total knee arthroplasty revision often results from failure of the femoral and/or tibial component. Occasionally, failure of total knee arthroplasty is isolated to the patella component. The purpose of this paper was to establish the frequency of patella only revisions and to isolate the failure mechanisms, which lead to revision. Additionally, we sought to determine the clinical outcome following isolated patella revision. Materials and Methods: From 1986 to December 2002, 632 revision total knee arthroplasties were performed. 15 (2%) patients from the registry underwent aseptic revision of the patella component only. Radiographic evaluation included pre- and post-operative merchant views in addition to standard AP and lateral images. Knee society radiographic scores were used to assess component fixation. Knee society pain and function scores were reported. Patella component failure mechanisms were categorized. Results: Of the 15 patients revised for patella related aseptic failure, 11 (73%) had patella components eccentrically placed on the patella. 8 of these (73%) were medially displaced and distinctly undersized relative to the undersurface of the patella. 3 (27%) were revised for failed metal backed components, all of which were well sized, fixed, and centrally implanted on the patella. 57% were radiographically loose at the time of revision. 3 (27%) all poly patella were well fixed but failed secondary to painful contact of the patella with the trochlear flange. The average knee society score improved from 57 to 94. Differences in alignment, patellar tilt and component manufacture did not reach statistical significance. Discussion: The frequency of isolated aseptic patella revision is 2% in this large revision TKA series. Knee society scores consistently improved following revision. A high percentage of patients presenting for isolated revision of the patella had undersized or eccentrically placed components, suggesting that the technique of purposeful medialization of the patella component for improved patella tracking should be reexamined.

PAPER NO. 178

Clinical Results of Isolated Polyethylene Bearing Revision in Mobile Bearing TKA

James E Dowd, MD, *Virginia Beach, VA (a, e – DePuy)*
Louis R Jordan, MD, Virginia Beach, VA (a, e – DePuy)
Jane Olivo, NP, Virginia Beach, VA (n)
Paul Voorhorst, MS, Warsaw, IN
(e – DePuy Johnson & Johnson)

INTRODUCTION: Recently several authors have reported a high rate of early re-revision in cases of isolated polyethylene bearing exchange. The current study reports our experience with isolated polyethylene bearing exchange in a mobile bearing TKA design. METHODS: Between October 1987 and April 2002, 32 isolated polyethylene bearing exchanges were carried out on patients who previously underwent primary TKA using a meniscal bearing total knee replacement (LCS, DePuy). All bearing

exchanges were performed due to polyethylene wear or dislocation. Average age at the time of bearing exchange was 74 years. Average time to revision from the primary surgery was 10.4 years (range 6-14 years). Average follow-up since the bearing exchange surgery was 5.9 years (range 1-9 years). RESULTS: Four knees required re-revision, one for subluxation at 5.8 years, one for polyethylene breakage at 6 years, one for polyethylene wear at 8 years, and one for femoral component breakage at 14 years postoperatively. The Knee Society scores improved significantly from pre-bearing exchange to most recent follow-up: knee score 74 to 92, function score 60 to 80, and flexion 110 to 115. CONCLUSION: Early design issues and polyethylene quality may have contributed to polyethylene bearing wear and fracture. In contrast to recent reports of disappointing results following isolated polyethylene exchange in fixed bearing TKA's, our results with meniscal bearing exchange in a mobile bearing TKA have been encouraging.

PAPER NO. 179

Predictors of Success with 2-Stage Revision TKA's for Deep Sepsis

Akihiko Yonekura, MD, *Nagasaki, Japan (n)*
Robert Barry Bourne, MD, London, ON Canada (n)
Cecil H Rorabeck, MD, London, ON Canada (a – DePuy, Johnson & Johnson)
Steven J MacDonald, MD, London, ON Canada (n)
Richard W McCalden, MD, London, ON Canada (n)

Purpose: The purpose of this study was to identify predictors of success for 2-stage revisions of infected total knee arthroplaasties (TKA). Methods: Our joint replacement database was used to identify 68 2-stage revision total knee replacements for deep sepsis with a 2 - 16 years follow-up (mean = 5.0+/-3.5). Results: 1) The overall success of 2-stage revision TKA was 88%. Of the 8 out of 68 patients who became reinfected, 1 was cured by incision and drainage, 2 were cured by repeat 2-stage revisions, 1 became reinfected after a repeat 2-stage revision, 2 were arthrodesed and 2 were still infected. 2) For infected primary TKA's, there was a 91% success rate versus an 82% for infected revision TKA's. 3) 2-stage revision arthroplasties for deep sepsis were most successful if the duration from infection onset to the first stage of the revision were short (i.e. 100% success less than 1 month, 93% from 1 - 3 months, and 79 % from 3 - 12 months). 4) Patient age, gender, body mass index, diagnosis and comorbidity had no effect on the success or failure of 2-stage revision TKA. 5) The poorest results occurred for Gustilo late chronic infections (85% success). 6) Coagulase negative staphylococcus (76%) and staphylococcus aureus (87%) were the most common organisms associated with failed 2-stage revision arthroplasties. Discussion: 2-stage revision knee arthroplasty for deep sepsis of a TKA is successful in 91% of infected primary total knee arthroplasties and 82% of infected revision TKA's. High levels of success are achieved with early post-operative and acute hematogenous infections.

PAPER NO. 180

Extensor Mechanism Problems after Revision Total Knee Arthroplasty

William Patrick Cooney, IV, MD, *Rochester, MN (n)*
Rafael J Sierra, MD, Rochester, MN (n)
Mark W Pagnano, MD, Rochester, MN (c – Zimmer)

Introduction: The purpose of this study was to study the reoperations rates after revision TKR in patients with extensor mechanism problems after primary TKR. Materials and Methods: From 1977-2000, 1814 condylar non-custom index knee revisions were done for aseptic reasons. 336 (18.5%) were done for extensor mechanism problems without intraoperatively confirmed malalignment of components. Reasons for revision included failure of metal back patella in 167 (49.7%), all poly patella wear/loosening in 75 (22%), patella subluxation or dislocation in 30 (8.9%), patella fracture in 13 (3.8%) and other patellofemoral problems in 51 (15%). The patella was revised in 290 knees (80.8%), but only revised with all components in 107 (31.9%). Results: 82 knees (24.4%) subsequently have been reoperated on one or more times with 56 knees reoperated on once, 15 twice and 11 knees 3 > times. The cumulative risk of 1st reoperation for any reason after index revision at 1, 5, and 10 years was 6.9%, 19.9% and 37.8% respectively. The cumulative risk for a reoperation for a recurrent extensor mechanism problem was 1.8%, 6.0% and 11.1% at 1, 5 and 10 years, respectively. The cumulative risk for a major reoperation (femoral, tibial or both components revised) was 0.9%, 7.8% and 13% (1, 5, 10 years). Conclusion: Patellofemoral complications after primary TKR are common and often difficult to resolve even with revision of components. Despite advancement in surgical design and technique, the reoperation rate after revision TKR for extensor mechanism problems was extremely high at almost 40% at 10 years.

PAPER NO. 281

Perioperative Blood Salvage in Lieu of Autologous Predonation for Primary Total Joint Replacement

John T Dearborn, MD, *Palo Alto, CA (e – Zimmer)*

Introduction: Blood transfusions after total joint replacement procedures are commonly required. Preoperative autologous donation, conventional cell salvage, and allogeneic blood transfusion all have undesirable features. The OrthoPAT device (Haemonetics, Braintree, MA) is an automated cell recovery system that allows perioperative (both intraoperative and postoperative) blood collection, purification and reinfusion. The purpose of this study was to evaluate the efficacy of this device in primary hip and knee arthroplasty in lieu of preoperative blood donation. Methods: The OrthoPAT was utilized perioperatively for a consecutive series of patients undergoing primary knee or hip replacement, including 451 unilateral knee replacements, 88 bilateral knee replacements, and 291 unilateral hip replacements. No patients donated blood preoperatively. Data collected included total red blood cell volume loss, volume of red blood cells reinfused, serial hematocrits, transfusion of allogeneic blood, and complications of reinfusion. Strict criteria for allogeneic transfusion were utilized. Results: There were no reinfusion complications. The allogeneic transfusion rate for unilateral TKAs was 5.7%, for bilateral TKA 9%, and for unilateral primary THA 4.8%. Preoperative anemia was the main predictor of the need for allogeneic transfusion. There was a substantial cost savings associated with following this protocol. Discussion and Conclusion: The allogeneic transfusion rates reported here are lower than those reported with other blood management strategies. Our protocol is more cost-effective and efficient than predonation of blood and improves postoperative hematocrits, which have been shown to correlate with vigor. The OrthoPAT is a viable tool for patients undergoing major surgery associated with predictable blood loss.

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

PAPER NO. 282

Comparing Knee Function by Gait Analysis after Total Knee Arthroplasty

Prof Hwa-Chang Liu, *Taipei, Taiwan (n)*
Sheng-Tsung Chen, Taipei, Taiwan (*)
Wen-chi Tsai, Taipei, Taiwan (*)
Tong-wu Lu, Phd, Taipei, Taiwan (*)

Introduction: Deep knee flexion after total knee arthroplasty may be an important index of knee function. Two PCL sacrificed prosthesis were compared (one designed for high flexion, Z-knee; and another ordinary knee prosthesis, O-knee). TKA were carried out by the same surgeon, similar post-op rehabilitation programs. Methods:Randomized selection of 26 patients (43 knees), who has follow-up more than 2 years. Ages are 69+/-6 years.13 patients received Z-knee, and the other 13 patients received O-knee. Knee alignment, active ROM, kinematic and kinetic knee functions by gait analyses (Vicon-512) and EMG (sitting, stairs-climbing, kneeling, and squatting) were carried out. Clinical outcomes compared with HSS scores and radiograms. Results: There were significantce (P<0.05) between Z-& O-knee in active ROM(107.1 +/-14.5 vs 97.7 +/-22.4), maximun flexion during walking (57.2+/-5.6 vs 61.3+/-6.4). However, there were no significance in EMG findings, maximum flexion (121+/-9.1 vs 117+/-13.1), kneeling angle(113.9+/-15.2 vs 111.8+/-15.7),squating angle(93 +/-14.2vs 100.6+/-18.7) and HSS score(93.4 vs 89.2).Returning nearly normal gait was in 6 months after TKA as reported by patients. Discussion and Conclusion: Pain-relief is the most efficacy of TKA, but achieving deep knee flexion are influenced by pre-op condition of knee, surgical techniques, type of knee prosthesis, patient's motivation and rehabilitation. In our study, newly developed prosthesis seems not superior to old one. In addition, non-weight-bearing ROM of TKA cannot bew reflected ROM during daily life activity. Thus, gait analysis provides objective evaluation of functional ROM of TKA.

PAPER NO. 283

Total Knee Arthroplasty in Complete or Partial Ankylosed Knee

Dae Kyung Bae, MD, *Seoul, Korea, Republic of (n)*
Kyoung Ho Yoon, MD, Seoul, Korea, Republic of (n)
Hee Sun Kim, MD, Seoul, Korea, Republic of (n)
Sang Jun Song, Seoul, Korea, Republic of (n)
Sung Chul Bae, Seoul, Korea, Republic of (n)

Thirty-two total knee arthroplasties (TKA) were performed in thirty-two patients with complete or partial ankylosed knees between July 1986 and August 1996. There were 25 females and 7 males. The mean age was 40 years (range 20 to 63 years), and follow-up averaged 10 years (range 5 to 13 years). Twenty knees had complete ankylosis and 12 knees were partially ankylosed prior to TKA. Modified V-Y quadricepsplasty was performed in 10 knees and tibial tubercle was proximally transferred in 3 knees. The postoperative range of motion averaged 75.3 degrees (range 30 to 115 degrees) in patients with complete ankylosis, and 98.7 degrees (range,60 to 130 degrees) in the partially ankylosed patients. The average Hospital for Special Surgery (HSS) knee scores increased from 57 to 86 points postoperatively. Complications were noted in 4 knees (12.5 percents), of which superficial infection (1 knee), deep infection (1 knee), supracondylar femoral fracture (1 knee), and transient paralysis of the common peroneal nerve (1 knee). Although the procedure of TKA in ankylosed knee is technically demanding and has a considerable complication rate, reasonable restoration of function can be obtained by careful patient selection, meticulous surgical technique, and aggressive rehabilitation.

PAPER NO. 284

Minimally Invasive Total Knee Arthroplasty - Two Year Follow-up

Peter M Bonutti, MD, *Effingham, IL (e – Stryker)*
Margot McMahon, RN, Effingham, IL (b – Stryker)
Michael A Mont, MD, Baltimore, MD (a – Stryker)

Introduction: Recently, there has been much interest in minimally invasive total knee arthroplasty. A minimally invasive technique utilizing a small incision (6 to 10 centimeters), minimal quadriceps muscle splitting, and no patellar eversion has been developed. This study evaluated the two-year minimum follow-up clinical and radiographic results of this procedure. Methods: This minimally invasive technique was utilized on 166 consecutive patients (216 knees) with minimum two-year follow-up (range, 2 to 4 years). A clinical follow-up evaluation was performed. Because this is a new procedure, a specific look for any perioperative complications was performed. Radiographic analysis included evaluation of immediate post-operative alignment variables as well as final evaluation of any progressive radiolucencies. Results: Overall, 195 knees (98%) have good and excellent objective Knee Society Scores and patient satisfaction indices. There were 6 knees that required a manipulation under anesthesia (all doing well). There were no perioperative surgical complications. Five knees have undergone reoperation; 2 for late hematogenous deep infection with one retained. Two tibial components were revised for chronic pain, and both components were revised in one patient after a PCL rupture that led to instability. Two knees have progressive 2-3 mm radiolucencies (one tibial and one femoral) and are being closely followed. Discussion: Almost all patients did well (98%) at short-term evaluation of this new technique. Patients were pleased cosmetically and the less invasiveness of the procedure appears to have led to excellent early functional recovery. These short-term results suggest that this limited invasive approach merits further evaluation.

PAPER NO. 285

TKR Through a Mini Midvastus MIS Approach and Comparison to Standard Approach TKR

Richard Sheldon Laskin, MD, *New York, NY (e – Smith & Nephew Consultants)*
Anuwat Phongkhunakorn, MD, Cedarhurst, NY (n)
John P Davis, RN, Cornwall, NY (n)

INTRODUCTION: This study evaluated the hypothesis that a short skin incision and mini-mid vastus approach without disruption of the suprapatellar pouch and without eversion (MIS approach) , would increase rate of regaining motion and would decrease post-op pain. MATERIALS AND METHODS: 51 consecutive patients undergoing a primary tricompartmental TKR with the MIS approach were compared to the immediate 51 previous primary TKR's using a standard incision. In the MIS group the deep capsule was opened 1 cm medial to the patella and extended proximally approximately 2 cm into the VMO. The patella was displaced but not everted. Spinal-epidural anesthesia supplemented by a femoral nerve block was used at surgery and continued for 48 hours. Operative time, BMI, amount of analgesics via PCA epidural catheter, oral analgesics needed in the hospital, the time to be able to perform a straight leg raise, daily range of flexion, component position , and Knee Scores were measured. RESULTS: In two heavily muscled males, the exposure

was not sufficient for the arthroplasty and the incision was extended into a standard exposure. BMI was not a contraindication to the ability to perform the MIS approach. The mean surgical time was 63′ in the MIS and 60′ in the STS groups. The patients in the MIS group had a statistically shorter time until they could straight leg raise , used less epidural analgesia, used less overall analgesics, and had a more rapid regaining of flexion, and achieved milestones permitting discharge 18% faster than the standard incision patients. The average MIS TKR patient achieved 90 degrees of flexion with 3.2 days after surgery. Knee scores at 3 months were statistically higher in the MIS group. DISCUSSION AND CONCLUSION: Using a small incision without patellar eversion and without disruption of the suprapatellar pouch resulted in more rapid regaining of flexion, decreased need for analgesics, increased rapidity in achieving milestones.

PAPER NO. 286

The Effect Of Implant Design On The Kinematic Performance Of Total Knee Replacements

Michael A Conditt, PhD, *Houston, TX (a - Institute of Orthopedic Research and Education, Centerpulse Inc)*
Matthew Thompson, Houston, TX (a - Institute of Orthopedic Research and Education, Centerpulse Inc)
Sabir Ismaily, Houston, TX (a - Institute of Orthopedic Research and Education, Centerpulse Inc)
Philip Noble, PhD, Houston, TX (a - Institute of Orthopedic Research and Education, Centerpulse Inc)

Introduction: While implant designs differ in many respects, few quantitative data exist to demonstrate the impact of these differences on the kinematics of the knee, allowing the surgeon to evaluate the contribution of specific features to the success or failure of individual designs. The purpose of this study was to systematically compare the impact of common design philosophies on the kinematic performance of knee prostheses during a deep knee bend. Methods: Twenty-four fresh-frozen lower limb specimens were mounted in a kinematic knee simulator. External forces were applied to flex the knee from 0-110 degrees, while the three-dimensional motions of the femur, patella and tibia were tracked in real time using a motion analysis system. The kinematics of the knee were measured before and after implantation of a TKA performed using standard techniques by surgeons routinely implanting each design. The three design types were a PCL-retaining design (N-K II, Centerpulse), a posterior stabilized (PS) design (NexGen Legacy PS, Zimmer) and a rotating platform (RP) design (LCS, Depuy). Results: The type of TKA design had a significant effect on the kinematics of both the patellofemoral and tibiofemoral joints. The most dramatic differences were observed in femoral rollback with tibiofemoral flexion. In full extension, all designs posteriorly displaced the femur (PCL: 2.6 ± 1.1mm; RP: 3.5 ± 0.3mm; PS: 3.8 ± 0.3mm). With flexion, the PCL and the PS components produced femoral rollback similar to the intact knee, while the RP design actually anteriorly displaced with flexion. In fact, knees with the RP actually experienced a net anterior displacement of the femur relative to the tibia between 0 and 110 degrees of flexion (1.0 ± 0.8mm), while the net posterior displacement with the PS was 3.8 ± 1.3mm and with the PCL was 7.5 ± 2.6mm (net intact rollback: 8.0 ± 1.2mm). Discussion and Conclusion: The kinematic performance of knee replacements is significantly affected by specific design features of the components. In particular, preservation of the PCL or features designed to compensate for the lack of the PCL significantly affect the relative positions of the femur, tibia and patella in full extension as well as their motion paths throughout the flexion arc. In general, these differences are most significant during early to mid-flexion.

PAPER NO. 287

Retrieval Analysis of Tibial Posts from Constrained Total Knee Arthroplasty Polyethylene Liners

Ivan M Tomek, MD, *Lebanon, NH (n)*
Bridgette D Furman, Res Eng, New York, NY (*)
Thomas P Sculco, MD, New York, NY (n)
Timothy M Wright, PhD, Stamford, CT (n)

Introduction: Constrained condylar knee replacement (CCK) provides increased constraint at the tibiofemoral articulation with an intimately-fitting tibial post and cam that limits motion in the frontal and axial planes. While useful in primary and revision surgery when collateral ligaments are compromised, concerns exist about post damage and implant loosening resulting from the increased level of constraint. Methods: Between 1986 and 2002, ninety-seven tibial trays were retrieved from failed CCK arthroplasties. Damage to the tibial posts was assessed, and radiographs and charts were reviewed to determine reasons for revision. Results: The most commonly observed damage mode was burnishing, seen on all 97 specimens; scratching (n=40), pitting (n=35), and deformation (n=23) followed in frequency. The lateral top region of the post had the most significant damage (n=44), followed by the medial top (n=37), medial bottom (n=28), and lateral bottom (n=17) regions. Five posts were fractured. The mean length of implantation was 3.0 ± 2.2 years (range 0.15 to 10.2). The most common reason for revision was infection (n=25), followed by aseptic loosening (n=20), instability (n=11), arthrofibrosis (n=4), and other (n=12). Thirty patients ultimately required additional knee surgery beyond the procedure during which the present CCK liners were retrieved. Conclusion: Retrieval analysis of tibial posts from failed CCK arthroplasties identified burnishing, scratching, pitting and deformation as the principal damage modes, with the upper medial and lateral faces of the post sustaining the most damage. However, infection and not tibial post failure was the most frequent reason for revision, followed by aseptic loosening and instability.

PAPER NO. 288

◆Dynamic In-Vivo Tibio-Femoral and Bearing Motions in Mobile Bearing Knee Arthroplasty

Fabio Catani, *Bologna, Italy (a – Stryker HowMedica Osteonics)*
Silvia Fantozzi, PhD, Bologna, Italy (a – Stryker HowMedica Osteonics)
Andrea Ensini, MD, Bologna, Italy (a – Stryker HowMedica Osteonics)
Sandro Giannini, MD, Bologna, Italy (a – Stryker HowMedica Osteonics)

INTRODUCTION. The numerous mobile bearing total knee arthroplasty designs differ for the constraint to motion of the bearing and for the degree of conformity between the femoral and the bearing components. The purpose of the present study is to determine mobile bearing motion in a not fully congruent design. METHODS Eleven patients with cruciate retaining mobile bearing were studied by means of a fluoroscopic 3D-analysis during chair rising-sitting and step up-down. Three to six tantalum beads had been inserted in the bearing. In this design, full conformity between the bearing and the femoral component

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

is lost at flexion angles larger than 22° - 26°. RESULTS A relatively small motion of the mobile bearing was observed. Mean internal-external rotation was 3.8° (min. 1.2°, max. 6.1°), and mean antero-posterior translation was 0.1 mm (min. -1.7, max. 1.1). Contact points were found located more posteriorly in chair rising-sitting than in step up-down. In both motor tasks, the mid point between the medial and the lateral contact points translated posteriorly and anteriorly for flexion ranges of 0°-30° and 30°-70°, respectively. DISCUSSION AND CONCLUSION This study represents one of the first reports on motion of the mobile bearing by means of tantalum beads, not inferred from the positions of the other prosthesis components. The results of this in-vivo study suggest that partially conforming and partially constrained mobile bearing knees exhibit small motion of the bearing and little constraint to tibio-femoral antero-posterior translation.

PAPER NO. 289

In Vivo Determination Of PE Bearing Motion In Subjects with a PS Mobile Bearing TKA

Douglas A Dennis, MD, *Denver, CO*
(a – Depuy, Johnson & Johnson)
Richard D Komistek, PhD, Knoxville, TN
(a – Depuy, Johnson & Johnson)
Mohamed Mahfouz, MS, Denver, CO
(a – Depuy, Johnson & Johnson)
Scott A Walker, MS, Denver, CO
(a – Depuy, Johnson & Johnson)

INTRODUCTION: The objective of the present study was to assess the magnitude of polyethylene bearing motion in mobile bearing posterior stabilized (PS) TKA under weight-bearing conditions. METHODS: In vivo kinematics for ten subjects implanted with a PS mobile bearing TKA were determined using video fluoroscopy. Each subject, while under fluoroscopic surveillance, performed a weight-bearing deep knee bend to maximum flexion. Using a 3D model-fitting process, the femoral and tibial components as well as the mobile bearing polyethylene insert (implanted with four tantalum beads) were overlaid onto the fluoroscopic images to determine the three-dimensional in vivo motions. RESULTS: All subjects experienced polyethylene bearing rotation relative to the metal tibial component and minimal rotation relative to the femoral component. On average, from full extension to maximum knee flexion, subjects experienced 4.6 deg of femorotibial rotation and 4.3 deg of polyethylene rotation relative to the tibia. Therefore, on average, only 0.3 deg of rotation occurred between the femoral and the polyethylene components. The average maximum rotation occurring during any flexion interval (ten degree intervals) of a deep knee bend was 8.3 deg between the femoral and tibial components and 8.5 deg between the polyethylene bearing and tibial components. The minimum and maximum amounts of polyethylene rotation relative to the tibia was 4.7 deg and 12.4 deg, respectively. DISCUSSION: This is the first known study to determine the in vivo rotation of the polyethylene bearing for subjects having a mobile bearing PS TKA. The results from this study determined that the polyethylene bearing is rotating relative to the metal tibial component, but not relative to the femoral component. Therefore, as the femoral component axially rotates, the polyethylene bearing is rotating a similar amount in the same direction. Since bearing rotation occurs under in vivo conditions, subjects implanted with a mobile bearing prosthesis may be subjected to lower contact stresses, reducing the potential for polyethylene wear.

PAPER NO. 290

Soft-Tissue and Intra-Articular Injection with Epinephrine and Narcotic: A Beneficial Effect In TKA

Adolph V Lombardi Jr, MD, *Columbus, OH (*)*
Keith R Berend, MD, Columbus, OH (*)
Thomas H Mallory, MD, Columbus, OH (*)
Kathleen Dodds, RN, Hilliard, OH (*)
Joanne B Adams, Columbus, OH (*)

Introduction: Adequacy of post-operative pain control can affect TKA outcomes. We examine the effectiveness of a simple and inexpensive method using long-acting local anesthetic (bupivacaine) with epinephrine and morphine injection on controlling pain, blood loss, and motion in primary TKA. Methods: We retrospectively reviewed 309 patients who underwent 378 primary TKA by a single surgeon between October 2001 and December 2002. The control group of 138 patients (181 knees) received no intra-operative injection. The study group of 171 patients (197 knees) received intra-operative injection of 0.25% bupivacaine with epinephrine and morphine divided two-thirds soft-tissue injection and one-third intra-articular injection. Bilateral simultaneous patients received a divided dose. The pain management protocol was otherwise identical. Results: In the PACU 84% of control patients versus 74% of study patients required breakthrough narcotic dosing (P= 0.0278). Twice as many control patients (8/138; 5.8% versus 4/171; 2.3%) required rescue doses of Narcan for narcotic reversal. Our results show a higher but not significantly different ROM at discharge and decreased incidence of manipulation in the study group. We observed a significantly lower bleeding index (P=0 .0065), and rate of blood loss (P< 0.0001) for patients in the study group. The transfusion rate was remarkably low for both groups, and although slightly lower for the study group, not significantly different. Discussion: Preemptive analgesia with intra-articular and soft-tissue injection of long-acting local anesthetic with epinephrine and morphine appears to decrease need for rescue narcotics and reversal agents. The use of the injection also increases ROM at discharge, which reduces the need for manipulation. Pain levels during the immediate postoperative period, blood loss and bleeding indices were significantly reduced. This inexpensive method is effective in improving the post-operative course of primary TKA.

POSTERS

POSTER NO. P092 – WITHDRAWN

POSTER NO. P093

Open Vesus Minimally Invasive Unicompartmental Knee Replacement-a Radiographic Comparison

Kuang-Ying Yang, MD, *Singapore, Singapore (n)*
Ngai-Nung Lo, MD, Singapore, Singapore (n)
Seng-Jin Yeo, MD, Singapore, Singapore (n)

Introduction. With the introduction of minimally invasive techniques for unicompartmental knee arthroplasty (UKA), there is a concern regarding its accurate alignment and implant placement as the surgeon has no access to many of the anatomical landmarks routinely available in a formal arthrotomy. Furthermore, there is still debate as to what constitutes an ideal implant position for an UKA. Methods:We reviewed the available literature for radiological features that influence the outcome of an UKA and

also established the optimum range of values for each radiological parameter. These include (1) tibio-femoral angle; (2) distal femoral joint line orientation; (3) proximal tibial joint line orientation (4) prosthesis-tibial angle in the coronal plane (5) posterior tibial slope angle. We then conducted a matched-pair radiological comparison of open and minimally invasive (MI) UKA with 21 patients each, performed by one single surgeon. These patients were matched to pre-operative tibio-femoral angle. Results:The mean post-operative alignments for the open and MI groups were similar at 3.9 and 3.2 valgus respectively (p=0.47). However, 86% of open UKA had acceptable tibio-femoral angle (1-6 valgus) while 71% MI UKA achieved so (p=0.24). Those with MI UKA also had a higher variance. There was no difference between the two groups with regard to the accuracy of femoral and tibial joint orientation, prosthesis-tibial angle and posterior tibial slope. In addition, open UKA had more patients satisfying at least 3 out of 5 ideal radiographic criteria (86% vs 62%, p=0.06). Conclusion: Minimally invasive UKA may be less likely to achieve the desired post-operative alignment. Further studies should be performed to evaluate the accuracy of the new technique before universal acceptance.

POSTER NO. P094

The Influence of HIV-1 infection to Orthopaedic Surgery in Haemophilia

Hideyuki Takedani, MD, *Fukui, Japan (n)*

Introduction: The most problem for both HIV-1 infected patients and joint arthroplasty is infection. In haemophilia, most of them have severe arthropathies and HIV-1 infection so that it is important for them whether operations were influenced on the condition of HIV-1 or not. Methods: We performed 55 primary arthroplasties for 35 haemophiliac patients between 1985 and 2001. 35 arthroplasties (21 cases) were HIV-1 positive and 20 arthroplasties (14 cases) were negative. We measured CD4 and 8 positive T lymphocytes (cells/ml) and HIV-1 RNA (copies/ml) before and after surgery. Also we investigated complications such as infection and prognosis. Results: In HIV-1 positive patients, CD4 counts before and after surgery were 464.8 and 459.5 respectively and CD8 counts were 982.6 and 958.9. In HIV-1 negative patients, CD4 counts before and after surgery were 868.7 and 566 respectively and CD8 counts were 1332.5 and 749.2. Copies of HIV-1 RNA of all positive patients were not increased after operation. 2 arthroplasties became deep infection at 4 weeks and 9 years after operation in HIV-1 patients and 2 arthroplasties were revised at 9 years (both cases) because of aseptic loosening in HIV-1 patients. While in HIV-1 negative patients, there were not major complications after surgery. 4 cases were died; 2 positive cases by AIDS and each case by bleeding. All of them were performed first operation before development of proteases inhibitors as anti HIV-1 drugs. Discussion and conclusion: The incidence of complications after arthroplasty in haemophilia is higher than that in other joint disorders such as osteoarthritis and rheumatoid arthritis, however there are small repots in which results were compared with HIV-1 patients and non HIV-1 patients. Greene and Astermark were reported that operative indication is asymptomatic and CD4 counts are more than 200 cell/ml. Savioz were reported asymptomatic patients are able to orthopaedic surgery even if CD4 counts is zero. Philips reported that there is no difference on prognosis among four haemophilia patients groups; operated or not and HIV positive or negative. In this study, we concluded orthopaedic surgery is not influenced HIV-1 conditions in short periods after surgery because of stable results of blood examinations, but we are anxious about the influence of HIV-1 infection to orthopaedic surgery, because of high ratios of complications.

POSTER NO. P095

Relative Contributions of the Patient, Surgical Technique, and Tibial Component to Wear and Survivorship of Unicondylar Knee Arthroplasty

Matthew B Collier, MS, *Alexandria, VA*
(a – Inova Health Services)
James P McAuley, MD, Alexandria, VA
(e – DePuy, Johnson&Johnson)
Gerard Anderson Engh, MD, Alexandria, VA (c – DePuy)

INTRODUCTION: Prosthetic wear commonly contributes to failure of unicondylar knee arthroplasty (UKA). We sought to identify factors associated with tibial component wear via analysis of revision-retrieved medial compartment UKA and assess how the same factors impacted clinical survivorship. METHODS: 25 Robert Brigham and 28 Omnifit metal-backed tibial components were retrieved. Wear was quantified as the change in tibial component composite thickness per years in vivo. Multiple linear regression was used to assess association between wear and 6 factors: original polyethylene thickness, polyethylene shelf age, postoperative mechanical axis varus, gender, patient age, weight. Logistic regression was used to assess how the 6 factors affected the revision risk of 112 Brigham and 142 Omnifit medial UKA. RESULTS: The 6 factors explained 71% ($p<0.01$, $R2=0.71$) of the variation in Brigham wear (mean ± standard deviation, 0.5±0.3 mm/year), with shelf age (0.9±0.7 years, $p<0.01$, $R2=0.42$) and mechanical axis varus (10±10 mm, $p=0.01$) explaining 66% ($p<0.01$, $R2=0.66$). The 6 factors explained 89% ($p<0.01$, $R2=0.89$) of the variation in Omnifit wear (0.5±0.5 mm/year) with shelf age explaining 85% (1.8±1.4 years, $p<0.01$, $R2=0.85$). Revision risk of a Brigham UKA (26 revisions) increased with decreasing thickness ($p<0.01$), decreasing patient age ($p<0.01$), and increasing shelf age ($p=0.04$). Only increasing shelf age ($p<0.01$) raised the Omnifit revision risk (29 revisions). DISCUSSION: Wear was most strongly associated with the shelf age of the gamma-irradiated-in-air bearing. Shelf age was the lone factor that raised the revision risk of Omnifit UKA, but was of tertiary significance to polyethylene thickness and patient age in elevating the revision risk of Brigham UKA.

POSTER NO. P096

Simulated Normal Gait Wear Testing of a Highly Crosslinked Polyethylene Tibial Insert

Orhun K Muratoglu, PhD, *Cambridge, MA*
(a,c – Zimmer)
Harry E Rubash, MD, Boston, MA
(a, e – Zimmer, a – Centerpulse)
Charles R Bragdon, BS, Boston, MA (a,c – Zimmer)
Brian Burroughs, PHD, Boston, MA (a – Zimmer)
Anna Huang, Boston, MA (a – Zimmer)
Gordon Plank, Boston, MA (a – Zimmer)
William H Harris, MD, Boston, MA (*)

Introduction: Performance of total knees can be compromised due to damage to polyethylene secondary to embrittlement or periprosthetic osteolysis secondary to adhesive wear of polyethylene. Radiation crosslinking with subsequent melting improves both oxidation and wear resistances of polyethylene. The hypothesis of the present study is that this technology will

improve the adhesive wear behavior of cruciate retaining tibial inserts with the clinical positioning of 7º posterior slope. Methods: We investigated the adhesive wear of six cruciate retaining NexGen inserts, three of conventional polyethylene and three that were electron beam irradiated (dose=65kGy) and subsequently melted. No artificial aging was done. The inserts were tested on an AMTI knee simulator (freq=1.1Hz) using normal gait kinematics with a 7º posterior slope. Wear was quantified by weight loss. Extent of creep and wear was quantified using a CMM. Results: The rate of weight loss was 21 and 4 mg/million-cycles with the conventional and crosslinked inserts, respectively, an 80% reduction. Wear rates measured by CMM were 23 and 5 mm3/million-cycles for conventional and crosslinked inserts, respectively. At the completion of seven million cycles of simulated gait, there were no delaminations, pitting or fatigue damage on any of the tests components. Conclusion: Electron beam crosslinking and subsequent melting of polyethylene reduces the adhesive/abrasive wear rate of cruciate retaining polyethylene tibial inserts when tested on a knee simulator with a 7º posterior slope under simulated normal gait. There were no adverse effects of crosslinking on the performance of the tibial inserts during our investigation.

POSTER NO. P097

Contact Stress Analysis at the Post-cam Mechanism Posterior Stabilized Total Knee Arthroplasty

Shuichi Matsuda, MD, *Fukuoka, Japan (n)*
Koichi Nakayama, MD, Fukuoka, Japan (n)
Hiromasa Miura, MD, Fukuoka, Japan (n)
Taro Mawatari, Fukuoka, Japan (n)
Yukihide Iwamoto, MD, Fukuoka, Japan (n)

INTRODUCTION: Complications of the post-cam mechanism such as fracture or severe wear of thetibial post have been reported after posterior stabilized TKA. Recently, many surgeons seek for more range of motion after TKA, however, biomechanical studies have shown that high posterior force (500-1500 N) is applied at the tibio-femoral joint in deep knee flexion. Questions remain regarding high contact stresses at the post-cam mechanism of the posterior stabilized TKA. METHODS: Contact area and stresses at the post-cam mechanism were measured with the Tekscan sensor when posterior force of 500 N was applied in the Kirschner Performance (Biomet), NexGen Flex (Zimmer), and Scorpio (Stryker) knee systems. Measurements were done at 90, 120, and 150 degrees of flexion with the neutral rotation and 10 degrees of internal rotation of the tibial component. RESULTS: Contact area at 90, 120, and 150 degrees was 66.1 mm2 , 34.0 mm2, and 41.9 mm2 with the Kirschner, 43.5 mm2 , 43.5 mm2, and 46.8 mm2 with the NexGen, and 45.2 mm2 , 41.9 mm2, and 61.0 mm2 with the Scorpio. Peak contact stress at 90, 120, and 150degrees was 24.0MPa, 33.9MPa, and 38.4MPa with the Kirschner, 34.1MPa, 31.5MPa, and 32.5MPa with the NexGen, and 25.9MPa , 32.4MPa, and 22.1MPa with the Scorpio. With the internally rotated tibia, contact stress increased in approximately 1.5-2.0 times with all the components. CONCLUSION: High contact stress is inevitable with the current posterior stabilized TKA designs, and contact stresses further increased with the internally rotated tibia due to edge loading.

POSTER NO. P098

The Relationship of Lateral Release and Tourniquet Deflation In Total Knee Arthroplasty

Adolph V Lombardi, Jr, MD, *Columbus, OH (e – Biomet)*
Keith R Berend, MD, Columbus, OH (a – Biomet)
Thomas H Mallory, MD, Columbus, OH (e – Biomet)
Kathleen Dodds, RN, Hilliard, OH (a – Biomet)
Jackie Russell, Columbus, OH(a – Biomet)
Daniel S Willsey, MS, PA-C, Columbus, OH (n)
Joanne B Adams, Columbus, OH (a – Biomet)

Patellar subluxation is troublesome and among the more common complications in TKA. A total of 242 knees in 199 patients were evaluated for the need for a lateral retinacular release before and after deflation of the tourniquet. Factors including deformity, motion, patient demographics, and position of the limb during tourniquet inflation were also evaluated. All knees were implanted using the same knee system by a single surgeon. The need for lateral release was determined using the rules of "no-thumbs" and "full contact" and visual evaluation. Lateral release was performed only after deflation of the tourniquet. A total of 171 (70.7%) of the knees appeared to need a lateral release before tourniquet deflation. After deflation of the tourniquet, only 53 (21.9%) required lateral release representing a 69% reduction. Obesity was the only other significant factor in lateral release requirement. If patellar tracking is evaluated with the tourniquet inflated, its effect on the quadriceps muscle is ignored. The purpose of this study is to report the effect of tourniquet deflation on lateral release rates, evaluate possible variables associated with the need for lateral release, and examine adequacy of intraoperative evaluation on final radiographic results. Based on the observations of this study, the authors recommend that the need for lateral release should be evaluated after tourniquet deflation. A 69% reduction in lateral release supports the hypothesis that tourniquet pressure has an effect on patellar tracking. Lateral release appears to be effective in restoring normal patellar tilt. Obesity increases the need for lateral release.

POSTER NO. P099

Wear on Retrieved Meniscal and Rotating Platform Polyethylene Bearings After 9 Years In-situ

Melinda K Harman, MS, *West Palm Beach, FL (n)*
George David Markovich, MD, Fort Myers, FL (*)
Scott A Banks, PhD, West Palm Beach, FL (*)
William Andrew Hodge, MD, West Palm Beach, FL (*)

The perceived advantages of mobile bearing knee prostheses are 1) reduced polyethylene wear associated with large tibial-femoral contact areas, and 2) low shear stresses at the bone interface due to relatively unrestrained bearing motion. However, abrasive polyethylene wear remains a concern, especially considering the 47 percent incidence of osteolysis recently reported in an 8.5 year follow-up study of LCS mobile bearing prostheses. Smaller particulate debris associated with the more conforming tibial-femoral articulation and additional wear associated with the mobile "backside" articulation may be contributing factors. This study evaluates polyethylene wear on retrieved LCS mobile bearing prostheses.Meniscal bearing and rotating platform inserts from uncemented LCS prostheses were retrieved from 29 and 13 knees, respectively. The mean age and time in-situ was 74 years and 9 years, respectively. Reasons for removal included bearing wear(12), patella wear(8), pain or stiffness(5), instability(3), autopsy(3), loosening(3), osteolysis(1), and other(7). The original femoral and tibial components were left in-situ in

85% of the knees at revision, such that only the polyethylene articulations were exchanged. Forty of 52 meniscal bearings analyzed were delaminated, including 20 bearings with fractured articular surfaces. Three of the rotating platforms had delamination. Twenty of 25 patellas had delamination, including 6 with fractured articulations. Scratching was the dominant backside wear mode.Despite severe damage on many of the polyethylene components, there was only a 5% incidence of osteolysis noted at revision and the need for complete revision of the metal tibial and femoral components was rarely deemed necessary.

POSTER NO. P100

Early Instability with Mobile Bearing Total Knee Arthroplasty

Joseph T Moskal, MD, *Roanoke, VA (n)*
Stephen R Ridgeway, MD, Greenville, SC (n)

Introduction: The proposed long-term advantages in terms of polyethylene wear with mobile bearing total knee arthroplasty (TKA) must be taken in context with any early complications compromising outcome. One such complication is instability with or without polyethylene insert dislocation The purpose of the current report is to present 25 cases of post-operative instability following mobile bearing TKA utilizing both menisical bearing and rotating platform implants. Materials and Methods: Between December 1987 and January 2002 , twenty-five cases of clinical instability following mobile bearing TKA with meniscal bearings or rotating platforms presented for evaluation at our institution. These cases were retrospectively identified. All were performed at outside institutions by a variety of surgeons. All available charts and subsequent operative notes were reviewed. Additional evaluation consisted of radiographs at the initial evaluation and at subsequent visits when appropriate. When indicated, stress radiographs were obtained to provide additional information. All clinical examinations were performed by the authors. Nine cases revised at our institution also had an examination under anesthesia, and the operative findings were available for review.See Abstract Text Part II for Results and ConclusionResults: All twenty-five cases had clinical evidence of severe coronal plane instability and pain. Eight cases had polyethylene dislocation or subluxation evident radiographically and clinically. Four cases had extensor mechanism dysfunction or frank patellofemoral instability. Additionally, one proximal tibial stress fracture was felt to be secondary to severe coronal plane instability. Symptoms occurred at a mean (and standard deviation) of 9.2 +/- 21.29 months (Range 0-92 months) following the index procedure. Eighteen cases had symptoms immediately postoperatively. Twenty-three of the twenty-five cases had symptoms within two years postoperatively. Conclusions: With mobile bearing TKAs, instability may present as one of two clinical presentations: painful coronal plane instability accompanied by painful effusions or frank subluxation, dislocation, or fracture of the polyethylene bearing elements. Most commonly, the instability presents within the early post-operative period. Any potential long-term benefit of design innovations must be balanced with known problems leading to early failure.

POSTER NO. P101

Extramedullary, Intramedullary and CAS Tibial Alignment Techniques for Total Knee Arthroplasty

William Michael Mihalko, MD, *Clarence Center, NY*
(a,e – Stryker Howmedica Osteonics)
Kenneth A Krackow, MD, Buffalo, NY
(a – Stryker Howmedica Osteonics)

Introduction: During total knee arthroplasty intramedullary or extramedullary tibial alignment instrumentation are normally utilized. Computer navigation techniques now give a third option This study compared the differences using these three techniques. Methods: Seven cadaveric lower extremities were tested using a computer navigation system to register the the mechanical axis of the lower extremity (Stryker Navigation System, Allendale, NJ). An instrumented extramedullary guide was used to align the tibial cut as positioned by a fellowship trained orthopaedic surgeon. An instrumented intramedullary rod was then inserted through an entry point in the insertion of the ACL. The alignment of the tibial cut was recorded for both techniques and compared to the mechanical axis recorded by the navigation system. Each cadaver underwent a CT scan to verify the computer navigation registration. Results: The intramedullary rod resulted in 1.3 + 1.4 degrees varus and the extramedullary instrumentation 1.5 + 1.8 degrees valgus compared to the navigation system. The posterior slope of the intramedullary rod on average was 4 + 2.1 degrees and extramedullary was 2.7 + 1.2 degrees. The registration points of the navigation system were within 1 to 2 mm of the CT scan data. Discussion and Conclusion: This study reported that IM instrumentation and extramedullary techniques for tibial alignment do a good job overall. The intramedullary rod did give more posterior slope that the extramedullary technique but was not significant. The one thing that study did substantiate is the fact that the outliers in both techniques may be considerable and can be avoided using computer aided surgery techniques.

POSTER NO. P102

Salvage Patellar Arthroplasty With A Porous Tantalum Implant - 2 to 4 Year Results

Sam Nasser, MD, *Detroit, MI (n)*
Robert A Poggie, PhD, Allendale, NJ (e – Implex Corp)

Introduction: Revision TKA patients who have severe patellar bone loss or undergo patellectomy often have inferior clinical results. Current treatments are limited and often unsatisfactory. This study reports the surgical technique and clinical follow-up (32 months) for 11 patients who underwent revision or salvage TKA and received a porous tantalum implant for replacement of their patella. Methods: The prosthesis is comprised of two parts, a porous tantalum base and titanium suture ring for initial fixation, and a polyethylene surface that is cemented to the base. The surgical technique evolved over the course of the first three cases, during which the suture technique and size (non-absorbable number 2) and bone preparation were defined. Results: Between 1998 and 2000, the senior author performed approximately 150 revision TKAs, 11 of which were treated prospectively with this implant. Pre-operative average knee function and pain scores were 24 and 20, respectively, and average ROM was 62 degrees. The low knee scores reflect the immobility, trauma and/or pain associated with the presenting conditions. At most recent follow-up, the average knee function and pain scores were 69 and 53, respectively, and the average ROM was 103 degrees. Radiographically all implants were stable and patient satisfaction excellent, with the exception of one case where trauma caused

dislodgement of the prosthesis. Discussion and Conclusions: The results of this study indicate that this porous tantalum patella is an effective prosthetic option that is capable of improving function and reducing pain for patients with severe patellar bone loss and complicating factors.

POSTER NO. P103

Metal Augments in Revision Knee Arthroplasty: A Hindrance or a Helper?

Scott A Swanson, MD, *Omaha, NE (n)*
Anthony J Lauder, MD, Omaha, NE (n)
Todd Sekundiak, MD, Omaha, NE (n)
Kevin L Garvin, MD, Omaha, NE (e – Smith&Nephew)

Introduction: Metal augmentation is widely used to fill bone defects in revision knee arthroplasty. The augment can be a wedge or rectangular block. The load transmission is very different in each of these settings. We hypothesized that rectangular augmentation would be superior to wedges in revision knee arthroplasty. Methods: Of 329 sequential revision knee arthroplasties retrospectively reviewed, thirty-eight were identified with rectangular block augments, while twenty were found to have full wedge augments. The components were all cemented with stems either press-fit or cemented. These fifty-eight augments were annually reviewed clinically and radiographically to determine their outcome. Results: Thirty-three females and twenty-five males of 66.7 years (41-89 years) were followed 5.7 years (2-10.5 years). Of the thirty-eight rectangular block augments, none were revised for aseptic loosening and none were found to be radiographically loose. Three of the twenty wedge augments required revision for loosening while five had radiographic loosening with stem migration. This was statistically significant ($p<0.05$). These eight failures all had press-fit stems. Only one of the fully cemented implants failed with a fracture of the tibial stem. Discussion and Conclusion: Although augments are a useful adjunct in revision knee arthroplasty, the authors caution the use of full angular wedges. With the angular bony and augment surfaces compressive loads are converted to shear which lead to the component's demise. Cemented stems need to be considered to decrease joint surface loads but do run the risk of stem breakage.

POSTER NO. P104

Reducing Backside Damage in Total Knee Replacements

Jan Mels B Brandt, *London, ON Canada (n)*
John B Medley, PhD, Waterloo, ON Canada
(a- Natural Science & Engin. Research Council, Canadian Arthritis Network, b – DePuy Orthopaedics, Medtronic Sofamor Danek)
Chris Haydon, London, Canada (n)
Richard W McCalden, MD, London, ON Canada (n)
Robert Barry Bourne, MD, London, ON Canada
(a – Smith&Nephew)
Steven J MacDonald, MD, London, ON Canada (n)
Cecil H Rorabeck, MD, London, ON Canada
(a – DePuy, Johnson&Johnson)

Introduction: Backside damage of the polyethylene tibial inserts in total knee replacement can contribute to implant failure due to wear particle-induced osteolysis. The purpose of the present study was to characterize backside damage on retrieved tibial inserts and identify tribological factors involved. Methods: Fifty-two retrieved tibial inserts were quantitatively analyzed (12 AMK with polished cobalt alloy tray and non-peripheral capture mechanism; 16 Genesis I with unpolished and 24 Genesis II with polished titanium alloy trays and partial peripheral capture mechanism). The retrieved tibial trays had no screw holes and the inserts were sterilized by either "gamma-in-air", gas plasma or ethylene oxide. A scoring system was applied based on the percentage of surface area containing burnishing, grooving, indentations, stippling, deformation, delamination, pitting and cracking. These damage features were characterized using scanning electron microscopy and surface profilometry. Results: Backside damage was observed on all retrieved tibial inserts with no strong influence of sterilization technique. The inserts on polished trays with non-peripheral locking mechanisms had higher backside damage than those on either polished or unpolished tibial trays with partial peripheral capture mechanisms (significant). Burnishing was the major damage feature for inserts on polished trays (significant) while grooves and indentations dominated for inserts on unpolished trays (significant). Discussion and Conclusions: Backside damage is caused by fretting from micromotion between insert and tray. Damage features were influenced by tray surface roughness. However, the overall damage score suggested that the partial peripheral capture mechanism was more effective than better surface finish in reducing backside damage.

POSTER NO. P105

Functional Results of Structural Allografting in TKA Revision

Todd Sekundiak, MD, *Omaha, NE (n)*

Introduction: Bulk femoral allografting as a salvage procedure in revision knee arthroplasty has previously been described but with little reporting on their functional result. Our goal is to elucidate the functional result of this salvage procedure. Materials and Methods: Fifteen bulk femoral allografts were prospectively followed for a minimum of 4 years (average 5.6). Revision arthroplasties were performed using cemented components with coronally constraining polyethylene. Patients were 42 to 88 years of age (average 74). Ten were performed for periprosthetic fractures with five for osteolysis. Results: All allografts healed to host bone. No aspetic loosenings occurred but 3 (20 percent) patients suffered from a chronic infection. Four patients developed knee flexion instability with recurrent dislocations. None of these patients had reattachment of their epicondyles while 10 of the 11 stable knees did. Stem pain occurred in 4 patients causing alteration of activity and walking assists. Pain and functional knee society scores were lower. Conclusions: Bulk structural allografting is an acceptable salvage procedure for the failed knee. Patients must be made aware of the high complication rate and lesser functional results. Autogenous epicondylar reattachment can aid in flexion stability by preventing posterior subluxation of collateral ligaments with flexion.

POSTER NO. P106

Hybrid Total Knee Arthroplasty: Clinical and Radiographic Outcomes at Average Ten Year Follow-Up

Jonathan L Tueting, MD, *Madison, WI*
(a – Stryker Howmedica Osteonics)
Richard Lynn Illgen, II, MD, Madison, WI
(a – Stryker Howmedica Osteonics)
Mary Ellen Hagenauer, BA, Madison, WI (n)
Timothy Enright, BS, Madison, WI (n)
Pete Stanich, HS, Madison, WI (*)
John P Heiner, MD, Madison, WI
(a – Stryker Howmedica Osteonics)
Andrew A McBeath, MD, Madison, WI (*)

Introduction: Total knee arthroplasty (TKA) using cemented techniques has demonstrated high success rates at 10-12 years. Concerns remain regarding the durability of cemented fixation beyond 10-15 years. Although many cementless TKA designs have demonstrated inferior outcomes when compared with cemented series, hybrid fixation (cementless femur, cemented patella and tibia) has not been studied in detail. Methods: We retrospectively reviewed the outcomes of 112 hybrid TKA's performed between 1987 and 1995 by two surgeons at our institution (Howmedica PCA- N= 67, and Howmedica Duracon- N=45). Forty-nine patients had died, 9 patients could not be found, and 54 were alive and available for follow-up. Outcomes were measured after clinical and radiographic review using the SF-12 and Knee Society Scores (KSS) at average 10 year follow-up (range 3-15.2 yrs). Results: The overall revision rate was 4.5 percent (5 of 112): four were performed in patients with metal-backed patellae and one for infection. No revisions were performed for aseptic loosening of the femoral component and all femoral components were well fixed at the time of revision. Average SF-12 scores were 46.0 preoperatively and 49.2 post-operatively. Average KSS clinical and functional scores increased from 32.0 and 46.7 preoperatively to 84.5 and 65.6 postoperatively, respectively. Discussion: Hybrid TKA with these implant designs provided durable fixation with excellent clinical and radiographic performance at 10 years comparable to cemented series. Aseptic loosening and radiographic failure rates were zero percent if patients with metal-backed patellae were excluded. The durability of hybrid fixation beyond 10 years deserves further study.

POSTER NO. P107

Retrospective Survey of Tibial Polyethylene Insert Shelf Aging in Total Knee Arthroplasty

Matthew B Collier, MS, *Alexandria, VA*
(a – Inova HealthServices)
James P McAuley, MD, Alexandria, VA
(e – DePuy, Johnson&Johnson)
C Anderson Engh Jr, MD, Alexandria, VA
(a – Inova HealthServices, e – DePuy, Johnson&Johnson)

Introduction: Shelf aging accelerates wear of gamma-irradiated-in-air polyethylene tibial components. We suspected that total knee arthroplasty (TKA) inserts implanted less frequently had longer shelf ages. Methods: 751 posterior-cruciate-ligament-retaining UHMWPE inserts of the Anatomic Modular Knee design were implanted between 1987 (design introduction) and 1993. We examined how shelf aging varied by insert size (5 options), thickness (6 options), and geometry (2 options). Results: The mean shelf age was 1.0±1.0yrs (mean ± standard deviation per year, 1987:0.4±0.2yrs, 1988:0.6±0.4yrs, 1989:0.9±0.6yrs, ...1993:1.9±1.7yrs). Sizes 2 and 3 were equally popular (37% TKA, 39% TKA) and had comparable shelf age distributions (0.9±0.9yrs, 0.8±1.0yrs). Size 4 was implanted in 17% TKA (shelf age: 1.2±1.1yrs). Size 1, the smallest size, was used in 7% TKA (shelf age: 2.1±1.4yrs). The 3 thickest insert thicknesses were used less frequently (20% TKA) and had longer shelf ages than the three thinnest thicknesses (1.7±1.3yrs versus 0.8±0.9yrs). Lipped inserts were rarely used (6% TKA) and had longer shelf ages than standard geometry inserts (1.8±1.0yrs versus 0.9±1.0yrs). Inserts implanted at revision were thicker (10±3mm versus 7±2mm) and older (1.4±1.2yrs versus 1.0±1.0yrs) than those implanted at primary TKA. Discussion: Rarer insert configurations (smallest size, largest size, thickest thicknesses, lipped geometry) had longer, more variable shelf ages than standard choices. Corresponding trends towards higher failure rates with rarer insert selections are evident. As our experiences likely parallel those of many surgeons, knees implanted with less popular insert configurations more than 2 years after design introduction may warrant increased attention at follow-up.

POSTER NO. P108

Use of the Less Invasive Stabilization System (LISS) for Periprosthetic Femur Fractures After TKA

Robert V O'Toole, MD, *Brookline, MA (n)*
Reuben Gobezie, MD, Boston, MA (n)
Malcolm Smith, MD, Boston, MA (n)
Mark S Vrahas, MD, Boston, MA (a – Synthes)
Andrew A Freiberg, MD, Boston, MA (n)
Thomas S Thornhill, MD, Boston, MA
(a,c – DePuy, Johnson&Johnson)

Background: Supracondylar periprosthetic femur fractures after total knee arthroplasty (TKA) are a difficult clinical problem. This study reports on a series of these fractures treated with the LISS (Less Invasive Stabilization System, Synthes Inc, Paoli, PA). Methods: We prospectively followed a series of 14 patients with postoperative, periprosthetic femur fractures about a TKA that were treated with the LISS. All were followed to union or failure. All patients were female, with an average age of 78 years. All injuries were closed fractures with a low energy fall as the mechanism of injury. Results: Two of the patients died postoperatively (one of MI and one of respiratory failure) and were lost to follow up. One additional patient was lost to follow up. The remaining 11 patients were followed an average of 11.5 months (range: 4.1 to 21.5 months). All achieved bony union. There were no cases of infection, hardware failure, loss of reduction, or other complication. Conclusion: The LISS is a locked internal fixation system with novel features including the potential for a less traumatic insertion, minimal bone-plate contact area, and improved biomechanics. These preliminary results indicate that the LISS may have utility as an important treatment modality in the management of this complication after TKA.

POSTER NO. P109

Improved Range of Motion After Knee Replacement with Restoration of Tibial Slope

Ormonde M. Mahoney, MD, *Athens, GA*
(c, e – Stryker Howmedica Osteonics)
Michael S Ferrara, PhD, Athens, GA (n)
Tracy Kinsey, RN, Athens, GA (n)
A Mutlu Vural, MD, Athens, GA (n)
Kathy J Simpson, PhD, Athens, GA (n)

Restoration of patients'anatomic tibial slope during knee replacement surgery was associated with greater post-operative knee range of motion. Purpose: To determine the effect of altering tibial slope on the two-year range of motion (ROM) of patients undergoing condylar total knee replacements (TKR). Methods: A single surgeon performed 83 primary cemented posterior stabilized tri-compartmental TKR's on 64 patients (23 males, 41 females) with mean age of 67.3 years, height 168.1cm, mass 85.9kg and BMI 30.4 kg/m2. The primary diagnosis was osteoarthritis in 76 cases and rheumatoid arthritis in 7 cases. A standard surgical technique was employed utilizing flexion axis localization to position the femoral components. Patients were followed for four years minimum using outcome measures and x-rays. Knees where tibial slope was restored to a degree angle equal to or slightly greater than their pre-op slope were compared to knees where tibial slope was decreased. Results: Univariate ANOVA found that where tibial slope was restored, there was significantly greater post-operative total knee ROM (128.40 v. 122.20, p<.001). Further, patients with restored tibal slopes had significantly greater pre- to post-operative increases in flexion (29.40 v. 21.00, p<.001) and pre- to post-operative increases in total joint range (39.20 v. 30.00, p<.001) compared to when the tibial slope was not restored. Discussion and Conclusion: Restoration of tibial slope was significantly associated with increased post-operative ROM in this study. Using one standard slope cut for every tibia may prevent many patients from achieving their maximum potential ROM.

POSTER NO. P110

Intramedullary and Computer Navigation Femoral Alignment in Total Knee Arthroplasty

William Michael Mihalko, MD, *Clarence Center, NY*
(a,e - Stryker Howmedica Osteonics)
Kenneth A Krackow, MD, Buffalo, NY (n)
James Boyle, MD, Buffalo, NY (n)
Lindsey Clark, BA, Buffalo, NY (n)

Different intramedullary starting points on the femur significantly changed the resulting femoral component flexion and coronal alignment was variable when compared to computer navigation techniques. Introduction: Intramedullary alignment is used during Total Knee Arthroplasty to mark the distal femoral resection. The entry point of the intramedullary rod may vary depending upon anatomy and surgeon experience. This study investigated the variability of different entry points for femoral instrumentation and compared it to a computer navigation system. Methods: Seven cadaveric extremities were used along with a computer navigation system to record the mechanical axis (Stryker Navigation, Inc). CT scans were obtained to verify the navigation system data. An intramedullary rod was instrumented with infrared markers. An anterior and a posterior point 5mm from the normal entry location along the AP axis were marked and then drilled. The IM rod axis was then compared to the navigation axis. Results: The anterior point resulted in -2.4 + 1.1 degrees flexion and the standard starting point 1.9 + 1.6 degrees compared to the computer axis. The posterior entry point resulted in 3.9 + 2.1 degrees flexion and was significantly different to the anterior point (p less than 0.05). For coronal plane alignment the IM rod readings were not significantly different for any of the points. On average the rod was 5.9 + 1.6 degrees varus. The CT scan landmarks were within 1-2 mm of the navigation system. Discussion and Conclusion: Different entry points for femoral IM instrumentation resulted in a significant variation in the placement of the femoral component compared to the computer navigation system. Long standing radiographs preoperatively may decrease the error in alignment. Computer navigation can accurately obtain the femoral component position without violating the intramedullary canal.

POSTER NO. P111

The Effect of Femoral Component Design on Ground Reaction Force Analysis of Chair Rise Movement

He Wang, MS, *Flushing, NY (n)*
Kathy J Simpson, PhD, Athens, GA (n)
Michael S Ferrara, PhD, Athens, GA (n)
Samatchai Chamnongkich, MS, Athens, GA (*)
Steve R Casto, MS, Athens, GA (*)
Tracy Kinsey, RN, Athens, GA (n)
Ormonde M. Mahoney, MD, Athens, GA
(c,e - Stryker Howmedica Osteonics)

Introduction: We have reported superior extensor mechanism function in total knee arthroplasties (TKA) of single radius (SR) design compared to multi radius (MR) design by clinical, biomechanical and kinematic measures. This study compares ground reaction force (GRF) characteristics exhibited during chair rising activity between SR and MR limbs in bilateral TKA patients who have one knee of each design type. METHODS: Ten healthy well functioning bilateral TKA patients performed chair rising movement on a force plate while high-speed video motion measurement systems tracked movement. Vertical, antero-posterior (AP) and medio-lateral (ML) ground reaction forces were analyzed. All patients had one SR and one MR TKA, implanted by a single surgeon. RESULTS: The SR leg exhibited greater AP force than the MR leg in the majority (7/10) of patients. SR limbs exhibited significantly greater change of the AP force from minimum to maximum (p<0.05) and longer time to vertical peak (p<0.05). Also, patients' SR legs tended to generate greater vertical impulse during the seat-off phase, greater peak ML GRF, and shorter time to peak ML GRF (6/10, 7/10 and 8/10, respectively). Discussion/Conclusion: These patients appeared to generate more of their total GRF from their SR limb. SR limbs produced more of the upward momentum by generating greater vertical GRF for a longer period of time. The differences in magnitude and timing of the GRF patterns suggests that these patients may tend to rely more on their SR leg during daily activities that require knee extensor strength, balance and stability (i.e. chair rising).

POSTER NO. P112

A Change in Technique Transforms the Results of Extensor Mechanism Allograft Reconstructions in TKA

Robert Stephen Burnett, MD FRCSC, *St Louis, MO (n)*
Richard A Berger, MD, Chicago, IL (n)
Craig Della Valle, MD, Chicago, IL (a,e – Zimmer)
Joshua J Jacobs, MD, Chicago, IL
(a,e – Zimmer, a – Wright Medical)
Wayne Gregory Paprosky, MD, Winfield, IL (e – Zimmer)
Seth S Leopold, MD, Seattle, WA (*)
Regina M Barden, RN, Chicago, IL (*)
Aaron Glen Rosenberg, MD, Chicago, IL (*)

Introduction: The purpose of this study was to compare two techniques of extensor mechanism allograft reconstruction in revision total knee arthroplasty using an allograft knee extensor mechanism. Methods: Twenty consecutive extensor mechanism reconstructions were performed during revision TKA using a quadriceps tendon-patella-patellar tendon- tibial tubercle extensor mechanism allograft for a failure of the host extensor mechanism. The first 7 reconstructions (Group I) were performed with the allograft loosely tensioned in full extension. The 13 subsequent reconstructions (Group 2) were performed with the allograft tightly tensioned in full extension. Disease specific (HSS Knee score) outcomes were recorded. An extensor lag of 30 degrees or revision for failure of the extensor mechanism were defined as clinical failure of the procedure. Results: At a minimum follow up of 24 months (range, 24-112 months), no patients were lost to follow up. All 7 reconstructions in Group 1 were clinical failures with a mean postoperative extensor lag of 59 degrees (range,40-80 degrees) and HSS score of 52 points. All procedures performed in Group 2 were clinical successes, with a mean extensor lag of 3 degrees (range, 0-15 degrees; p=0.002) and HSS score of 89 points (p=0.003). Mean postoperative flexion was not different between Group 1 and 2 (108 versus 106 degrees; p=0.80)Conclusion: Extensor mechanism allograft reconstruction results are dependant on initial allograft tensioning. Clinical success with the use of a knee extensor mechanism allograft requires the allograft to be initially tightly tensioned in full extension.

POSTER NO. P113

Differences in Knee Kinematics After Unicondylar and Total Knee Arthroplasty

Shantanu Patil, MS, *La Jolla, CA (*)*
Kace A Ezzet, MD, La Jolla, CA (n)
Seung Baik Kang, MD, Seoul, Korea, Republic of (n)
Clifford W Colwell, Jr, MD, La Jolla, CA
(a – DePuy, Johnson&Johnson)

Introduction: Total knee arthroplasty (TKA) is extremely successful in providing lasting pain relief. However, a return to normal function has not been reported. A significant proportion of patients currently undergoing total knee arthroplasty have unicompartmental disease. Unicondylar knee replacement (UKA) offers the benefits of less bone resection and of better soft tissue retention. However, knee kinematic changes after UKA have not been established. Methods: Eight fresh-frozen cadaver knees were sequentially tested under four conditions: Normal, UKA, UKA with resected anterior cruciate ligament (ACL), and TKA. The UKA was a current generation design with low tibiofemoral conformity. The TKA was a posterior cruciate-retaining, moderately conforming design. Knee kinematics were measured for each experimental condition, using three-dimensional electromagnetic sensors in a dynamic loaded quadriceps-driven knee rig, with from 0 to 120 degrees flexion. Results: In the normal knee, knee flexion was accompanied by femoral rollback and by tibial internal rotation. Similar patterns of rollback and rotation were seen after UKA. Resecting the ACL did not affect rollback or tibial rotation. However, tibial rotation was significantly different and was more variable after TKA. Discussion and Conclusion: Abnormal kinematics have been previously reported after TKA. However, UKA did not affect normal kinematics. Surprisingly, resecting the ACL had no effect on tibiofemoral rotation under conditions of dynamic loaded knee flexion. This suggests that loss of the ACL may not be the major cause of abnormal kinematics after TKA. This study reports kinematic advantages to UKA in addition to less bone resection and to better recovery.

POSTER NO. P114

Total Knee Arthroplasty in Parkinson's Disease: A Protocol for Improved Extension

David George Nazarian, MD, *Philadelphia, PA*
(e – Zimmer)
Paul R Reynolds, MD, Springfield, VA (e – Zimmer)
Majid Kamrin, BS, Philadelphia, PA (e – Zimmer)
Robert Emrey Booth Jr, MD, Philadelphia, PA
(a, c – Zimmer)

INTRODUCTION: There are few reports regarding total knee arthroplasty in patients with Parkinson's Disease. This study is a review of a consecutive series of patients with the diagnosis of Parkinson's Disease who underwent primary total knee arthroplasty. METHODS: Fifty-six knees were treated in patients with a prior diagnosis of Parkinson's disease who underwent primary knee arthroplasty with a cemented posterior stabilized component and an all polyethylene patellar component. Bone cuts were made such that the extension gap was purposely made 2 mm larger than the flexion gap. A soft tissue tensor device and extramedullary alignment guide was used, a thorough posterior release performed and Botox injections in the hamstrings postoperatively were given. Patients were treated with extension slings at night and were evaluated clinically and radiographically using a modified Knee Society rating system. RESULTS: All patients had severe pain and disability prior to their index procedure. The average Knee Society Score went from 49 to 86, while the functional score improved from 44 to 80, with an average follow-up of 4.9 years (range 2 to 10). All patients had good or excellent pain relief and improvement in their functional ability. Nine patients had a flexion contracture greater than 5 degrees. The average range of motion was 4 to 110 degrees. Seven patients required manipulation under anesthesia. Four of these were treated with manipulation and casting. There were 4 cases of non-progressive radiolucencies and no cases of loosening. DISCUSSION AND CONCLUSION: Total knee arthroplasty in patients with Parkinson's disease has been fraught with complications, including flexion contractures with decremental functional results. This study reports on a consecutive series of patients who achieved very good functional results through a predetermined intraoperative protocol and an aggressive postoperative physical therapy regimen including Botox injections. The patients in this report compare favorably with previous studies and suggest that total knee arthroplasty in this difficult population may provide a satisfying outcome.

POSTER NO. P115

Prospective, Randomized Study of Two Mechanical Devices for DVT Prophylaxis after Knee Arthroplasty

Paul F Lachiewicz, MD, *Chapel Hill, NC (a – Aircast)*
Scott S Kelley, MD, Durham, NC (a – Aircast)
Lisa Haden, RN, Chapel Hill, NC(a – Aircast)

The optimal characteristics for pneumatic compression devices for thromboembolism prophylaxis after total knee arthroplasty are not known. This is a prospective, randomized study which compared a circumferential calf compression device (S) to a higher flow asymmetric calf compression device (V). Both groups also received aspirin. The hypothesis was that the device which provided for a larger increase in peak venous velocity would have a lower prevalence of thromboembolism. This study included 423 patients (472 knees) who had primary or revision total knee arthroplasty. Patients were randomized using sealed envelopes. Duplex ultrasonography was performed by experienced technologists who were unaware of the device used. Overall, 206 patients (232 knees) had device V and 217 patients (240 knees) had device S. There was one death (0.2 percent) from myocardial infarction and one pulmonary embolism (0.2 percent), both with device S. Overall, the prevalence of venous thromboembolism was 6.9 percent (16 thrombi in 232 knees) with device V compared to 15 percent (36 thrombi in 240 knees) with device S. This difference was statistically significant (p=.007). The prevalence of thrombi with unilateral primary knees was 8.4 percent with device V compared to 16.5 percent with device S (p=.031). Of 47 bilateral one stage primary knees, the prevalence of thrombi was 4 percent with device V compared to 22.7 percent with device S (p=.09). There is a low prevalence of death and pulmonary embolism using mechanical calf compression and aspirin. However, the higher flow asymmetric calf compression device had a significantly lower prevalence of thromboembolism.

POSTER NO. P116

Relative Contributions of the Patient, Surgical Technique, and Polyethylene Tibial Component to Wear in Total Knee Arthroplasty

Matthew B Collier, MS, *Alexandria, VA (a – Inova Health Services)*
C Anderson Engh Jr, MD, Alexandria, VA (a – Inova Health Services, e – DePuy, Johnson&Johnson)
James P McAuley, MD, Alexandria, VA (e – DePuy, Johnson&Johnson)
Gerard Anderson Engh, MD, Alexandria, VA (c - DePuy, Johnson&Johnson)

INTRODUCTION: Our objective was to identify and prioritize factors associated with tibial polyethylene wear. METHODS: 68 cruciate-retaining primary total knee arthroplasties of the Anatomic Modular Knee design were performed for varus osteoarthritis and retrieved at revision or autopsy. Wear of each tibiofemoral compartment of the gamma-sterilized-in-air insert was defined to be the change in minimum thickness per year in vivo. Multiple linear regression was used to assess relative contributions of 3 patient (age, gender, weight), 3 technique (postoperative mechanical axis varus, tibial component varus, femoral component valgus), and 5 polyethylene (resin, fabrication method, shelf age, size, original thickness) factors to wear of the medial compartment and lateral compartment. RESULTS: The 11 factors explained 62% of the variation in medial compartment wear (mean ± standard deviation, 0.36±0.30 mm/year) and 35% to 39% of the variation in lateral compartment wear (0.18±0.16 mm/year). Medial compartment wear correlated strongest with shelf age (1.4±1.6 years), but also increased with decreasing patient age (66±10 years) and increasing mechanical axis varus (4±9 mm). These three factors together explained 58% of the variation in medial compartment wear. Shelf age was the lone variable associated with lateral compartment wear. Shelf age became insignificant only after eliminating inserts with shelf ages above 1.2 years. DISCUSSION: Shelf aging compromises the clinical wear performance of gamma-irradiated-in-air polyethylene tibial components. These linger in product inventories worldwide and should not be implanted if older than one year. Young patient age and incomplete correction of mechanical axis varus may also increase medial compartment polyethylene wear.

POSTER NO. P117

Metal Ions Induce Apoptosis of Human Bone Forming Osteoblasts

Carmelita Frondoza, PhD, *Baltimore, MD (a – Medstar Research Grant)*
Jinny Ha, BS, Baltimore, MD (n)
Harpal S Khanuja, MD, Cockeysville, MD (a – Medstar Research Grant)
Anna V Polotsky, MD, Baltimore, MD (a – Medstar Research Grant)
David S Hungerford, MD, Baltimore, MD (a – Medstar Research Grant)

Introduction: Concern regarding adverse tissue response to polyethylene wear debris prompted renewed interest on metal on metal bearing surfaces. However the use of this design results in metal ion release. Recent studies have implicated metal ions in osteolysis possibly by damaging bone forming osteoblasts and favoring increased osteoclast activity. The present study investigated the ability of metal ions to induce osteoblast cytotoxicity and whether the mode of cell death involves apoptosis. Methods: Human osteoblasts isolated from trabecular bone were cultured with: control medium alone, cobalt (Co [II]), chromium (Cr [III], Cr [VI]) ions at different concentrations for up to 48 hours. Cell viability, proliferative capacity and apoptotic indices were evaluated. Results: Co [II] and Cr [VI] induced cell death in a dose and time-dependent manner. Incubation with a concentration greater than 10µg/ml of Co [II] or greater than 1µg/ml of Cr [VI] induced caspase-3 expression, nuclear condensation and fragmentation of chromatin by 48 hours. Apoptosis was confirmed by ultrastructural changes viewed by transmission electron microscopy. The concentrations of metal ion that induced apoptosis were relatively close to that detectable in peri-prosthetic tissue. Cr [III] did not induce apoptosis at the concentrations tested. Discussion/ Conclusion: We discovered that Co [II] and Cr [VI] induce osteoblast death via apoptosis. Chronic exposure to critical concentrations of metal ions could result in osteoblast death by apoptosis around and distant to the prosthesis. This could lead to potential osteolytic lesions. Our study suggests the potential deleterious effect of metal ions released from prosthesis on bone integrity.

POSTER NO. P118

Effect of Compressive Loading on Cartilage Regeneration after High Tibial Osteotomy

Takeshi Kanamiya, MD, *Fukuoka, Japan (n)*
Michiya Hara, Fukuoka, Japan (n)
Keihan Cho, MD, Fukoka, Japan (*)
Kazuhiko Saeki, MD, Saint Louis, MO (*)
Masatoshi Naito, MD, Fukuoka, Japan (n)

Purpose: A widening of the medial joint space has been observed after HTO with a proper correction as a result of a decrease in the stress of the load-bearing cartilage in the medial compartment. A repair of the articular cartilage and a clinical improvement has been reported after HTO.. However, it still remains unclear as to what factors influence cartilage regeneration. The purpose of this study was to quantitatively evaluate the influence of cartilage regeneration after HTO. Method: Fifty-eight knees in forty-seven patients were followed. Eighteen months after surgery, the patients underwent a second look arthroscopic examinations. The articular cartilage was evaluated by second look arthroscopy was classified as no regenerative change (Grade 1), white scattering with fibrocartilage (Grade 2), a partial coverage with fibrocartilage (Grade 3), and an even coverage with fibrocartilage (Grade 4). The functional results were evaluated using femoro-tibial angle, percentage mechanical axis (%MA) , body mass index and knee functional score.Result: A repair of the even and partial coverage with fibrocartilage (Grade 3 and 4) was achieved in 35 knees. A repair of the white scattering with fibrocartilage (Grade 2) was achieved in 20 knees and three knees showed no regenerative change (Grade 1). Significant differences were observed in the mean knee score and %MA at the follow-up between Grade 1 and Grade 4. Conclusion: This study show that the degree of correction obtained with a lateral closing wedge HTO correlated with both the visible improvement in the articular surface and the functional score.

POSTER NO. P119

Patellofemoral Arthroplasty: A Preliminary Report

Jess H Lonner, MD, *Philadelphia, PA(c,e – Zimmer)*
Robert Emrey Booth, Jr, MD, Philadelphia, PA (e – Zimmer)

Background: Patellofemoral arthroplasty (PFA) may be a reliable alternative to total knee arthroplasty, patellectomy, and tibial tubercle unloading procedures for the treatment of isolated patellofemoral arthritis. The purpose of this study is to review our short-term experience with patellofemoral arthroplasty. Methods: Thirty-seven PFA's were performed in 33 patients. The average patient age was 40 years (range, 31 to 53 years). The diagnosis was osteoarthritis or posttraumatic arthritis in all patients. An average of two prior surgeries had been performed in each patient. Patients were evaluated with preoperative and postoperative patellofemoral scores and visual analog scores (VAS). Results: Follow up averaged 2.5 years (range, 1 to 6 years). Mean VAS improved from 9 to 3. Mean patellofemoral pain scores improved from 5 to 40; functional assessment scores improved from 12 to 32. Improvement in anterior knee pain and ambulation on stairs was less pronounced when there was persistent quadriceps atrophy. Four patients required conversion to TKA; two for patellar maltracking, secondary to malposition of the trochlear implants, and two for progressive tibiofemoral arthritis. Conclusion: Patellofemoral arthroplasty can successfully reduce patellofemoral pain and improve functional performance in patients with debilitating patellofemoral arthritis. Component malposition, soft tissue imbalance, design flaws, and progressive tibiofemoral arthritis may contribute to premature failure. Conversion to TKA has been easy.

POSTER NO. P120

Screening for Symptomatic Metal Sensitivity: A Prospective Study of 109 Total Knee Arthroplasties

Yasuo Niki, *Tokyo, Japan (n)*
Hideo Matsumoto, MD, Tokyo, Japan (n)
Toshiro Otani, MD, Tokyo, Japan (n)
Taku Yatabe, MD, Tokyo, Japan (n)
Atsushi Funayama, MD, Tokyo, Japan (n)
Shinichi Maeno, MD, Tokyo, Japan (n)
Yoshiaki Toyama, Tokyo, Japan (n)
Makoto Kondo, MD, Nara, Japan (*)
Fumihiro Yoshimine, MD, Tokyo, Japan (n)

Introduction: Prevalence of metal sensitivity (MS) among patients who have undergone total joint arthroplasty (TJA) is approximately 20-25%, which is 10% higher than that in the general population. This is because implant-related MS develops after TJA. However, symptomatic MS with eczematous reaction is currently estimated to occur in only 1% of patients with TJA. The modified lymphocyte stimulation test (mLST) has been developed to determine precise lymphocyte reactivity to metals using anti-HLA antibody. Conventional LST and skin patch test are insufficient, due to nonspecific reactions caused by metal ion-derived activated oxygen species (presented in 70th AAOS). This study prospectively investigated prevalence of symptomatic MS in patients who are mLST-positive preoperatively, and evaluated the ability of mLST to screen patient predisposition towards symptomatic MS. Methods: Between 2000 and 2002, a total of 109 primary total knee arthroplasty (TKAs) were performed on 92 patients (all Co-Cr implants). Preoperatively, mLST was performed on all patients. Prevalences of MS symptoms, such as eczema around operative scars were investigated. Results: Of the 92 patients, 24 (26%) displayed positive responses to Ni, Co, Cr or Fe according to mLST. Among these mLST-positive patients, eczema and erythema were identified in 5 and 4, respectively. One of the 5 patients with eczema and 4 patients with erythema spontaneously recovered within 3 months, whereas 2 patients required TKA revision and the rest of 2 still had eczema at final follow up. Discussion: Mild eczema may be easily missed post-operatively, due to factors such as post-operative swelling, compress-induced eruption and early development of immunological tolerance. In this study, about 5% patients could be diagnosed as implant-induced eczema, and responsible metals were mostly Cr. In addition, according to mLST, preoperative Cr sensitivity is useful predictor in screening for patient predisposition to symptomatic MS.

POSTER NO. P121

Kneeling After Total Knee Arthroplasty

Stephen J Incavo, MD, *Burlington, VT*
(a,e – Stryker Howmedica Osteonics)
Eric Ronald Mullins, MD, Burlington, VT (n)
Kathryn M Coughlin, MD, Burlington, VT (*)
Scott A Banks, PhD, West Palm Beach, FL
(a – Stryker Howmedica Osteonics)
Anne Banks, MS, West Palm Beach, FL
(a – Stryker Howmedica Osteonics)
C Lowry Barnes, MD, Little Rock, AR
(a,b,e - Stryker Howmedica Osteonics)
Justin de Beer, MD, Hamilton, ON Canada (*)
Bruce Beynnon, PhD, Burlington, VT (n)

Introduction: Many TKA patients wish to resume normal activities, including kneeling, after total knee arthroplasty (TKA). This work describes the in vivo tibiofemoral kinematics during standing and kneeling after TKA. Methods: Ten posterior substituting (PS) and 10 cruciate retaining (CR) TKA designs were studied in 18 patients (6-24 months post-operatively). Radiographs were taken when standing, kneeling at 90 degrees, and kneeling at maximal flexion. An image matching technique provided three-dimensional measurements of the femoral component position relative to the AP midpoint of the baseplate. Results: When standing, the CR tibiofemoral contact position (medial:7mm, lateral:6mm) was more posterior than the PS design (medial:5mm, lateral:5mm). Movement from standing to kneeling at 90 degrees produced different responses. CR knees translated anteriorly (medial:4mm, lateral:2mm), while PS knees translated posteriorly (medial:0.2mm, lateral:1mm). During kneeling, movement from 90 degrees to maximum flexion produced posterior translation of the femur (CR medial:5mm, CR lateral:5mm, PS medial:6mm, PS lateral:6mm). The relationship between the tibiofemoral contact position and flexion angle was more variable for CR than PS knees. Discussion: PS knees dislocate when the arch of the femoral cam slides over the tibial post; CR knees sublux when the femoral contact position translates beyond the edge of the baseplate. The minimum distance from the contact position to the edge of the baseplate averaged 20mm. The minimum distance from the femoral arch to the top of the tibial post averaged 13mm. Neither dislocation of the PS design, nor subluxation of the CR design appeared likely to occur in these patients.

POSTER NO. P122

The Use of Porous Components in Revision TKA: A 5 Year Follow-Up

S David Stulberg, MD, *Chicago, IL (e – Zimmer)*

Introduction: Segmental defects, in TKA revisions, require treatment that provides rigid, initial and long-lasting structural replacement of the defect. In these situations, said metal augments attached to the femoral and tibial implants are useful. However, solid metal augments are attached to bone with cement. The bone against which this cement is applied is often of poor quality. In addition, solid metal augments do not lead to the restoration of bone stock. Porous implants made of tantalum have been applied in a number of clinical conditions in which the restoration or preservation of bone stock is desired. The purpose of this study was to evaluate the safety and efficacy of porous augments attached to revision TKA femoral and tibial components during revision TKA surgery. Methods: Between 1998-2002, 43 revision TKA procedures were performed using porous, tantalum, augments. In older patients (>60 years), cement was placed the distal femoral and proximal tibial augments. No cement was placed on the bone or augments in patients less than 60. Cement was not placed on the posterior femoral augments in any patients. KS clinical and x-ray scores were obtained on all patients prior to surgery and at most recent follow-up. In addition, fluoroscopic inter-face x-rays were obtained to determine the quality of attachment of the porous implants. Results: Average KS pre-op score was 54 (33- 62) and average post-op score was 87 (79-100). Four knees have undergone further surgery: 2 for revision of a patellar implant and 2 for infection. No knees have been revised for loosening. At final follow-up, all implants appear to be well fixed. Interface x-rays suggest bone attachment of the uncemented posterior augments. At the time of the 2 patellar implant revision, the distal and femoral augments were observed to have been attached to bone. The have been no mechanical failures of the porous augments. Conclusions: Porous augments allow biologic fixation of revision TKR components placed in the presence of segmental bone loss. This fixation may be particularly useful for younger patients requiring revision and for patients with bone stock which is inappropriate for cement fixation.

POSTER NO. P123

Total Knee Arthroplasty in Young: Minimum of 10 Years Results

Gurdev S Gill, MD, *Lubbock, TX (e – Biomet)*
Atul B Joshi, MD, Lubbock, TX (n)

Introduction: The total knee arthroplasty is one of the most successful arthroplasty. However, published results in young patients are scares, and with shorter follow-up. Aim: To asses the outcome of the knee arthroplasty in patients under 55 years old. Material and Methods: 106 knees were performed in patients who were 55 years and younger by one surgeon. No patient was lost to follow-up. The assessment was done using the Knee Society scoring systems. Survivorship analysis was done using the Kaplan-Meier method and analysed with log rank test. Results: The average age at surgery was 48 (19-55) years. Osteoarthrosis was diagnosis in 69 knees and 37 had rheumatoid arthritis. All living patients had a minimum of 10 years (10-23) of follow up. Failure occurred in seven (6.6 per cent). 82 per cent of patients had complete pain relief and 91 per cent the knee had excellent knee score (of more than 85) at the final follow up. Survivorship analysis showed implant survival of 90 per cent at 15 years, and 75 per cent at 23 years for revision as end point. Diagnosis had no significant effect on the survivorship (p=0.66). Conclusions: The conventional total knee arthroplasty provides in this young group of patients with excellent clinical results and moderate survivorship analysis for 23 years follow-up.

POSTER NO. P124

Is Osteolysis a Problem with a Modular Posterior-Stabilized Knee Arthroplasty?

Elizabeth S Soileau, RN, *Chapel Hill, NC (a – Zimmer)*
Paul F Lachiewicz, MD, Chapel Hill, NC (a, e – Zimmer)

Osteolysis and increased polyethylene wear have been reported with several designs of modular total knee arthroplasties. This study evaluated a modular posterior-stabilized prosthesis for clinical performance, component loosening and osteolysis. This is a prospective, consecutive study of 193 knees in 131 patients with the modular Insall-Burstein II posterior-stabilized total knee arthroplasty implanted by one surgeon who is not a designer of the prosthesis. The preoperative diagnosis was

osteoarthritis in 154, rheumatoid arthritis in 33, and other in six knees. The mean follow-up time was 7 years (range 5-13 years). Tibial component implantation included water-pik lavage and placement of cement by syringe. Hyperextension was carefully avoided. Clinical evaluation was performed using standard knee scoring systems. Radiographs were evaluated for radiolucent lines, osteolysis, and loosening. The overall clinical result was rated as excellent in 112 knees, good in 60, fair in 15 and poor in 6 knees. The mean flexion was 112 degrees post-operatively. There were no clinically or radiographically loose tibial components. There were eight knees (4 percent)with small osteolytic lesions of the tibia. Radiolucent lines were noted in 15 percent of the tibial components. One patient who was on hemodialysis, had late synovitis and tibial osteolysis. Despite synovectomy and liner exchange, hemarthroses recurred and the result was poor. One patient had liner exchange for instability. Despite reports of osteolysis, polyethylene wear and loosening with some modular total knee arthroplasty designs, there was no loosening in 193 modular, posterior-stabilized total knee arthroplasties and only eight knees had tibial osteolysis.

POSTER NO. P125

Simultaneous Bilateral Total Knee Arthroplasty: Safety, Complications, and Outcomes

Edward Charles Brown, III MD, *Gaithersburg, MD (n)*
Giles R Scuderi, MD, New York, NY (a,c,e – Zimmer)
W Norman Scott, MD, New York, NY(c – Zimmer)
Fred D Cushner, MD, New York, NY (n)
John N Insall, MD, New York, NY (n)

Introduction: The safety of simultaneous bilateral total knee arthroplasty is an issue of concern. Some studies report increased cardiac and neurologic complications and increased risk of early mortalilty compared to unilateral total knee arthroplasty. Methods: This is a retrospective clinical review of all simultaneous bilateral total knee arthroplasty patients at one institution from January 1994 to March 2002. Both inpatient and outpatient charts were reviewed. Pertinent demographic and clinical information, including all complications, were recorded. Results: The study population comprised 274 patients. One-month follow-up was present for 273 patients and 246 patients had follow-up greater than 12 months.The average patient age was 64.7 years (35 - 86 years) and average follow-up was 33.8 months. The average preoperative and postoperative Knee Society Score was 44.1 and 94.9, respectively. The average preoperative and postoperative Function Score was 50.3 and 90.4, respectively. The average hospitalization was 7.04 days. The average ICU stay was 0.49 days and the ICU admission rate was 14.1 percent. The transfusion rate was 70.2 percent and the average transfusion was 1.83 units. The average postoperative hemoglobin loss was 3.32 gm/dl. The major systemic complication rate was 13.5% and the major local complication rate was 7.0%. The most common complications were urinary retention (6.7%), confusion (5.9%), cardiac arrhythmias (5.1%), and deep venous thrombosis (4.5%). The re-operation rate was 3.9%.There were no fatalities in the first postoperative month. Two patient deaths occurred in the first postoperative year and five patient deaths occurred later than one year after surgery. The 30-day mortality rate was 0.0% and the one-year mortality rate was 0.8%. Conclusions: The results of this study do not support reports of increased morbidity for patients undergoing simultaneous bilateral total knee arthroplasty.

POSTER NO. P126

10+ year Outcome of Total Knee Arthroplasty - Results from a UK Arthroplasty Register

Colin Esler, MD, FRCS, *Leicester, United Kingdom (n)*
Anna Bennett, Leicester, United Kingdom (n)
William Harper, MD, Leicester, United Kingdom (n)

INTRODUCTION: Published results from specialist orthopaedic centres indicate that a 95% 10 year survival may be achieved for total knee arthroplasty. The outcome of total knee arthroplasty when performed in a general orthopaedic setting may not approach this level of success. METHOD:The Trent Knee Arthroplasty Register has collected prospective data on all knee arthroplasties performed in this region of the UK since 1990 (population 5.18 million). A self-administered validated questionnaire, including EuroQol, was mailed to patients who had knee arthroplasties in 1990 to 1992. This surgery was performed by 76 Consultants and their trainees. The mean age at the time of TKA was 70.1 yrs. 39.9% of the 4677 patients had died in the 10years since their TKA. RESULTS:The TKA had met the patients expectations in 80% of cases, though 30% claimed to have had a problem with their knee in the subsequent 10 yrs. 7.7% had required an MUA to regain flexion in the first year. 12.3% of knees had required a revision procedure by 10 years. 22% of patients were experiencing constant or regular pain in their replaced knee. 13% of patients experienced severe pain in their knee. DISCUSSION: The results of TKA in a generalist setting don't appear to match published series. It is not clear whether the deterioration in the outcomes of TKA by 10 years is due to wear /aseptic loosening ,or deterioration in the physical state of the patients. We would encourage regular clinical and radiological follow-up of all TKA's indefinitely.

POSTER NO. P127

◆Mini-Invasive Implantation of a Unicompartmental Knee Prosthesis with a Navigation System

Jean-Yves Jenny, MD, *Illkrich, France (e – Aesculap)*
Cyril Boeri, MD, Illkirch, France (n)

Introduction: The accuracy of implantation is an accepted prognostic factor for the long term survival of a unicompartmental knee prosthesis (UKP). Minimal invasive technique is recommended for faster post-operative recovery, but its accuracy is questionable. We developed an adaptation of a non image based system for either conventional or minimal invasive UKP implantation. We hypothesized that the used non image based navigation system will allow to place a UKP in the same position for both conventional and minimal invasive approach. Methods: Three infrared localizers are fixed in the distal femur, the proximal tibia and the foot, and their relative motion is tracked by an infrared camera. The software calculates the respective axes of femur and tibia. A localizer is fixed on the tibial or femoral resection blocks, and the block tracked for optimal orientation before performing the bony resection. For minimal invasive technique, resection blocks were modified to allow the whole procedure through a 8 cm antero-medial skin incision.20 patients were operated on for a medial unicompartmental knee osteoarthritis with this experimental minimal invasive navigated technique (group A). Radiological quality of implantation was compared to a group of 20 cases operated with the conventional navigated technique (group B), and matched according to age, gender and severity of the coronal deformation.All patients had a post-operative antero-posterior and lateral long leg X-rays. Prosthesis implantation was considered as satisfactory when all X-rays

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

angles were within the desired range by a given patient. The rate of satisfactory implanted prostheses was compared in both groups with a Chi-square test with a 0.05 limit of significance. Results: There was no significant difference in the pre-operative data between both groups. The post-operative coronal mechanical femoro-tibial angle was within the desired range in 16 cases in group A and 17 cases in group B. The femoral component was optimally implanted in 17 cases in group A and 18 cases in group B. The tibial component was optimally implanted in all cases. No difference was significant. Mean length of the skin incision was 8 cm (range, 7 to 10 cm) in group A. Discussion-Conclusion: The used navigation system allowed a very precise implantation of a UKP for both conventional and minimal invasive navigated technique. The use of the minimal invasive technique did not decrease the radiological quality of implantation in comparison to the conventional navigated techniques. It may become the reference technique for UKP implantation.

POSTER NO. P128

Complication Rates Following Medical Opening Wedge Osteotomy

William I Sterett, MD, *Vail, CO (a,e – EBI)*
Valerie Rich, MD, Vail, CO (a – EBI)
Elizabeth M Barry, Vail, CO(a – EBI)

Purpose: Evaluate complication rates following High Tibial Osteotomy in active patients using either the distraction technique or Puddu plate. Methods: 132 patients following High Tibial Osteotomy were reviewed, 63 patients using the distraction technique with an external fixator, and 69 patients with a Puddu plate. Mean age was 50.2 (19-70), with a minimum follow- up of 1 year. Complications were classified as major (requiring repeat hospitalization or surgery, or minor (not requiring repeat hospitalization or surgery). Complications included infection requiring medication, infection requiring surgery, loss of correction, broken hardware, non-union, delayed union (>4months to heal), and revision surgery. Results: The overall complication rates utilizing both techniques were very similar, with the distraction technique this was 67%, whereas it was 65% with the Puddu plate. 66% of complications in the Puddu Plate group were classified as Major, while 29% in the distraction group required hospitalization or surgery. Following the use of the distraction technique an infection requiring oral medication, was the most common complication at 46% of all cases, followed by infections requiring surgery 6%, loss of correction 6%, delayed union 3%, revision surgery 3%, and non-union 2%. With the Puddu plating system, the most common complication following surgery was a delayed union at 17% of all cases, followed by broken hardware not requiring surgery in 12%, infection requiring oral medications in 9%, and infection that required surgery in 6%. There were 4 non- unions (6%), 3 with a loss of correction (4%). Additionally 8 patients had a revision (12%) to gain union and/or correction. Conclusions: We have previously reported more than a 25 point increase in Lysholm scores at 2 year follow-up with these procedures despite a high complication rate. The majority of complications with the distraction technique were minor pin site infections treated with oral antibiotics that quickly resolved. The Puddu plate had many more major complications requiring further hospitalization or surgery with delayed unions, broken hardware, and the need for revision surgery. We conclude the Puddu system may need design modifications to decrease the major complication rate, especially delayed and non-union requiring further surgery.

POSTER NO. P129

Evaluation of Failure in Unicondylar Knee Arthroplasty: A Clinical and Retrieval Analysis

Sabine Schmitt, MD, *Mannheim, Germany(n)*
Sven Roessing, MD, Mannheim, Germany (n)
Hanns-Peter Scharf, MD, Manheim, Germany (n)

Introduction: Despite continued controversy, there is a renewed interest in unicondylar knee arthroplasty (UKA). Few studies have assessed failure analysis. The purpose of this study was to evaluate contributions of factors leading to revision and to distinguish the role of surgical technique, implant alignment, and polyethylene (PE) wear in UKA failure. Methods: 32 consecutive cemented medial unicondylar knee arthroplasties were retrieved from 26 female and 6 male patients due to failure (aseptic loosening, pain, infection). The average age at arthroplasty was 69.8 years (56 to 82 years). The average time in situ was 5.4 years (0.9 to 13 years). Retrospectively, clinical and retrieval analysis were performed using the knee society score, radiographic evaluation, and polyethylene damage analysis. Results: Mean pain and functional score improved initially. A gradual decrease in scores back to pre-operative levels was found prior to revision. Pitting and deformation were found to be the most common polyethylene damage modes (81.2%; 26/32) located in the centre and/or in the dorsal part of the PE component. Wear had significant correlation with in situ time. Damage size did not correlate with pain or function score. Discussion and Conclusion: Wear and fatigue of the tibial PE component with a distinct central damage region were common in our unicondylar knee retrievals. However, our data show that wear has not been the leading cause for revision surgery. Stringent selection criteria and good surgical technique remain primary factors to ensure satisfactory outcomes in UKA.

POSTER NO. P130

Clinical and Radiographic Outcome in High Activity Patients Compared to Non-High Activity Patients

Michael A Mont, MD, *Baltimore, MD(a – Stryker)*
Noah Gordon, BS, Baltimore, MD (n)
Lynne C Jones, PhD, Baltimore, MD (a – Stryker)
David S Hungerford, MD, Baltimore, MD(a – Stryker)
Gracia Etienne, MD, Baltimore, MD (n)

Introduction: There is a relative paucity of information on the effect of high activity sports on the clinical and radiographic outcome of total knee arthroplasties (TKA). This study analyzed the clinical and radiographic results of tricompartmental arthroplasty in patients who participated in high activity sports versus non-high activity individuals after total knee replacement. Methods: Fifty patients with a unilateral TKA with a minimum of 4 years of continuous high activity sports such as singles tennis, jogging, cycling, and skiing on a regular basis were identified. A strict high activity scale was used to allow demarcation of patients. These patients were matched to a similar cohort of fifty patients who had a TKA and did not have high activity levels. The two groups of patients were matched for 7 clinical parameters and were evaluated both clinically and radiographically at final follow-up. Results: No differences in clinical outcomes were observed between the two groups at a mean seven-year follow-up. Two knees required revision in each group with two other clinical failures (one in each group). Non-progressive radiolucencies were observed in both groups, but none were progressive. The degree of satisfaction with the TKA was similar in the two groups. Discussion: High activity levels had no detrimental effect on the outcome of total knee replacement at seven-year follow-

up. The long-term outcome of these patient cohorts deserves further study, though the authors are encouraged by the good results of high activity patients found in this study.

POSTER NO. P131

Extension-, Flexion-, and High-Flexion Gaps During Total Knee Arthroplasty

Ryuichi Gejo, MD,PhD, *Toyama City, Japan (n)*
Yuji Morita, MD, Tayama-City, Japan (n)
Isao Matsushita, MD, PhD, Toyama-City, Japan (n)
Tomoatsu Kimura, Toyama-City, Japan (*)

INTRODUCTION: Equally balanced gaps in full extension and flexion are prerequisite for satisfactory soft tissue balancing during total knee arthroplasty (TKA). To evaluate the balancing in deep flexion, we analyzed high (deep)-flexion gap at 135 degrees of flexion in addition to common flexion-extension gaps. METHODS: Thirty-one knees undergoing mobile bearing PS TKA were studied. After bone cuts and standard soft tissue balancing using spacer-block technique, extension and flexion gaps were measured using a V-STAT tensor (Zimmer.) under 40-lb distracting force before and after resection of the posterior cruciate ligament (PCL). In addition, with the femoral component in position, high-flexion gap was measured at 135 degrees of deep flexion. RESULTS: The mean values of flexion gap increased significantly after PCL resection, whereas the extension gap remained constant. When the joint gap was measured with the femoral component in position, the value was significantly increased from extension toward high-flexion; plus 4.6mm at 90 degrees of flexion, plus 7.3mm at high-flexion and further increase in high-flexion-internal rotation. DISCUSSION: The present results indicated that there was a significant increase in the joint gap at flexion after PCL resection and in the high-flexion. Bearing the current trend of high-flex knees with PS design in mind, soft tissue balancing and knee stability in deep flexion during TKA should be carefully adjusted and deliberated.

POSTER NO. P132

Varus Supracondylar Femoral Osteotomy using a Lateral Approach

Frank A B Gottschalk, MD, *Dallas, TX (n)*
Charles B May, MD, Vail, CO (*)

INTRODUCTION. Supracondylar femoral osteotomy for valgus deformity of the knee is an accepted procedure in patients under 60 years. METHOD. From 1993 to 2001, 24 knees in 23 patients underwent supracondylar femoral osteotomies for valgus deformity and lateral compartment arthritis. A lateral approach was used for the osteotomy and fixation. Patients completed osteotomy and WOMAC questionnaires. RESULTS. All patients were followed to healing. Four patients were lost to subsequent follow-up. Twenty knees averaged 5.5 years follow-up, range 2.1 to 9.8 years. Average age was 43.8, range 15.9 to 62.3 years. Pre and postoperative alignment was calculated using standing long leg films. Preoperative valgus averaged 15.2 degrees. Postoperative correction averaged 12.7 degrees and range of motion improved up to 30 degrees. Patients with less severe arthritis preoperatively had better scores postoperatively. Sixteen patients had a total of 30 knee surgeries prior to the osteotomy. Eleven had had prior lateral meniscectomies. Four patients required additional surgery; two hardware removals and two arthroscopic debridements. Complications were two non-unions, one loss of fixation, and one fracture at the osteotomy site early postoperatively DISCUSSION. Although the patient numbers are small and there are limited outcome measures, it is felt that this technique is technically easier than those previously reported and that the results are similar. The technique allows for an osteotomy that does not require an arthrotomy. This may account for the maintenance or improvement of range of motion. Complications in our study were similar to those in other studies. There was a high patient satisfaction rate

POSTER NO. P133

Tibial Cutting Guides Used in TKA are Inconsistent in Reproducing Tibial Slope

Arthur L Malkani, MD, *Louisville, KY (n)*
Raymond G Shea Jr, MD, Louisville, KY (*)
Ninad S Karandikar, MD, Louisville, KY (n)
Dale Baker, BA, Louisville, KY (*)

Introduction: The purpose of this study was to determine if preoperative tibial slope could be reproduced following total knee arthroplasty using various tibial cutting guides. Methods: This is a retrospective review of 76 patients undergoing total knee arthroplasty using three different cutting instrumentation systems for the tibial cuts. In Group A (n equals 25), an extramedullary alignment guide was utilized. In Group B (n equals 27), an intramedullary alignment guide with a five degree cutting block was utilized. In Group C (n equals 24), an intramedullary goniometer was utilized. We measured posterior sagittal tibial slope on preoperative and postoperative lateral radiographs in each of the three groups. Results: In Group A, mean preoperative tibial slope was 8.08 degrees whereas mean postoperative tibial slope was 1.4 degrees. In Group B, mean preoperative tibial slope was 8.07 degrees whereas mean postoperative tibial slope was 3.59 degrees. In Group C, mean preoperative tibial slope was 7.875 degrees whereas mean postoperative tibial slope was 4.04 degrees. The t values were not significant for any of the above groups. Discussion and Conclusion: In all three groups, preoperative tibial slope could not be achieved regardless of the cutting instrumentation utilized. Limitations preventing accurate posterior tibial slope included inconsistency in current cutting guides and lack of intraoperative sagittal plane information. Although the ideal tibial slope in TKA is not clearly defined, this study emphasizes the need to improve methods to reproduce tibial slope following total knee arthroplasty.

POSTER NO. P134

An Assessment of Polyethylene Backside Wear in a Modular Tibial Total Knee System

Roy D Crowninshield, PhD, *Warsaw, IN(a,e – Zimmer)*
Marcus Wimmer, PhD, Chicago, IL (a – Zimmer)
Jian Yao, PhD, Warsaw, IN (e – Zimmer)
Joshua J Jacobs, MD, Chicago, IL
(a,e – Zimmer, a – Wright Medical)
Aaron Glen Rosenberg, MD, Chicago, IL (a,c,e – Zimmer)

Introduction: Backside wear of modular tibial components has been reported to be a significant contributor to osteolysis. This study examines the backside wear performance of tibial components from both a laboratory and clinical perspective. Method: Zimmer NexGen tibial components were studied, 27 components retrieved after 24 to 80 months in situ and 6 having undergone 2 million cycles in knee joint simulator testing. Backside wear was quantified by engraving mark depth measurements. Additionally, the severity of third-body abrasion was recorded. Results: Joint simulator testing produced backside wear of 6.4 micrometers/milcyles (4.5 mm3/milcycles) which was 30% of total component wear. Backside wear in clinically retrieved components was sufficient to completely remove the manufac-

turers engraving marks on 3 of 27 components. The remaining 24 components all experience backside wear insufficient to remove all engraving. In 11 retrieved components, backside wear was measurable by engraving depth change (from unworn engraving) and averaged 14 micrometers at an average of 37 months in situ or 4.4 micrometers/year. The severity of third-body abrasion was generally associated with greater backside wear. None of the retrieved components were clinically associated with osteolysis. Conclusion: In this tibial component system, with a peripheral rail and dovetail locking mechanism, backside wear was moderate for both the joint simulator and clinically retrieved specimens. Backside wear does not appear to be the major contributor of total polyethylene wear in this implant system. The presence of third-body particles contributed to greater wear on both the articular and back surfaces.

POSTER NO. P135

Total Knee Arthroplasty in Patients with Parkinson's Disease

Samir Mehta, MD, *Collingswood, NJ (n)*
Jonathan P Van Kleunen, MD, Philadelphia, PA (n)
Robert Emrey Booth Jr, MD, Philadelphia, PA (e – Zimmer)
Paul A Lotke, MD, Philadelphia, PA
(e – Johnson&Johnson, Osteonics)
Jess H Lonner, MD, Philadelphia, PA (c,e – Zimmer)

Total knee arthroplasty has been shown to be successful in patients with Parkinson's disease. The purpose of this study is to evaluate the effect of early medical management of Parkinson's on outcomes following total knee arthroplasty. From January 1997 to August 2002, 34 patients (39 knees) with Parkinson's disease who underwent primary total knee arthroplasty were identified. Patients were placed in two groups based on the timing of neurologic consultation. Patients either had a pre-operative or immediate post-operative (POD #0) consultation (IC) or a delayed consultation (DC). Patients were scored on the severity of their Parkinson's disease, range of motion, and function and pain (using the Knee Society score). Univariate and multivariate analyses were performed. Follow-up was obtained in all 34 patients (average 2.5 years). 14 surgeries (13 patients) had immediate neurologic consultation, while 25 surgeries (22 patients) had a delayed neurologic consultation. There was no significant difference between the two cohorts with regards to age, sex, pre-operative pain, function, ROM, Parkinson's score, or post-operative Parkinson's score and post-operative ROM. However, the IC group had a 2.5 day shorter length of stay (p=0.001), a 19-point enhancement in their KSS pain scores (p=0.000), and a 19-point increase in their KSS function scores (p=0.000). Early consultation of a neurologist for patients with Parkinson's disease appears to significantly decrease length of stay, decrease pain, and increase function following primary total knee arthroplasty.

POSTER NO. P136

Outcome of Calf Deep Vein Thrombosis After Total Knee Arthroplasty

Ching-Jen Wang, MD, *Kaohsiung Hsien, Taiwan (n)*
Lin-Hsiu Weng, MD, Kaoshiung Hsien, Taiwan (n)
Chia-Chen Hsu, MD, Kaoshiung Hsien, Taiwan (n)
Jun-Wen Wang, MD, Kaohsiung Hsien, Taiwan (n)

Introduction: The purpose of this study was to retrospectively evaluate the outcome of calf deep vein thrombosis (DVT) after total knee arthroplasty (TKA) in Asian population with 3- to 4-year follow-up. Methods: The outcomes of calf deep vein thrombosis after TKA in 48 patients were evaluated by clinical assessment and venographic study in 3 to 4 years from the index surgery. The average age was 67.2 ?Oacute; 7.7 years and the average follow-up was 42.6 ?Oacute; 2.7 months. The diagnoses were osteoarthritis in 47 and rheumatoid arthritis in 1. The locations of the thrombi were 44 in the calf, 4 popliteal and none in the femur or iliac region. Twenty-four cases were clinically symptomatic, whereas the remaining 24 cases were asymptomatic. 41 patients were examined clinically of whom ascending venography was performed in 37, and 7 patients were evaluated by telephone interview. Results: All 48 patients reported to have no symptoms or signs of recurrent DVT or venous insufficiency in the affected leg, or history of pulmonary embolism. None of the patients had ever been treated for problems related to DVT of the affected leg from last treatment to the follow-up examination. Thirty-six of 37 venographic studies revealed negative findings for either old or new DVT in the affected leg. One case showed residual thrombi in the muscular branches. There were no major complications related to the venographic study. Discussion and Conclusion: The results of this study showed that calf deep vein thrombosis after TKA in the Asians had a tendency to spontaneous dissolution with time. None of the cases showed recurrent deep vein thrombosis, proximal propagation or distant embolization including pulmonary embolism. Therefore, treatment of calf deep vein thrombosis after TKA should be addressed according to the severity of clinical symptoms during the immediate postoperative period.

POSTER NO. P137

Radiographic Comparison of TKA: CT-Free Navigation vs. Conventional Technique

Chin Pak Lin, MBBS,MRCS, *Singapore, Singapore (n)*
Lo Ngai Nung, MD, Singapore, Singapore (n)
Yeo Seng Jin, MBBS, FRCS, Singapore, Singapore (n)

90 matched patients with knee arthritis were randomized into 3 groups: Conventional Technique: Extra (EM) and Intramedullary (IM) tibia guide vs. Computer Navigation Surgery (BL). The latter uses a CT-free, surface registration technique. The same endoprosthesis is implanted along the mechanical axis determined by the navigation system. The conventional approaches routinely use intramedullary femur guides. All procedures were performed by 2 senior surgeons. The implant positioning was assessed using standardized post-operative long leg coronal and lateral radiographs by another blinded assessor.Mean Tibia Placement to tibia axis: EM +0.21° (+3.0° to -3.0°), IM +2.71° (+6.5° to -2.0°) and BL +0.13° (+3° to -4.0°). Mean Tibia implant placement to Mechanical axis: EM +0.62° (+5.0° to -3.0°), IM -0.5° (+3.0 to -2.5°) and BL +0.04° (+2.0° to -3.0°). Mean Femoral Component placement to femur axis: EM +1.56° (+6.0° to-2.0°), IM +1.71° (+12.5 to -2.0°) and BL +0.54° (+4.0° to 0). Mean Femoral placement to Mechanical axis: EM -0.71° (+3.0° to -4.0°), IM -0.5° (+3.0° to -2.5°) and BL +0.04° (+2.0° to -3.0°). Mean Tibia slope was EM -5.77° (+3.0° to -12.0°), IM -3.39° (0° to -7°) and BL -3.83° (5° to -8.5°). These are statistically significant.The mean operating time is only increased by 20 minutes.

POSTER NO. P138

◆Polyethylene Wear Against Metal-Ceramic Composite Femoral Components

Juan C Hermida, MD, *La Jolla, CA(a – Smith&Nephew)*
Shantanu Patil, MS, La Jolla, CA (a – Smith&Nephew)
Darryl D D'Lima, MD, La Jolla, CA(a – Smith&Nephew)
Clifford W Colwell, Jr, MD, La Jolla, CA
(a – Smith&Nephew)
Kace A Ezzet, MD, La Jolla, CA(a – Smith&Nephew)

Introduction:Composite bearing materials consisting of a (non-oxidized) metal zirconium core with an oxidized zirconia surface have recently become available. Wear properties of this material in total knee arthroplasty (TKA) are under investigation. Methods: Three oxidized zirconium femoral components (OxZirc) were mounted in a knee wear simulator coupled to standard tibial polyethylene inserts and to modular tibial baseplates. Three femoral components of identical geometry made of conventional cobalt-chrome (CoCr) components were also tested as controls. Knees were taken through 5 million cycles of normal gait and stair-climbing simulation. Wear in polyethylene inserts was quantified by gravimetric measurement. In a second experiment, the same femoral components were tested under conditions of increased varus moments, and increased dynamic tibial rotation. This was to simulate an athletically active patient with non-optimal component alignment. Results:The use of oxidized zirconium reduced polyethylene wear by 44% under optimal alignment. Mean polyethylene wear rate was19.99 (±2.1) mg/million cycles for the CoCr group and 11.6 (±1.3) mg/million cycles for the OxZirc group ($p<0.001$). A similar reduction in polyethylene wear (by approximately 40%) was also found in the inserts worn against OxZirc femoral components when tested under conditions of increased varus moments and increased dynamic tibial rotation. Discussion and Conclusion:Tibial polyethylene wear can be substantially reduced through the use of oxidized zirconium femoral components. There is an increased potential for damage and fatigue failure in highly crosslinked polyethylene. "Metal-ceramic composites" represent promising alternative bearing surfaces for TKA prostheses.

POSTER NO. P139

Dynamic Confirmation of Fixation Techniques of the Tibial Tubercle Osteotomy

Paul E Caldwell, III MD, *Richmond, VA*
(a – Virginia Commonwealth University)
Barry Bohlen, MD, Hastings, NE
(a – Virginia Commonwealth University)
Jennifer S Wayne, PhD, Chesterfield, VA
(a – Virginia Commonwealth University)
William A. Jiranek, MD, Richmond, VA (n)
John R Owen, Richmond, VA
(a – Virginia Commonwealth University)
Barton Harris, MD, Charlottesville, VA (n)
Michael H Brown, BS, Richmond, VA (n)

Introduction: The tibial tubercle osteotomy (TTO) is used for patellofemoral realignment and revision total knee arthroplasty. However, concerns of tubercle displacement have limited rehabilitation protocols. This study tested osteotomy fixation methods under loads of a standard rehabilitation protocol. Materials and Methods: 40 paired fresh cadaveric tibiae were divided into 2 groups, with one tibia in each pair having a TTO fixed with screws, and the other half fixed with cerclage wires. 20 pairs were tested with the patella tendon at 0 degrees of inclination to the osteotomized surface, and 20 pairs at 25 degrees. Loading conditions were calculated based on a straight leg raise in an 80 kilogram patient. Cyclic loading was applied for 500 cycles via an Instron 1321, followed by static loading to failure at 25mm/min. Results: Cyclic loading of the two techniques demonstrated no difference in failure rates based on type of fixation, or angle of pull. Failure rates were higher in tibiae with lower bone density. Load to failure testing revealed that screw fixation is significantly stronger (p greater than 0.05) than wire fixation regardless of the angle of pull. Discussion: Postoperative rehabilitation is vital to outcome after TTO. In situations where intramedullary stems preclude the use of screw fixation, cerclage fixation of the TTO fragment will allow rehab protocols of straight leg raise and knee extension against gravity. Greater loads (resistance exercises) should be avoided, and special care should be taken in the large patient, and in those with decreased bone density.

POSTER NO. P140

Genotype Influences the Effect of Patient-Controlled Analgesics in Patients after Knee Arthroplasty

Chien-Jen Hsu, MD, *Kaohsiung Hsien, Taiwan (n)*
Wen-Ying Chou, MD, MS, Kaohsiung Hsien, Taiwan (*)

Introduction: Many patients use patient-controlled analgesics as post-operative pain control. The used amount of morphine differs greatly. Previous studies showed the different substitution on single nucleotide polymorphisms (SNPs) of the £g opioid receptor (MOR) gene might play an essential role in mediating effects of opioids. One of these candidate coding region SNPs is the A118G substitution which occurs at high allelic frequencies. Material and Method: We excluded the patients with history of heroin addiction. In 99 patients after total knee replacements, we used pyrosequencing technology to detect the SNP of the MOR gene. First, PCR-amplified genomic DNA samples were used to produce target fragments. The target fragments were used as templates for analysis by Pyrosequencing of the mutation spot. Results: We found 58 patients with A118A, 30 patients with A118G, and 11 patients with G118G. The group of G118G had highest demand. They consumed largest amount of morphine in first 24 hours postoperatively and also the total amount.When compared with the other two groups by ANOVA method, the difference was significant. For the other two groups with A118G and A118A, the difference between their demand and consumption of morphine was not statistically significant. Conclusion: Genotype may decide the response to pain. Hence, it causes different demand of analgesics in patients after total knee replacements. Patients with the genotype G118G have poorest response to morphine for postoperative pain control.

POSTER NO. P141

Chondral Lesions in Patients Treated with Microfracture & Medial Opening Wedge HTO

William I Sterett, MD, *Vail, CO (a,e – EBI)*
David W Wing, BA, Vail, CO (a – EBI)
Timothy O'Brien, MD, Bozeman, MT (a – EBI)
J Richard Steadman, MD, Vail, CO
(a – EBI, c – Linvatec)

Purpose: To arthroscopically evaluate percent regenerate cartilage at a minimum of 12 weeks following microfracture combined with medial opening wedge high tibial osteotomy(HTO/MCFX) and correlate results with Lysholm score. Methods: From 1995-2002, the HTO/MCFX was performed on 150 knees with varus

malalignment >5 degrees and medial compartment DJD. Size of defect was estimated on the medial femoral condyle (MFC) and medial tibial plateau (MTP) at HTO/MCFX. Sixty-seven knees had subsequent arthroscopy, at which time percent coverage of the original defects with regenerate cartilage was estimated. The regenerate cartilage was not biopsied. Thirty-four knees (51%) (32 patients, 26 males, 6 females, mean age 51 years, range 32-66) had complete data. Results: Preoperatively, average size of MFC lesion was 533 mm2 (0 – 1600) and average size of MTP lesion was 377 mm2 (0-960). Average time from HTO/MCFX to subsequent arthroscopy was 25 weeks. Regenerate cartilage covered 81.5% (25%-100%) of original MFC lesion and 81.8% (25%-100%) of original MTP lesion. A significant association between number of days from HTO/MCFX to arthroscopy and percent coverage of MFC (but not the MTP) was found, indicating maturation of the regenerate cartilage. Post-operative Lysholm score correlated with percent coverage of the MFC ($p = 0.023$). Conclusion: With more than 80% coverage of chondral defects, chondral resurfacing is possible in degenerative knees. Percent coverage of MFC increased with time and correlated significantly with post-operative Lysholm score. Coverage of the MTP proved less predictable. There are likely many confounding factors affecting functional outcome in this combined procedure.

POSTER NO. P142

The Incidence and Significance of Complex Regional Pain Syndrome After Total Knee Replacement

Victoria Anne Brander, MD, *Chicago, IL (n)*
Angela Adams, BA, Chicago, IL (n)
S David Stulberg, MD, Chicago, IL (n)
R Norman Harden, MD, Chicago, IL (n)
Stephen Bruehl, PhD, Chicago, IL (e – Medtronic)
Steve Stanos, DO, Chicago, IL (n)

Introduction: Sympathetically mediated pain (complex regional pain syndrome (CRPS)), has been proposed as one cause of unusual postoperative TKA pain. The purpose of this investigation was to define the prevalence and impact of CRPS after TKA; and to evaluate the relationship between psychological and pain-related factors and CRPS after TKA surgery. Specifically, preoperative emotional distress and pain intensity were hypothesized to predict occurrence of CRPS following TKA. Methods: Prospective, observational, single surgeon design. 77 consecutive patients with non-inflammatory osteoarthritis who underwent TKA were evaluated preoperatively and at 1, 3 and 6 months postoperatively. Outcome measures included: clinical evaluation, flexion/extension, stability, functional status, HSF-36 short form, Knee Society Score and radiographic measures of alignment and fixation. Measures of depression (Beck Depression Inventory; BDI), anxiety (State Trait Anxiety Inventory; STAI), pain (McGill Pain Questionnaire-Short Form; MPQ; visual analogue scale), and signs and symptoms for CRPS (such as measures of autonomic function) were obtained. Results:The prevalence of CRPS signs and symptoms was 21.0% at one month, 13.0% at 3 months, and 12.7% at 6 months postoperative. However, the presence of CRPS signs and symptoms was not associated with greater postoperative pain. Higher preoperative anxiety predicted positive CRPS status at 1-month follow-up ($p<.05$), with a similar nonsignificant trend for preoperative depression ($p<.10$). Neither emotional distress measure predicted CRPS at later follow-up (p's >.10). In contrast, greater preoperative sensory pain intensity predicted CRPS at 3 and 6-month follow-up (p's <.05). Patients with CRPS were more depressed at 1-month follow-up ($p<.05$) and more anxious at 6-month follow-up ($p<.05$) than non-CRPS pain patients, with all other comparisons nonsignificant ($p>.10$). Discussion: CRPS-like phenomena (using widely accepted diagnostic criteria) occur frequently in the early recovery period after TKA. However, CRPS does not appear to be a cause of greater postoperative pain in the early recovery period.

POSTER NO. P143

The Effect of Total Synovectomy on Functional and Clinical Outcome of Total Knee Arthroplasties

Ormonde M. Mahoney, MD, *Athens, GA*
(c,e – Stryker Howmedica Osteonics)
A Mutlu Vural, MD, Athens, GA (n)
Tracy Kinsey, RN, Athens, GA (n)

Introduction: In total knee arthroplasty (TKA) surgery some surgeons routinely perform total synovectomy, while others do limited synovectomy due to concerns of increased bleeding, stiffness and pain. This study evaluates differences in post-operative functional and clinical outcomes in TKA's with and without routine total synovectomy. Methods: Seventy-nine consecutive patients with osteoarthritis underwent bilateral TKA under the same anesthetic, by the same surgeon, using the same fully cemented posterior stabilized implant. In one knee a limited quadriceps tendon and intercondylar synovectomy was done, while total synovectomy was done in the other. Patients were followed for 2 years post-operatively by radiographic and clinical measures. Patients were 55% female with average age 67.8 years, height 172 cm, weight 88.4 kg, BMI 29.80 kg/m_. Results: At one year post-op the average range of motion for all TKA's was 0.2 to 125.6 degrees, and knee society scores were 98 clinical / 97 functional. There were no measurable clinical differences between the total and limited synovectomy groups. However, more patients blindly reported their totally synovectomized knee felt stiff compared to the other knee during the first 6 months post op ($p<.001$). There was no significant difference in post-operative knee circumference measurements, operative or post-operative blood loss, torniquet time, incidence of transfusion, or post operative synovia related complications. Discussion/Conclusion: Total synovectomy is recommended in cases of pigmented villonodular synovitis, hemophilia, rheumatoid arthritis, or fibrous synovial xanthoma. However, limited synovectomy reduces discomfort to patients, and is adequate to prevent post TKA synovia related problems in the osteoarthritic knee.

POSTER NO. P144

Use of Pelvic Markers in Measuring the Center of the Femoral Head with Computer Navigation

William Michael Mihalko, MD, *Clarence Center, NY*
(a,e – Stryker Howmedica Osteonics)
Matthew J Phillips, MD, Buffalo, NY
(e – Stryker Howmedica Osteonics)
Kenneth A Krackow, MD, Buffalo, NY (n)

Introduction: Computer navigation techniques are now available to aid in mechanical axis alignment during total knee arthroplasty. This study investigated the variability of using a computer navigation system with and without pelvic registration as well as any intersurgeon variability. Methods: Six lower extremities were tested from three cadavers using a commercially available surgical infrared navigation system (Stryker Navigation, Allendale, NJ). Six surgeons of varying levels of experience (intern, resident, fellow, two junior faculty and one senior faculty member) used a computer algorithm to determine the center of the femoral head first using a pelvic and femoral infrared marker

and second a femoral marker only. All values were recorded and differences compared. A CT scan was also utilized to verify the coordinate measurements from the navigation system. Results: On average the centers of rotation with a pelvic marker were 1.9 + 0.7 mm and without a pelvic marker 3.9 + 3.5 mm. This resulted in a variation of the mechanical axis of 0.4 + 0.2 degrees with a pelvic marker and 0.8 + 0.2 degrees without a pelvic marker. Similar differences were recorded for the center of the femoral head across surgeons. Discussion and Conclusion: Minimal differences resulted when comparing intersurgeon variability. Differences between utilizing a pelvic marker revealed less than a 1mm variation on average and less than a degree difference in the calculated mechanical axis. This amount of variability should not appreciably change the overall resulting mechanical axis and may be a viable alternative to utilizing a pelvic marker.

POSTER NO. P145

Optimal Fixation of Press-Fit Stems in Revision TKA Using a Tibial Offset

Arthur L Malkani, MD, *Louisville, KY (n)*
C Lowry Barnes, MD, Little Rock, AR
(a,e - Stryker Howmedica Osteonics)
Dale Baker, BA, Louisville, KY (*)

Introduction: Tibial tray placement during revision total knee arthroplasty is often dictated by the location of the press-fit stem. Appropriate placement of the tibial tray can require under sizing the stem which can compromise fixation or utilizing cement. The purpose of this paper is to report our results of revision total knee arthroplasty with independent placement of the tibial tray and optimum press-fit stem size using a tibial offset. Methods: Sixty-three consecutive patients who underwent revision total knee arthroplasty with press-fit stems and cemented tibial trays were prospectively reviewed. Forty-nine (78 percent) required use of a tibial offset. Average age was 66 years (range 43 to 87 years). Average follow up was 33 months (range 24 to 39 months). Average stem diameter was 13 mm (range 10 to 19 mm). The average tibial stem offset was 5.38 mm (range 4 to 8 mm). Results: At the latest follow up, there were 49 patients available for review. The average preoperative Knee Society Pain Score was 50.7 which improved to 82.5 at postop (p less than 0.05). There were no cases of aspetic loosening. Two patients developed patella subluxation. There were no complications with the use of tibial offsets. Discussion and Conclusion: The use of tibial offsets should optimize independent fixation of both the tibial tray and the press-fit stem. The wide range of tibial offsets utilized in this series demonstrates the variation of the proximal tibial anatomy, which demonstrates the need for a wide range of tibial offsets in revision TKA.

POSTER NO. P146

Does Thickness of Tibial Polyethylene Matters in Total Knee Arthroplasty?

Gurdev S Gill, MD, *Lubbock, TX (e – Biomet)*
Atul B Joshi, MD, Lubbock, TX (n)

Introduction: Thickness of polyethylene of the tibial component has been reported to be one of the significant variable affecting the outcome of the knee arthroplasty. However, clinical literature is scarce regarding the minimum required thickness of the polyethylene.Aim: To analyze effect of thickness of tibial polyethylene on the outcome of total knee arthroplasty. Material and Methods: 859 knees were performed by one surgeon between 1982 and 1990 with metal backing of tibial component. Two groups were analyzed, Group 1: knees (399) with polyethylene thickness of 4.5 mm or less, and Group 2: knees (460) of more than 4.5 mm of polyethylene thickness. All living patients had a minimum of 10 years (10-19) of follow up. No patient was lost to follow-up. Results: The mean follow-up of all patients was 8.9 years.The follow up for living patients was of minimum of 10 years (10-24). The average age at surgery was 69.7 (SD + 9.0, range 20-92 years).Total of 19 knees were revised for aseptic loosening, 9 were from the Group 1 and 10 knees were from Group 2. (p=0.933) Survivorship showed survival of 88.6 per cent (74.4 to 94.5) for Group 1 and 95.3 per cent (90 to 97.6) for Group 2. (Log rank =0.97)Conclusions: Our study shows that polyethylene thickness had no influence in the outcome of TKA on a long term basis. This challenges previous studies, which were mainly based on laboratory analysis and raises doubts on the utilization of thicker polyethylene.

POSTER NO. P147

Femoral Nerve Block Efficacy in Conjunction With Epidural Analgesia for Total Knee Arthroplasty

Mark W Zawadsky, MD, *New Jersey, NJ (n)*
Janet Cahill, MD, New York, NY (n)
Christine Morelli, BS, New York, NY (*)
Richard L Kahn, MD, New York, NY (n)
Friedrich Boettner, MD, Munster, Germany (*)
Jacques YaDeau, MD, New York, NY (n)
Nigel E Sharrock, MD, New York, NY (n)
Thomas P Sculco, MD, New York, NY (*)

Introduction: Epidural analgesia following total knee arthroplasty improves pain relief, lowers narcotic consumption, and enhances rehabilitation. This study evaluated whether addition of a femoral nerve block would further improve outcome. Methods:80 patients of a single surgeon undergoing routine primary TKA for osteoarthritis were enrolled in an IRB approved, prospective, randomized, controlled, and blinded study. The patients consented to enrollment prior to surgery and were randomized into a femoral nerve block group and a no block group. Both groups received combined spinal epidural analgesia. The block group of 41 patients received a femoral nerve block consisting of 30ml 0.37% bupivacaine prior to surgery and epidural placement. Clinicians who were blinded to group assignment conducted post-operative pain management, rehabilitation, and data analysis. Results:Statistically significant differences were identified between groups. The femoral nerve block group had lower total volume of epidural analgesia (p value .01), lower VAS pain scores through post-operative day 3 (p value .01), and increased flexion ROM for the first three post-operative days (p value .04). No significant difference was found between the groups for side effects, ambulation distance, rehabilitation milestones, or length of stay. Conclusion:The administration of a long acting femoral nerve block in conjunction with combined spinal epidural analgesia significantly reduces post-operative epidural dosage and significantly lowers VAS pain scores extending well beyond the duration of the block. A femoral nerve block advanced flexion range of motion during the early post operative period with a non-statistically significant trend towards advancement of other rehabilitation milestones.

POSTER NO. P148

Biomechanical and Functional Comparison of Artificially Fused Knees at 0 and 20 Degrees

Janet Donohue Conway, MD, *Baltimore, MD (b – DePuy Casting)*
Anil Bhave, PT, Baltimore, MD (b – DePuy Casting)
Roland Starr, MS, Baltimore, MD (n)
Rudrani Bavage, Baltimore, MD (*)
Scott Tennis, PT, Baltimore, MD (b – DePuy Casting)

Introduction: There has been no consensus regarding the optimum position of knee fusion for treating difficult knee problems. We evaluated the optimum position of knee fusion by comparing 0 and 20 degrees of flexion in a healthy population using gait analysis, oxygen consumption, and functional scoring. Methods: Ten healthy volunteers (average age 30) underwent gait analysis and oxygen consumption measurements for three conditions (normal walking, knee fixed at 0 degrees or at 20 degrees). Knee position was held with a cylinder cast. Patients self-selected a comfortable walking speed in all three conditions. A Knee Fusion Score was used to evaluate function (worst 0, best 140). Results: All patients compensated for fusion with increased hip abduction, pelvic tilt and obliquity on the casted leg. Ankle dorsiflexion was significantly increased at both 0 and 20 degrees in the swing phase. The 20 degree position had significantly more dorsiflexion than the 0 degrees position, 6/10 patients selected the same walking speeds for 0 and 20 degrees and 4 /10 patients selected a slower walking speed at 0 degrees. Oxygen cost was significantly increased for both fusion positions (p equals 0.0037) but there was no significant difference in oxygen cost between the two fused positions (p equals 0.37). All volunteers preferred the 20degree position. There was significant difference in the average Knee Fusion Score for the 0 and 20 degree positions. Discussion: Knee fusion at 20 degrees of flexion provided better function and faster walking speed than 0 degrees of flexion in 40 percent of the study population.

POSTER NO. P149

Soft Tissue Balancing with the t Pie Crustv Technique in Valgus Knees in TKR- An In Vivo Study

Henry D Clarke, MD, *New York, NY (a,e – Zimmer)*
Giles R Scuderi, MD, New York, NY (a, c, e – Zimmer)

Introduction: Creation of balanced flexion and extension spaces is a key principle in TKR. The technique of "Pie Crusting" the contracted lateral side in Valgus knees involves transversely cutting the Arcuate complex, followed by multiple stab incisions through the ITB, lateral capsule and LCL, with preservation of the Popliteus Tendon, until soft tissue balance is achieved. Although prior cadaver studies have been performed, little is known about the in vivo results using this technique. This study was undertaken to examine whether, in vivo, symmetric flexion and extension gaps with balanced medial and lateral soft tissues can be created. Methods: Twenty-one valgus knees (mean 13 degrees valgus) in 19 adult patients (mean age 68 years), in whom the "Pie Crust" technique was used were studied. After the "Pie Crust" releases were performed and the spaces were considered clinically balanced, a tensiometer, which provides a standard distraction force of 40 inch-lbs, was used to measure to the femoro-tibial spaces medially and laterally. These spaces were measured first in flexion and then in extension. Results: Medial and lateral gaps within 1mm were created in 20 knees in extension (95%) and 21 knees in flexion (100%). Mean flexion and extension gaps within 3mm were achieved in 20 knees (95%). There was no consistent tendency to over or under-release. Discussion and Conclusions: Use of the "Pie Crust" technique allows creation of balanced flexion and extension gaps. Although minor differences exist in subjectively well-balanced knees, the "Pie Crust" technique produces adequate soft tissue balance in-vivo.

POSTER NO. P150

Patella Baja and Arthrofibrosis S/P TKR: A More Simple Surgical Solution?

Richard Sheldon Laskin, MD, *New York, NY (n)*
Manuel Villanueva, MD, New York, NY (n)
Antonio Rios, MD, New York, NY (n)
John P Davis, RN, Cornwall, NY (n)

Introduction: Patella baja and arthrofibrosis after TKR is a challenging dilemma. Surgical options include: patellectomy, proximal transposition of the tibial tuberosity, distalization of femoral component and z-plasty of patella tendon. Methods: 3 patients were treated with a surgical technique that utilized a standard medial approach with a rectus snip, a release of the medial tibial capsule and excision of fibrous tissue around patella. The polyethylene insert was removed to shorten the extensor mechanism and to reduce its tension. A resection of the distal patella pole was performed to increase the tendon length. The patella was subluxed, not everted, allowing for resection of periprosthetic tissue, the PCL and posterior capsule. A proximal patella button was placed. A new poly insert of similar or lower height was inserted. Contact between anterior lip of polyethylene and the remnant distal pole of patella during maximum flexion was avoided. Results: Measurements included KSS, ROM, Insall – Salvati, Blackbourne and Caton index and radiographic evaluation. Post-op flexion averaged 95°. The average flexion increase was 45°. The KSS improved by an average of 70 points. The Insall-Salvati, Blackburne and Caton index were normal or within more physiologic ranges after surgery. Discussion and Conclusion: Other described surgical options pose complications related to: avulsion of the tibial tubercle, increased blood loss, prolonged surgical time, devascularization, fractures and bone loss. This less extensive technique shows early comparable results and poses less associated surgical risks.

POSTER NO. P151

The Effect Of Flexion-Extension Gap Symmetry On Functional Outcome in Total Knee Arthroplasty

John R Schurman II, MD, *Wichita, KS (a – Stryker Howmedica Osteonics)*
J Christopher Banwart, MD, Joplin, MO (n)
David A McQueen, MD, Wichita, KS (a – Stryker Howmedica Osteonics)
Michael J Long, PhD, Wichita, KS (n)
Wagdy S Rizk, MD, Nicholasville, KY (n)

Introduction:Ligament balance in total knee arthroplasty is a vital component of success. Our hypothesis is that ligament balance with equal flexion-extension gaps leads to higher functional scores. Materials and Methods:One hundred and twenty total knee replacements were performed by three of the authors.The flexion and extension gap tension and ligament symmetry were recorded during surgery with a specially designed apparatus (Howmedica). Patients were evaluated with several measures including the WOMAC, Nottingham Health Profile, and SF36 questionnaire at twelve to twenty four months after surgery. Each patient was examined for functional knee balance, range of motion and stability. The knee score was recorded. Results: Statistical analysis demonstrated that the smaller the

difference between the flexion and extension gap angles at the time of surgery, the greater the SF 36 functional score ($p < 0.05$) and the greater the WOMAC score ($p < 0.01$). Also, There was a significant decrease in the Nottingham score with a smaller difference in gap angle. Discussion:Symmetrical and equal flexion-extension gaps are essential for a stable knee replacement. Attention to intraoperative ligament balance, tension and flexion-extension gap symmetry will yield more satisfactory results with improved functional outcome.

POSTER NO. P152

The Influence of the ACL on Articular Contact of a Fixed Bearing UKA: An In-Vitro Investigation

Jeremy F Suggs, BS, *Boston, MA (a – Zimmer)*
Guoan Li, PhD, Boston, MA (*)
Sang Eun Park, MD, Cambridge, MA (n)
Peter G Sultan, MD, Old Westburry, NY (*)
Scott Steffensmeier, Iowa City, IA (*)
Andrew A Freiberg, MD, Boston, MA (a – Zimmer)
Harry E Rubash, MD, Boston, MA (a – Zimmer)

Introduction. While UKA has been increasingly popular in treatment of unicompartmental knee disease, polyethylene wear and damage and component loosening have been reported. This study investigated the articular contact mechanism of a medial UKA with and without a functional ACL. Methods:Seven human cadaveric knee specimens were tested using a robotic testing system from 0 to 120 degrees of flexion. The UKA was tested with and without the ACL. The position of the contact point of the femoral component on the polyethylene surface was measured under a combined quadriceps/hamstring load (400/200N) using a TekScan pressure sensor. Results:When the ACL was intact, tibiofemoral contact under the muscle load occured at the anterior portion of the polyethylene component. The contact moved posteriorly as flexion increased from 0 to 30 degrees and then moved anteriorly beyond 30 degrees of flexion. ACL deficiency caused a posterior shift of the contact position at low flexion angles but did not affect the contact beyond 30 degrees of flexion. Discussion and Conclusion:The tibiofemoral contact location of the UKA remained in a small area anterior to centerline of the polyethylene component when the ACL was intact. ACL deficiency resulted in an increase in the motion of the tibiofemoral contact in posterior direction at low flexion angles. This increased contact motion indicates an increase in knee laxity. A functional ACL after UKA may be important in retaining knee stability and, hence, reducing excessive polyethylene damage.

POSTER NO. P153

The Effect of Alendronate on Bone Mineral Density After Total Knee Arthroplasty

Ching-Jen Wang, MD, *Kaohsiung Hsien, Taiwan (n)*
Lin-Hsiu Weng, MD, Kaoshiung Hsien, Taiwan (n)
Chia-Chen Hsu, MD, Kaoshiung Hsien, Taiwan (n)
Han-Shiang Chen, MD, Kaohsiung Hsien, Taiwan (*)

Introduction: Bone mineral density (BMD) is related to the mechanical property of the bone and component fixation and prosthetic survival including periprosthetic fracture after total knee arthroplasty (TKA). BMD was reported to decrease after TKA. Alendronate has been shown effective in the treatment of osteoporosis and reduction of osteoporotic fractures. The purpose of this study were to evaluate the changes of bone mineral density and to investigate the effect of alendronate on BMD after total knee arthroplasty. Methods: 96 women with an average age of 70 ?Oacute; 8 years undergoing TKA were randomly divided into two groups with 48 patients in each group. Patients in the study group received oral alendronate 10 mg/day for 6 months, whereas patients in the control group received no medication. The BMD was performed preoperatively, and at 6 and 12 months postoperatively. Results: In the control group, the BMD decreased 13.8% and 7.8% in the distal femur, and 6.5% and 3.6% in the proximal tibia at 6 and 12 months respectively, and the decrease was statistically significant. The rate of decrease was faster in the first 6 months. In the study group, however, the BMD increased 10.0% and 1.9% in the distal femur, and 9.4% and 5.4% in the proximal tibia at 6 and 12 months respectively, and the increase was statistically significant. The overall difference in BMD between the study and control groups was statistically significant. Discussion and Conclusion: BMD in the distal femur and proximal tibia showed a significant decrease after TKA. Administration of 6 months of oral alendronate therapy to women who had undergone TKA significantly improved the BMD versus a control group. While the clinical benefits of alendronate after TKA remain unproven, the improvement in BMD may be clinically important concerning prosthetic fixation and peri-prosthetic fractures after TKA.

POSTER NO. P154

Femoral Component Sizing In TKA: Size Matched Resection Versus Flexion Space Tensioning

Stephen J Incavo, MD, *Burlington, VT*
(e – Stryker Howmedica Osteonics)
Kathryn M Coughlin, MD, Burlington, VT (*)
Bruce Beynnon, PhD, Burlington, VT (n)

INTRODUCTION. There are two methods to select the femoral component size to achieve AP balance during total knee arthroplasty (TKA). The Size-Matched Resection (SMR) technique uses AP referencing jigs to cut the thickness of femoral bone replaced by the component. Flexion Space Tensioning (FST) involves tensioning collateral ligaments by anterior distraction of the femur at 90 degrees. The posterior femoral resection corresponding to the size of the extension space is cut. Our goal was to compare the SMR and FST methods of selecting the femoral component size. METHODS. Fifty TKAs (45 patients) were studied. The surgical technique included anterior referencing instrumentation and epicondylar axis alignment. Components differed in AP size by 4mm increments. Measurements 2mm or less resulted in the same size femoral component. A difference of more than 3mm was considered a different size femoral component. RESULTS. The FST method led to a smaller size than the SMR method in 28 (56 percent) knees. The FST method never resulted in a larger size than the SMR technique. Varus knees were more sensitive to the differences in measurement methods than valgus knees. DISCUSSION AND CONCLUSION. The two techniques resulted in a selection of different femoral component sizes in many cases. This is primarily because the AP sizing guide, when orientated along the FE axis, may not touch the posterior lateral femoral condyle. This is an important consideration. A small flexion space could result in poor range of motion and posterior wear. A large flexion space may result in posterior instability.

POSTER NO. P155

Eight and One Half Year Clinical Experience with the Optetrak Total Knee Prosthesis

John Z Edwards, MD, *Akron, OH (n)*
Ivan A Gradisar, Jr, MD, Akron, OH (a,b,c,d – Exactech)
Matthew C Nadaud, MD, Knoxville, TN (*)
Mark W Kovacik, Akron, OH (a – Exactech)
Michael Askew, Akron, OH (a – Exactech)

INTRODUCTION: We began using the Optetrak Total Knee (Exactech, Inc., Gainesville, FL) in June of 1994, and have now performed 1526 primary arthroplasties with this prosthesis. This report presents our clinical experience with these cases and the results of 2 and 5-year follow-up evaluations. METHODS: The 1526 arthroplasties were performed as 878 unilateral procedures and 324 sequential, same-day, bilateral procedures. The mean age of the patients was 70 years (33 years to 90 years), 59% of whom were female. The cruciate retaining design was used in 525 of the cases and 1001 involved the posterior stabilized design. Follow-up evaluations of 365 of the knees at 2-years, and of 100 again at 5-years, have been conducted by an independent examiner. RESULTS: At the time of surgery, 19 of the knees required lateral retinacular releases (1.2%), and 13 required release of a lateral ligamentous structure (0.9%). No medial releases were needed. The mean Hospital for Special Surgery Score, the Knee Society Knee and Function Scores, 59, 47, and 49 pre-operatively, were 88, 81, and 84 at 2 years and improved to 91, 88 and 90 at 5 years. The range of motion at 2 years, 114 degrees, also improved to 117 degrees at 5 years. Knees rated good and excellent by the Hospital for Special Surgery Score: 96% at 2 years, 99% at 5 years. Patients self-reporting good and excellent results rose from 94% at 2 years to 100% at 5 years. Twenty-two of the knees have undergone re-operation (1.4%), none for implant-related problems. DISCUSSION AND CONCLUSION: The experience to date (8_ years) indicates that the Optetrak Knee is performing well. The number of required soft tissue releases at primary surgery is low, and physical, functional and patient satisfaction outcomes are high and are improving with post-operative time

POSTER NO. P156

Does the Mid-Vastus Approach Compromise the Vastus Medialis Obliquus?

David F Dalury, MD, *Baltimore, MD (n)*

Introduction: The mid-vastus approach has been demonstrated to be an effective approach that may have some early benefits to the patient (earlier, easier rehabilitation and less pain). This approach splits the vastus medialis muscle at the supero-medial border of the patella as the means of entering the joint. There have been some questions as to whether this muscle splitting approach is deleterious to the muscle. Methods: Nine patients undergoing total knee replacement surgery via the mid-vastus approach were the study group. Intra-operative EMG's were performed. Baseline motor unit activity was recorded and stimulated EMG was also recorded. Measurements were obtained prior to incision, after incision, during retraction and after closure with sutures. Results: Each patient had a slightly different baseline EMG and response to stimulated EMG. There was no noticeable difference in EMG in any knee when an incision was made through the vastus medialis muscle. In 2 of the 9 knees there was noticeable increased EMG activity during maximal retraction. This activity returned to baseline once the retractors were removed and remained there at the end of the procedure. Otherwise there were no noticeable differences between recordings on either side of the muscle during or after the surgery. Conclusion: This study suggests that an EMG cannot demonstrate any muscle damage caused by surgical manipulation of the vastus medialis obliquus muscle during the mid-vastus approach to the knee.

POSTER NO. P157

Post Impingement in Posterior Stabilized Total Knee Arthroplasty

Olivier Verborgt, MD, *Berchem, Belgium (n)*
Jan M K Victor, MD, Brugge, Belgium (n)

INTRODUCTION: Posterior stabilized implants are a well-proven treatment for patients requiring primary total knee arthroplasty. Concerns about the posterior stabilized design have been raised and recent studies suggest that the post-cam articulation can be an additional source of polyethylene wear debris. In this study, we report impingement of the tibial post against the patellar component in deep flexion in posterior stabilized total knee arthroplasty. MATERIALS: Peroperatively, impingement of the tibial post against the patellar component in deep flexion was determined in 23 consecutive patients who received a posterior stabilized total knee prosthesis. In addition, we determined by radiographic evaluation whether 1) joint line position, 2) patellar height, 3) anterior-posterior offset of the tibial component and 4) femoral component size are associated with post impingement. RESULTS: Nineteen out of 23 cases showed frank post impingement in deep flexion. There was a a significant correlation between the angle of impingement and 1) the change in joint line position, 2) the Insall-Salvati ratio, 3) the anterior-posterior offset of the tibial component and 4) the femoral component size. DISCUSSION AND CONCLUSION: Impingement of the tibial post against the patella in deep flexion in posterior stabilized total knee arthroplasty is associated with 1) a raised joint line, 2) patella baja, 3) too anterior placement of the tibial component and 4) a smaller femoral component size. Post impingement may lead to extensor mechanism problems and additional polyethylene wear and therefore may affect the long-term functional results of posterior stabilized total knee arthroplasty.

POSTER NO. P158

Does Pre-operative Alignment Affect Outcomes & Survivorship After TKA Using a Mobile Bearing Device?

R Barry Sorrells, MD, *Little Rock, AR (a,b – DePuy, Inc)*
Jeffrey A Murphy, MS, Warsaw, IN
(e – DePuy Orthopaedics)

INTRODUCTION: Do patients with severe pre-operative malalignment have inferior long-term outcomes after receiving a mobile bearing knee device?MATERIALS & METHODS: 917 consecutive cementless TKA's using a single mobile bearing knee system were performed on 705 patients by the senior author between 2/84 and 2/98. All cases underwent life table survivorship analysis with event = revision for any reason. 466 of the 917 cases obtained >5-year post-operative clinical evaluations (avg. = 8.2 years, range 5 - 17 years). Three categories were defined based on pre-operative mechanical axis alignment: 'Normal' = 0 - 5 degrees (338), 'Abnormal' = 6 - 10 degrees variation (58), and 'Very Abnormal' = greater than 10 degrees variation (70). A standardized 100-point knee scoring system was used with pain, function, and flexion being the primary assessment tools. RESULTS: Ten year survivorship analysis results were as follows: 'Normal' = 94.8%, 'Abnormal' = 95.6%, and 'Very Abnormal' =

89.7%. The Wilcoxon test for equality of survival functions was statistically significant (p-value = 5%). Both function (p-value = 4%) and flexion (p-value = 2%) measurements were statistically inferior for the 'Very Abnormal' group compared to the other two groups. However, the same trend was seen pre-operatively indicating improvement from surgery was about the same in both function (8 point score) and flexion (8 degrees) outcomes. CONCLUSION: Survivorship of severely mal-aligned patients is inferior compared to better aligned patients. Nonetheless, regardless of pre-operative alignment, patients can expect similar clinical improvements using this mobile bearing knee prosthesis.

POSTER NO. P159

The Anterior Femoral Resection in Total Knee Arthroplasty and Its Effects on Passive Flexion

William Michael Mihalko, MD, *Clarence Center, NY (a,e – Stryker Howmedica Osteonics)*
Zair Fishkin, MD, Buffalo, NY (n)
Kenneth A Krackow, MD, Buffalo, NY (n)

Introduction: The anterior femoral resection during TKA is chosen to prevent notching. The trochlear height may be increased depending on the femoral component geometry. This study investigated the effects of increasing the trochlear height after femoral component placement on passive knee flexion. Methods: Anterior femoral resections from 50 consecutive TKA cases were measured. The medial and lateral trochlear heights and groove thickness were recorded. The same dimensions of five different femoral components were recorded for comparison. Eight cadaveric specimens had the medial and lateral trochlear heights increased by 2 and 4 mm and the cadaveric leg was held with the femur in the vertical position. The change in knee flexion was recorded using a computer navigation system (Stryker Navigation, Inc.). Results: For the cadaveric model, 2 mm showed no decrease in flexion (1.8 + 0.4 degrees) and 4 mm significantly decreased flexion (5.1 + 2.8 degrees, p less than 0.05). The different implants revealed trochlear height ranges from 5 to 7.9 mm medially, 5.5 to 11.1 mm laterally and 1.7 to 5.0 mm groove thickness depending upon manufacturer and size. In the operating room an increase of 2.9 + 0.7 mm of the lateral and 2.5 + 0.6 mm of the medial heights resulted. Discussion and Conclusion: The results suggest that 4 mm of anterior buildup may have a significant effect on passive flexion. Many clinical variables have been reported to have an affect on postoperative flexion but this study is the first to report the possible relationship between the geometry of the anterior femoral component and a decrease in passive flexion.

POSTER NO. P160

◆Joint Gap Measurement in Total Knee Arthroplasty Using a New Tensor with the Navigation System

Hirotsugu Muratsu, MD, *Kakogawa, Japan (n)*
Tomoyuki Matsumoto, MD, Kobe, Japan (n)
Nobuhiro Tsumura, MD, Mayfield Heights, OH (n)
Koichi Tanaka, MD, Kobe, Japan (*)
Katsuhiko Ishimoto, Kobe, Japan (*)
Kazuo Tujimoto, MD, Kobe, Japan (n)
Ryoichi Shiba, MD, Kobe, Japan (n)
Shinichi Yoshiya, MD, Kobe, Japan (n)
Masahiro Kurosaka, MD, Kobe, Japan (n)

IntroductionWe developed a new tensor for total knee arthroplasty (TKA) enabling the gap measurement throughout the range of motion with the patello-femoral (PF) joint reduced. The design features of this tensor and preliminary data were presented at the last AAOS Meeting. In this study, the tensor was used with the navigation system to perform a more detailed intraoperative analysis. Materials and MethodsThirty osteoarthritic knees implanted with the posterior stabilized TKAs were subjected to the intraoperative gap measurements. Image free navigation system (Vector Vision, BrainLAB) was used for accurate assessment of knee flexion angle. ResultsAverage center joint gaps were 11.3, 13.2, 14.2, 15.0, 16.4, 17.7, 18.7, 20.6, and 21.3 mm with the patella everted, and 11.7, 13.7, 14.6, 15.7, 16.9, 17.9, 18.8, 17.4, and 11.2 mm with the patella reduced at 0, 5, 10, 15, 30, 45, 60, 90 and 135 degree of flexion respectively. Joint gap with the PF joint reduced was significantly less than that with patellar eversion at 90 and 135 degree. In the measurement with patellar reduction, a distinct increase in joint gap was found from full extension to the early phase of flexion, and the measured value was largest at 60 degree of flexion. DiscussionWe found the application of new tensor device with TKA navigation system would be useful for the accurate evaluation of joint gap kinematics. Analysis of the relationship between the results of intra-operative gap measurement and post-operative outcome will help to optimize the surgical procedure.

POSTER NO. P161

Patellar Resurfacing During Total Knee Arthroplasty: A Meta-Analysis

Venkat Rapuri, MD, *Philadelphia, PA (n)*
Javad Parvizi, MD, Philadelphia, PA (n)
Michael A Mont, MD, Baltimore, MD (n)
Khaled J Saleh, MD, Minneapolis, MN (*)
Gracia Etienne, MD, Baltimore, MD (n)

Patellar resurfacing using a modern condylar design of knee prosthesis is likely to reduce the incidence of anterior knee pain without increasing complications related to patellofemoral joint.Introduction:The need for patellar resurfacing during total knee arthroplasty remains a controversial issue. A vast number of conflicting reports have been published in the literature. The objective of this meta-analysis was to evaluate the role of patellar resurfacing. Methods: A computerized literature search was conducted to identify all citations, between 1966 to 2003, concerning patellar resurfacing or retention during total knee arthroplasty. All the English-language abstracts were obtained. A multistage assessment was then used to identify articles fulfilling the inclusion criteria for the study. All randomized, prospective studies reporting the result of total knee arthroplasty using modern condylar design prosthesis with and without patellar resurfacing were included. Details of any reported data were extracted and extensive analysis of relevant vari-

ables carried out. Results: 158 published articles pertaining to patellar resurfacing were identified of which 22 studies were potentially eligible. 14 articles met all inclusion and exclusion criteria. This comprised 1,496 knees of which the patella was resurfaced in 48.6%. 8 of the 14 studies comprising of 1,096 knees favored patellar resurfacing. The remaining studies (400 knees) did not detect a significant benefit for resurfacing of the patella. Knees with patellar resurfacing had lower incidence of anterior knee pain ($p<0.001$) and higher cumulative functional scores ($p<0.005$). The incidence of reoperation and revision for patellofemoral problems was the same in both groups. Discussions and Conclusion: Patellar resurfacing using a modern condylar design of knee prosthesis is likely to reduce the incidence of anterior knee pain without increasing complications related to patellofemoral joint.

POSTER NO. P162

Systemic Safety of High Dose Antibiotic Spacers Following Resection of an Infected Total Knee

Bryan Donald Springer, MD, *Rochester, MN (n)*
Gwo-Chin Lee, MD, New York, NY (n)
David J Jacofsky, MD, Rochester, MN (n)
George John Haidukewych, MD, Rochester, MN (n)
Douglas R Osmon, MD, Rochester, MN (*)
Arlen D Hanssen, MD, Rochester, MN
(a – Hawkins Chemical Corp)

Introduction: To assess the systemic safety and adverse effects of using a high-dose antibiotic cement spacer following resection arthroplasty of an infected total knee replacement. Methods: From October 2000 to December 2002, 36 knees (34 patients) underwent resection arthroplasty of infected total knee prosthesis with placement of a high-dose antibiotic cement spacer by a single surgeon. There were 24 males and 10 females with an average age of 66.5 years. All spacers placed contained an average of 3.4 batches of cement containing an average total dose of 10.5 g of Vancomycin (range 3-16g) and 12.5 g of Gentamycin (range 3.6-19.2g). All patients were followed postoperatively until the time of re-implantation for evidence of renal failure. The preoperative creatinine ranged from 0.7-1.8 mg/dL. All patients were concomitantly treated with 6 weeks of intravenous antibiotics. Results: One patient with normal preoperative renal function had a perioperative one-day transient rise in serum creatinine postoperatively that subsequently normalized. No patients showed any clinical evidence of acute renal insuffiencey /failure or other systemic side effects of the antibiotics. Discussion and Conclusion: In this series, treatment with high-dose vancomycin and gentamycin antibiotic spacers appears to be clinically safe in treating patients with an infected total knee arthroplasty.

POSTER NO. P163

A Biomechanical Evaluation of Fixation Devices for the Medial Opening Wedge High Tibial Osteotomy

Bruce Miller, MD, *Ann Arbor, MI (a – EBI)*
Cari R Bryant, MS, Ann Arbor, MI (*)

As joint preservation techniques for complex knee problems gain popularity, there is an increasing interest in the role of the medial opening wedge high tibial osteotomy. Although the medial opening procedure offers several advantages over the lateral closing osteotomy, the medial osteotomy has been associated with nonunion and fixation failure. To date, no study has addressed the biomechanical properties of commercially available devices for the medial osteotomy. The purpose of this study was to evaluate the biomechanical performance of three commercially available fixation devices for the medial opening high tibial osteotomy.Sixty medial opening wedge high tibial ostetomies were performed on validated synthetic tibia models and tested under physiologic loads in compression and torsion on a servo-hydraulic machine (Device A n=20, Device B n=20, Device C n=20). Each specimen was cycled under physiologic loads for 1000 cycles, and both global and local load deformation were measured.Fixation Device A demonstrated greater stiffness in both compression and torsion than Device B or Device C. Mean axial stiffness for Device A was 2425 N/mm, for B 2358, and for C 2258. Mean torsional stiffness for Device A was 4.48 Nm/degree, for B 4.09, and for C 4.02.Our study supports that one of the three commercially available fixation devices for the medial opening wedge high tibial osteotomy demonstrates greater stiffness under both compressive and torsional loads. The application of a more rigid device should help reduce the incidence of non-union and hardware failure, the two most common fixation-related complications of this challenging operative procdure.

POSTER NO. P164

Computer and Arthroscopic-Assisted Mini Lateral Approach in Total Knee Arthroplasty

James F Wenz Sr, MD, *Baltimore, MD (*)*
Ilksen N Gurkan, Towson, MD (n)
Kenan Bayrakci, MD, Ankara, Turkey (*)

Introduction: A navigated mini-lateral approach (MLA) without ligament release in total knee arthroplasty (TKA) may avoid many of the potential disadvantages of medial parapatellar approach (MPA). However, such an approach warrants cadaver studies before considering it for further clinical investigations. Materials & Methods: We present a novel surgical approach for navigated TKA, which was successfully performed on 10 cadaver knees. The approach includes arthroscopically assisted removal of menisci and anterior cruciate ligament and placement of the lateral skin incision lateral to the patella. The initial step in the performance of TKA with the use of image-free navigation system was the determination of the centers of the hip, knee, and ankle joints. Navigation was also used to guide the positioning of the cutting blocks during the TKA. On average, a 7-cm skin incision was used for the approach. Results: It took approximately five pilot procedures for the surgeon to acquire a comfortable and reproducible use of MLA combined with the image-free registration technique. Once the registration process was completed, it was possible to orient the specially designed femoral and tibial cutting blocks attached to the lateral aspect of the knee joint and to position them to guide the levels of resection. Discussion and Conclusion: MLA was designed to preserve the vascularity on the medial side and decrease the extensive soft-tissue trauma after TKA with MPA. The combination of the mini-incision surgical techniques with the application of computer assistance, especially in TKA, requires an improvement in current prosthetic designs and devices.

POSTER NO. P165

Patellar Tendon Bone Grafting in Revision Total Knee Arthroplasty

Hari Bezwada, MD, *Philadelphia, PA (n)*
David George Nazarian, MD, Philadelphia, PA (*)
Robert Emrey Booth Jr, MD, Philadelphia, PA (*)

Introduction: Results of total knee arthroplasty done after patellectomy have been reported to be inferior to those done in patients without previous patellectomy. This has been attributed to quadriceps weakness and anterior-posterior instability. Our purpose was to evaluate the use of allograft in patellar tendon bone grafting in previously patellectomized patients undergoing revision total knee arthroplasty. Materials & Methods: From

1993-1998, six patellar tendon bone grafting procedures were performed during revision total knee arthroplasty. A 2.5 x 1cm slice of fresh fozen distal femoral allograft from the condyle was obtained. This bone graft was sutured in place into a subsynovial pouch. Pre-operative and post-operative clinical and roentgenographic evaluations were performed. Results: Follow-up ranged from 3-8 years (average 5). Knee society knee scores improved from 41 to 88. Roentgenographic evaluation showed no significant graft resorption. Patients reported a greater sense of stability. Additionally they experienced less anterior knee pain and had better stair climbing than pre-operatively. There was one complication of a 30 degree extensor lag that required a vastus medialis obliqus advancement. Conclusion: This technique of patellar tendon bone grafting appears to be a viable option in revision total knee arthroplasty following patellectomy.

POSTER NO. P166

The Tibiofemoral Axis. A Comparison of Long Leg and Short Knee Films

Philip Hopgood, MD, *Cheshire, United Kingdom (n)*
Steven R Mitchell, MD, Crumpsall Manchester, United Kingdom (*)
David H Sochart, MD, Manchester, United Kingdom (*)
Paul Rae, FRCS, Manchester, United Kingdom (*)

Aim The aim of this research was to assess the difference in the observed tibiofemoral axis between long leg and short AP films of the knee.Method20 patients who were undergoing primary total knee replacement, and had had no previous surgery on the affected limb were x-rayed using the a long leg cassette to include both the hip and ankle joints.A special screen was constructed to obscure all the x-ray except for a field, the size of a standard AP x-ray of the knee. The tibiofemoral angle was measured by two independent observers first on the short film and then on the long leg film. ResultsOur results have shown that the short leg film consistently overestimates the true tibiofemoral angle. Intraobserver correlation is also better when comparing the long leg film rather than the short film. ConclusionMeasurement of the tibiofemoral or anatomical axis of the knee is best performed using long leg films, as this appears to give more consistent and reproducible results.

POSTER NO. P167

Ten to Twelve Year Survivorship of Posterior Stabilized Modular TKAs with Cemented and Hybrid Femurs

Ormonde M Mahoney, MD, *Athens, GA (n)*
Tracy Kinsey, RN, Athens, GA (n)
Steve R Casto, MS, Athens, GA(*)
Isao Asayama, MD, Fukuoka, Japan (n)

Introduction: This is the first report of a long term experience comparing hybrid and cemented femoral fixation in a prospective series of consecutive primary posterior stabilized total knee arthroplasties (TKA). Methods: In 2 calendar years one surgeon performed 183 consectutive TKA's on 171 patients using the the same posterior stabilized modular implant. Cemented femoral components were used in 49% of cases and press-fit porous coated components in 51%. All tibia were cemented, and all patellae resurfaced. Patients were followed prospectively by clinical and radiographic measures. Implant survivorship was analyzed and between-groups analysis was conducted to evaluate the effect of fixation on survivorship . Cases of failure were carefully studied for causative and related factorsResults: At 10.7 minimum post-operative years, 17 knees have been revised, nine (2 cemented, 7 hybrid) for femoral component loosening with or without tibial loosening, and eight (4 cemented, 4 hybrid) for isolated polyethelene (PE) insert revision due to radiographically evident wear. PE wear and osteolysis were present in all cases of loosening. Method of femoral fixation did not appear to affect survivorship. Revised patients were on average 9.3 years younger at the index procedure than unrevised patients ($p<0.001$). Discussion: In this study PE wear is implicated in every failure. Femoral osteolysis was more pronounced in press-fit cases. Younger patients may be at higher risk for revision. Early revision of the insert is advised when clinical and radiographic signs of PE wear are evident, especially if the femoral component is press-fit.

POSTER NO. P168

Total Knee Arthroplasty with Cemented NexGen Legacy Posterior Stabilized (LPS) Versus the Cementless NexGen Cruciate Retaining (CR) Implants: A Prospective Evaluation

D Gordon Allan, MD, *Springfield, IL (a,d,e – Zimmer)*
William D Payne, MD, Springfield, IL (n)
Rita A Trammell, Springfield, IL (a – Zimmer)

Introduction: A prospective study was done to compare the early clinical, radiographic and quality of life outcomes between the NexGen Legacy Posterior Stabilized cemented (LPS) and the NexGen Cruciate Retaining noncemented (CR) primary total knee implants. Methods: Patients were implanted with either the LPS (128 patients) or the CR (41 patients) prosthesis. Patients were prospectively evaluated with a mean follow-up time of 4.1 years (2-7 years). Hospital for Special Surgery (HSS), Knee Society Scores (KSS), range of motion (ROM), SF12 and knee pain were compared. Patient selection criteria included younger age and higher body mass index for implant of the CR prosthesis. Results: As expected, based on patient selection criteria, patients in the CR group, when compared to the LPS group, were significantly younger (56 versus 67 years) and heavier (223 versus 196 lbs) ($P<0.001$). There was significantly more knee pain in the CR group at last follow-up ($P<0.03$). Mean flexion was 108 degrees for the CR group and 114 degrees for the LPS group at last follow-up ($P<0.01$). HSS and KSS scores were significantly better in the LPS group than in the CR group ($P<0.05$). Discussion/ Conclusion: The CR prosthesis facilitates preservation of bone stock, therefore, this implant may be clinically useful for younger and heavier patients, however, the significant increase in knee pain and decreased flexion, when compared to posterior stabilized prostheses, like the NexGen LPS, should be considered.

POSTER NO. P169

◆Self-Powered Computers within Prosthetic Joints - Is it Time?

Hani Haider, PhD, *Omaha, NE (n)*
Steve R Platt, PhD, Lincoln, NE (n)
Shane M Farritor, PhD, Lincoln, NE (*)
Kevin L Garvin, MD, Omaha, NE (e – Smith&Nephew)

Introduction: Future "Smart Implants" could process measurements, store results and non-invasively communicate them out during follow-up. We hypothesized that sufficient power to drive them may be harnessed from the knee axial force during daily activities. We assessed the "quantity" and "quality" of energy that could be generated by piezoelectrics in a TKR. Method: Computations on different types, shapes and sizes of piezoelectric elements were performed. Given material properties, each was modeled as an elastic body producing a voltage proportional to the mechanical stress, as a voltage source in series with a capaci-

tance. These were validated by testing a lead zirconate-titanate piezoelectric ceramic with the knee axial force during walking on an MTS machine. Further tests helped assess the longevity and consistency/degradation of power generated. Results: The useable regulated power was 0.85mW (15 millionths of a domestic light bulb!). This correlated with the levels calculated theoretically, and could drive a microprocessor capable of many functions (eg. counting walking cycles). The system is currently undergoing longevity tests, equivalent to 20 years walking. At 1.5 million cycles so far, it remains structurally intact, with average power delivered to a resistive load after relaxation following a predicted logarithmic curve, decreasing by 3.5 percent per logarithmic-time-decade. Discussion and Conclusions: Generating regulated electrical power to run a microprocessor is feasible without time degradation posing a significant concern. A fixed bearing TKR was modified to accommodate piezoelectric elements inside the tibial tray to address challenging design details, energy storage, energy transfer efficiency and sensor configurations.

POSTER NO. P170

The Use of Electrical Stimulation to Avoid Total Knee Arthroplasty

Michael A Mont, MD, *Baltimore, MD (n)*
David Y He, MS, Baltimore, MD (n)
Lynne C Jones, PhD, Baltimore, MD (n)
Kent C Hoffman, Parkton, MD (d,e – Bionicare Medical Technologies, d – Murray Electronics)
David S Hungerford, MD, Baltimore, MD (n)
Thomas M. Zizic, MD, Baltimore, MD (d,e – Bionicare Medical Technologies)

Introduction: The limited capacity of articular cartilage to heal has stimulated a number of approaches to try to effectuate cartilage repair. Animal and clinical studies have suggested that pulsed electrical stimulation may have salutary effects on articular cartilage healing. The purpose of the present study was to evaluate the safety and effectiveness of pulsed electrical fields delivered to patients who had moderate/severe knee osteoarthritis and were total knee arthroplasty candidates. Methods: One hundred and fifty-seven patients with osteoarthritis of the knee were treated with pulsed electrical stimulation to their knee for three months. These patients were compared to a matching group of 101 patients with osteoarthritis of the knee. Both groups were followed yearly till 4 years. Results: Among electrically-stimulated patients by year of follow-up from one to four, 83%, 75%, 65% and 60% avoided a total knee arthroplasty. In contrast, the matched group had 67%, 51%, 46% and 35% of patients avoiding a total knee arthroplasty. Electrically stimulated patients were 50% less likely to have a total knee arthroplasty (p=0.0004) and study patients who avoided a total knee arthroplasty had significant improvement in evaluations of pain scores (mean 40%), function (mean 38%), and physician global evaluation (mean 38%). Discussion: This study demonstrated that pulsed electrical stimulation is a safe and effective method for avoiding total knee arthroplasty as well as relieving clinical signs and symptoms of osteoarthritis of the knee.

POSTER NO. P171

Replication of the Axis of Flexion-Extension of the Non-Replaced Knee by a Total Joint Replacement

J David Blaha, MD, *Ann Arbor, MI (*)*
Williams S. Simons, MD, Morgantown, WV (n)
Vincent L. Kish, ASEE, Morgantown, WV (n)

INTRODUCTION:The human knee can be modeled as having a single axis for flexion-extension. In theory, the proper position for total knee arthroplasty components would be such that the axis of flexion-extension replaced joint matches that of the non-replaced. This study using a standard cadaver model tests the hypothesis that the axis of flexion-extension of a replaced human knee would match the non-replaced joint. METHODS:Six cadaver limbs were prepared and stabilized fixing the femur and moving the tibia. A 3-D digitizer determined the position of the tibia while the knee was moved at 20º /second. Data were captured for the non-replaced knee, then total knee arthroplasty components were inserted using standard technique and data captured. An averaged finite helical (screw) axis was calculated. This axis for the non-replaced knee was compared to the corresponding axis for the implant knee. Results are expressed as the angular deviation between the flexion-extension axis of the non-replaced knee compared to that of the replaced knee. RESULTS:The axis of the replaced knee showed an average difference in angle of 10.4° compared to the non-replaced knee. DISCUSSION: The normal knee moves about a single axis of flexion-extension that passes approximately through the centers of the two spherical condyles. This study demonstrates there was a significant difference in the axis of the replaced knee compared to the native knee when standard insertion technique was used.

POSTER NO. P172 – WITHDRAWN

SCIENTIFIC EXHIBITS

SCIENTIFIC EXHIBIT NO. SE027

Comparison of Isokinetic Strength in Resurfaced and Retained Patella in Bilateral TKA

Jens G. Boldt, MD, *Dusseldorf, Germany (b – DePuy)*
Peter A. Keblish, Jr, MD, Allentown,PA (e – DePuy, Johnson & Johnson)
Mario Bizzini, MD, Zurich, Switzerland (n)
Urs Munzinger, MD, Zurich, Switzerland (n)

Methods: Bilateral TKA, one with, one without patella resurfacing was performed in 22 osteoarthritic patients, mean age was 68 years using the Low-Contact-Stress prosthesis. Minimum follow-up was 5 years. Evaluation included clinical investigation, specific patella scores, radiographic analysis and isokinetic strength measurement of both knee flexion and extension at 60 degrees per second (Biodex). Results: There was no significant clinical score difference, but mean isokinetic strength of knee extension was significantly (p<.0001) stronger in the nonresurfaced patella TKA (40.5 Nm) compared with the resurfaced TKA (38,5 Nm). Flexion was also significantly stronger in the patella nonresurfaced group with 22.4 Nm versus 19.5 Nm in the resurfaced group. Mean lateral deviation was significantly (p<.001) less ideal in the resurfaced group as was postoperative patellofemoral congruent contact (p<.001). However, there was no correlation between lateral patella deviation or congruent contact and isokinetic strength. Discussion and Conclusions: The results of this study indicate that mean isokinetic

strength of both knee flexion and extension was significantly stronger in the nonresurfaced patella TKA. This study provides encouraging data for patella nonresurfacing. However, clinical scores or patient's preference did not show any difference.

SCIENTIFIC EXHIBIT NO. SE028

Revision Total Knee Arthroplasty and Accurate Restoration of the Joint Line

Stephen M. Kurtin, MD, *Salt Lake City, UT (n)*
Aaron A. Hofmann, MD, Salt Lake City, UT (*)
Michael P. Bolognesi, MD, Salt Lake City, UT (n)
Amie M. Tanner, BS, Salt Lake City, UT (*)
Marcelo P. Camargo, MD, Salt Lake City, UT (n)
Thomas Cook, DO, Salt Lake City, UT (n)
Katy Stirland, AS, Salt Lake City, UT (*)

Introduction: A clinical and radiographic analysis was undertaken to evaluate the results of one hundred consecutive revision total knee arthroplasties. The postoperative joint line position was evaluated and correlated with the clinical outcome. Methods: Stemmed revision components were implanted in 93 patients by a single surgeon using a single revision knee system. Forty-eight females and 45 males were studied with an average age of 66 years. Radiographs of the opposite unoperated knee, the pre-revision knee, and the postoperative revision knee were reviewed. The joint line was evaluated relative to a line drawn from the distal point of the slope of the medial distal femur at the adductor tubercle. Average follow-up was 10.4 years. Clinical evaluations included flexion, extension, total range of motion, HSS score, Knee Society Score, and pain score. These values were then correlated to reproduction of the normal joint line. Results: Average preoperative HSS score was 60 with a postoperative improvement to 90. Average total arc of motion improved from 88∞ to 100∞. Better flexion was obtained with the joint line being closer to normal. As the joint line deviated from what was measured as normal on the preoperative knee, the flexion decreased ($p=0.001$). Extension was statistically correlated to normal position of the joint line ($p=0.004$), as was total arc of motion ($p<0.001$), HSS score ($p<0.001$), and pain ($p=0.025$). If the joint line was elevated either 3mm proximal or distal from the normal location, all dependent variables studied (flexion, extension, total arc of motion, HSS score, pain score) were compromised. Discussion: This paper demonstrates excellent clinical results with the accurate restoration of the joint line. Accomplishing this goal led to predictable success in revision knee arthroplasty. Our patients performed clinically better irrespective of age, sex, mechanism of failure, infection, or length of follow-up if the joint line is accurately reproduced.

SCIENTIFIC EXHIBIT NO. SE029

Long-Term Survivorship of Revision Unicompartmental Arthroplasty

Jack M. Bert, MD, *Saint Paul, MN*
(a – Wright Medical Technology)
Terence Gioe, MD, Saint Paul, MN
(a – DePuy, a Johnson & Johnson Co.)
Kathleen Killeen, OT, Saint Paul, MN (n)

The purpose of this study was to evaluate the long-term survivorship of revision UKA in a community based implant and explant registry. Thirty-one previously reported and 16 additional UKA's revised to TKA's by 3 different surgeons were evaluated with respect to long-term survivorship. The etiology of the revisions included medial-lateral mismatch, progression of arthritis, polyethylene wear of the tibial insert, and component loosening. The mean age at the time of revision TKA of this group was 65.4 years. Follow-up ranged from 2.1 to 14 years. The mean F/U was 9.4 years. There have been three failures of revision TKA to date. Seventeen percent of the revision cases required tibial wedges to fill the defect in the tibia created at the time of the index procedure. Utilizing additional femoral or tibial augmentation implant devices did not adversely affect survivorship. There were no infections in this patient cohort. Several studies have reported inferior survivorship after revision UKA compared to primary TKA. This study reviews a series of patients who had failed UKA requiring revision TKA with mean F/U of 9.4 years, maximum F/U of 14 years and a 93.9% survivorship. In this retrospective study, revision TKA subsequent to failed UKA resulted in successful long-term survivorship similar to primary TKA.

SCIENTIFIC EXHIBIT NO. SE030

Stability, Alignment, and Contact Stress in Two Techniques of Total Knee Arthroplasty

Hirofumi Hanada, MD, *St. Louis, Missouri, USA (n)*
Leo A. Whiteside, MD, St. Louis, Missouri
(a, b, c – Smith & Nephew, Inc.)
Jerry Steiger, St. Louis, Missouri (*)
Paul Dyer, St. Louis, Missouri (*)
Masatoshi Naito, MD, Fukuoka, Japan (*)

This study evaluated the alignment and stability characteristics of knees aligned and resected using the tensioned-gap technique and the measured-resection technique for total knee arthroplasty. Twelve normal cadaver knees were tested in a knee-kinematics testing device for stability, alignment, and loadbearing stress-transfer characteristics after total knee arthroplasty. In six knees total knee arthroplasty was done using the tensioned gap technique, and in another six knees the measured resection technique was used, aligning the anterior and posterior cuts perpendicular to the median sagittal plane. Alignment and stability testing was done at 0°, 30°, 60°, 90°, and 120° flexion under axial load of 50N, 10N-m varus and valgus torque, and 10N-m internal and external rotational torque. Loadbearing stress-transfer characteristics were tested with a digital electronic pressure sensor (I-Scan-75 sensor, Tekscan) at 0°, 45°, and 90° flexion in all knees. All knees prepared using the tensioned-gap technique shifted toward varus, but maintained good stability in flexion. The patellar groove was shifted laterally relative to the neutral position. Loadbearing stresses on the tibial surface shifted markedly medially in flexion. All knees prepared with the measured resection technique had near-normal varus and valgus and rotational stability. Using the tensioned-gap technique can cause major varus or valgus deformity in flexion even in knees with normal ligaments. Using anatomic landmarks on the femur to align the anterior and posterior femoral cuts results in near-normal alignment, ligament balance, and load transfer.

SCIENTIFIC EXHIBIT NO. SE031

Early Instability With Mobile Bearing Total Knee Arthroplasty

Joseph T. Moskal, MD, *Roanoke, VA (n)*
Stephen Ridgeway, MD, Greenville, SC (n)

Between December 1987 and January 2002 , twenty-five cases of clinical instability following mobile bearing TKA with meniscal bearings or rotating platforms presented for evaluation at our institution. These cases were retrospectively identified. All were performed at outside institutions by a variety of surgeons. All clinical examinations were performed by the authors. Nine cases were revised at our institution. All twenty-five cases had clinical evidence of severe coronal plane instability and pain. Eight cases had polyethylene dislocation or subluxation evident radiographically and

clinically. Four cases had extensor mechanism dysfunction. Eighteen cases had symptoms immediately postoperatively. Twenty-three of the twenty-five cases had symptoms within 2-years postoperatively. Any potential long-term benefit of design innovations must be balanced with known problems leading to early failure.

SCIENTIFIC EXHIBIT NO. SE032

Fascia Iliaca Blocks for Postoperative Analgesia in Total Knee Arthroplasty Patients

Steven L. Blum, MD, *Skokie, IL (n)*
Dickson Wu, MD, Skokie, IL (n)
Wayne M. Goldstein, MD, Skokie, IL (n)
Alison Schroeder, RN, Skokie, IL (n)
Kim Quarnstrom, RN, Skokie, IL (n)

After epidural analgesia was discontinued and Visual Analog Scores (VAS) were >5 (for pain), FIB was offered. It is easily performed with a 22g B bevel needle inserted 1cm below the junction of the lateral 1/3 and medial 2/3 of the inguinal ligament and anesthetizes the femoral and lateral femoral cutaneous nerves. The needle is inserted perpendicularly until two pops are felt (fascia lata and fascia iliaca). After negative aspiration, 20 ml 0.25% bupivacaine with 200mcg epinephrine and 100mcg clonidine is injected. In 405 patients there were no complications with the FIBs we performed and 98% of these patients were satisfied. VAS to assess pain at 1 hour after FIB were reduced by an average of 3.86 ± 2.22 and similar to VAS in patients with epidural analgesia (3.04 ± 1.96 vs. 2.68 ± 2.8 respectively). Although quadriceps weakness was noted during the morning physical therapy (PT) visit, it did not impede the patient's ability to accomplish the given tasks. By the afternoon PT visit, no weakness was noted. The ease of performing fascia iliaca blocks, their high degree of success and satisfaction, and the lack of complications make them useful adjuncts in managing the postoperative pain in TKA patients. Quadriceps weakness may be potentially beneficial since it can prevent spasm, and reduces resistance to flexion, a common cause of failure to progress in PT.

SCIENTIFIC EXHIBIT NO. SE034

An Algorithmic Approach to the Valgus Total Knee Arthroplasty

Kathleen L. Dodds, BS, RN, *Hilliard, OH (a – Biomet)*
Adolph V. Lombardi, Jr, MD, FACS, Columbus, OH (e – Biomet)
Keith R. Berend, MD, Columbus, OH (a – Biomet)
Thomas H. Mallory, MD, FACS, Columbus, OH (e – Biomet)
Joanne B. Adams, BFA, Columbus, OH (a – Biomet)

Valgus knees are characterized by bone loss involving the lateral femoral condyle, lateral soft-tissue contractures, and instability. Valgus deformities may be classified into three major variants (I – III) based upon degree of deformity and MCL status. For variant I, the MCL is intact and minimal release is required, distal cuts are made in 3° valgus and a PCR or PS device is used. In variant II, where a more generous concave release is necessary, resultant joint line alteration may require a PS device. With an attenuated MCL (variant III), concave release must be performed to reestablish the mechanical axis and a constrained or rotating hinge device should be used. Ninety-seven consecutive TKA for valgus arthritis performed utilizing the described algorithmic approach and having minimum 2-years follow-up were reviewed. Average preoperative deformity was 14.4° valgus (SD 4.2). At average 3.6-years follow-up, alignment averaged 5.9° and Knee Society scores improved 45 points. A PCR component was used in 15 knees, PS in 78, constrained in 3 and rotating hinge in 1 knee. There was one incidence of transient peroneal nerve palsy. One tibial and five patellar components (all single-peg) have been revised yielding a 94% survival. Utilizing stepwise correction and gradual ligamentous balancing combined with a distal femoral resection performed in less valgus results in a well-aligned TKA and restoration of normal mechanical axis. Mild and moderate deformities can be managed with PCR designs, while more severe deformity may require more aggressive releases and a PS, PSC, or hinged TKA.

SCIENTIFIC EXHIBIT NO. SE035

Long-Term Clinical Results of Cruciate-Retaining Total Knee Arthroplasty Using the Alumina Ceramic Condylar Prosthesis

Kazunori Yasuda, MD, *Sapporo, Japan (n)*
Tokifumi Majima, MD, Sapporo, Japan (n)
Harukaz Tohyama, MD, Sapporo, Japan (n)
Akio Minami, MD, Sapporo, Japan (n)
Masayuki Inoue, MD, Sapporo, Japan (n)
Masaru Ueno, MD, Kyoto, Japan (e – Kyocera Corporation)

No studies have evaluated long-term results of cruciate-retaining total knee arthroplasty (TKA) using the alumina ceramic condylar prosthesis. The purpose of this study is to evaluate them in comparison with the Co-Cr alloy prosthesis. In a prospective semi-randomized study, 218 patients underwent cruciate-retaining TKA with the prosthesis composed of an alumina ceramic femoral component and a titanium-alloy tibial component with a UHMWPE insert (LFA-I®, Kyocera) or the metal prosthesis (Kinemax®, Howmedica). In each surgery, both components were fixed with PMMA cement. All the patients underwent the same postoperative management. Finally, 105 knees with the ceramic prosthesis and 84 knees with the metal prosthesis were followed up for 5 to 10 years. Two (tray breakage, infection) and three (2 loosening cases, infection) revisions were performed in the ceramic and metal groups, respectively. In the remaining patients, there were no significant differences in the HSS knee score (85 and 86 points, respectively) and the ROM (112 and 113 degrees) between the two groups. In radiological evaluation, a radiolucent line was more frequently observed with the significance ($p<0.05$) in the metal group (10.5%) than in the ceramic group (2.7%). The clinical results of the ceramic TKA are equivalent to those of the metal alloy TKA. In addition, the ceramic prosthesis showed some statistical tendency of superiority to the metal prosthesis concerning the radiolucent line. These results encouraged us to conduct a 10-year follow-up study on the ceramic total knee prosthesis.

SCIENTIFIC EXHIBIT NO. SE036

Effect of Posterior Cruciate Ligament and Posterior Osteophytes Removal on Gaps Changes in Total Knee Arthroplasty

Andrea Baldini, MD, *Florence, Italy (n)*
Giles R. Scuderi, MD, New York, NY (a ,c, e – Zimmer)
Paolo Aglietti, MD, Florence, Italy (e – Zimmer)
John N. Insall, MD, New York, NY (*)
David Lee Chalnick, MD, Trinton Falls, NJ (*)

Influence of Posterior Cruciate Ligament (PCL) removal and reestablishment of the posterior condylar recess on flexion and extension gaps width during posterior-stabilized Total Knee Arthroplasty (TKA) is still controversial. It has been reported that PCL resection lead to a selective increase of the flexion space of 3-

4mm, creating a potential for instability in flexion. Our hypothesis was that these surgical steps will equally increase both gaps. Measurements of the flexion and extension gaps heights were obtained during different surgical phases in 50 consecutive primary posterior-stabilized TKA using a tensor device and a calibrated torque wrench. There was a symmetrical slight increase in both gaps after PCL release. In extension the width of the gap increased on average 1.3mm and 1.0mm in the medial and lateral compartment respectively. The same pattern was observed in flexion, averaging 1.3mm medially and 1.3mm laterally. Another increase of the two gaps was observed after the posterior condylar osteophytes were removed and the posterior recess was reestablished. The gaps in extension increased, respect to the baseline value, on average 1.8mm medially and 1.8mm laterally, while in flexion averaged 2.0mm and 2.2 respectively on the medial and lateral side. Again there were no statistical differences between flexion and extension gaps. No independent differences between the flexion and extension gaps were found in any considered surgical phase. PCL removal and reestablishment of posterior condylar recess does not seem to require any additional consideration in gap balancing during posterior-stabilized TKA.

SCIENTIFIC EXHIBIT NO. SE037

Knee Laxity After Anterior Cruciate Ligament Reconstruction Using the Single-Bundle Technique in Two Femoral Positions and the Double-Bundle Technique

Oliver M. Ziegler, MD, *Zurich, Switzerland (n)*
Hilaire A.C. Jacob, PhD, Zurich, Switzerland (n)
José Romero, MD, Zurich, Switzerland (n)

The most common method of anterior cruciate ligament (ACL) reconstruction is the single-bundle technique in the 10 or 11 o`clock positions. The double-bundle technique restores the anteromedial- and posterolateral bundles of the ACL. Because differences in knee laxity after ACL repair are to be expected, how significant are they? Anterior translation and internal tibial rotation under defined loads in various degrees of flexion were measured on eight cadaveric knees with the ACL intakt, after sectioning the ACL and after reconstruction. Measurements were performed in full extension, 15°, 30°, 60° and 90° of flexion. Starting point for all measurements was with a posterior tibial force of 20 N. The anterior tibial force and tibial torques applied were 100 N and 10 Nm, respectively. Intact knees showed anterior tibial translation of 5.8mm (range: 3.7 to 8.1mm). All the three reconstruction methods resulted in anterior tibial translation of 8.5mm (range: 5.2 to 11.0) in all degrees of flexion. No significant differences in anterior tibial translation between the three methods of ACL reconstructions could be shown (p= 0.498) with a tendency toward less anterior tibial translation with the single-bundle technique in the 11 o`clock position. The results of the three reconstruction methods are very close to each other with no particular advantage of one method over the other. The single-bundle technique in the 11 o`clock position might, however, produce less anterior laxity. Considering the substantial surgical effort required with the double-bundle method, the single-bundle technique in the 11 o`clock position could be possibly the method of choice.

SCIENTIFIC EXHIBIT NO. SE038

Accuracy of Alignment in Total Knee Arthroplasty Using Computer Assistance

Michael P. Bolognesi, MD, *Salt Lake City, UT (n)*
Stephen M. Kurtin, MD, Salt Lake City, UT (*)
Aaron A. Hofmann, MD, Salt Lake City, UT (*)
Thomas Cook, MD, Salt Lake City, UT (n)
Tyler Goldberg, MD, Salt Lake City, UT (n)

Intraoperative computer assistance has been introduced an as adjunct to total knee arthroplasty (TKA) for correct positioning of bone resection and subsequent component alignment. This study reports the accuracy of alignment with computer assisted TKA. Methods: The computer system used consisted of a workstation, an optical tracking system, and standard extramedullary surgical instrumentation. Intraoperatively, tracking devices were attached to the femur and tibia, and to the alignment and pointing instruments, in order to track and display their relative locations in real-time. Pointing instruments were used to digitize the relative locations of anatomical landmarks that are commonly used clinically for TKA alignment. The center of the femoral head was computed based on a motion analysis of the femur. The computer system displayed the traditional alignment axes. The bone cuts and component positioning were then performed using a computer assisted posterior referencing TKA system. Forty-nine patients in 6 centers were operated on using this system. Results: Computer assisted TKA demonstrated improved accuracy compared to published intramedullary referencing (91.5% of patients within +/- 4 degrees deviation from normal alignment). Using computer assistance, 47 of the 49 patients (96%) had final alignment within +/- 4 degrees of the established mechanical axis. No complications occurred relative to placement of the optical trackers. Conclusion: Computer controlled image-guidance systems are intended to assist surgeons in determining reference alignment axes when performing TKA. This system showed improved accuracy and reproducibility when compared to published standards of medullary referencing.

SCIENTIFIC EXHIBIT NO. SE039

In Vivo Kinematic Analysis of Deep Knee Flexion After Total Knee Arthroplasty

Sang Yang Lee, MD, Kobe, Japan (n)
Nobuzo Matsui, MD, Kobe, Japan
(a – DePuy, a Johnson & Johnson Co.)
Hirotsugu Muratsu, MD, Kobe, Japan
(a – DePuy, a Johnson & Johnson Co.)
Ryosuke Kuroda, MD, Kobe, Japan (n)
Richard Komistek, PhD, Knoxville, TN
(a – DePuy, a Johnson & Johnson Co.)
Mohamed Mahfouz, PhD, Knoxville, TN
(a – DePuy, a Johnson & Johnson Co.)
Douglas A. Dennis, MD, Denver, CO
(a – DePuy, a Johnson & Johnson Co.)
Masahiro Kurosaka, MD, Kobe, Japan
(a – DePuy, a Johnson & Johnson Co.)
Shinichi Yoshiya, MD, *Kobe, Japan*
(a – DePuy, a Johnson & Johnson Co.)

INTRODUCTION: The objective of this study was to analyze the in-vivo kinematics of deep knee flexion after total knee arthroplasty (TKA). The kinematic results were compared between posterior cruciate-retaining (PCR) and posterior-

stabilized (PS) TKAs as well as intraoperative passive and postoperative weightbearing flexion. METHODS: Among the 18 subjects implanted with bilateral paired PCR and PS TKAs, 9 patients who achieved postoperative flexion of more than 120 degrees at 2 years after surgery were selected for this study. Three-dimensional kinematics of knee flexion was analyzed using a computer model fitting technique. The analysis was focused on flexion kinematics beyond 90 degrees of flexion. RESULTS: During intraoperative flexion, subjects experienced marked posterior translation (more than 5mm in average) of contact positions (posterior femoral rollback: PFR) from 90 degrees to maximum flexion both in the PCR and PS TKAs. Especially, in the PCR knees, PFR was observed predominantly in this flexion range. Although the PFR from 90 degrees to maximum flexion was observed also in the weightbearing flexion both for the PCR and PS knees, the average amount of translation in this flexion range was between 2 to 3mm and less than that observed in the intraoperative study. DISCUSSION: Majority of the previous studies have dealt with the flexion kinematics up to 90 degrees. However, achievement of deep knee flexion is vital in certain life style and religious affairs. This study revealed that flexion kinematics beyond 90 degrees is different from that up to 90 degrees.

SCIENTIFIC EXHIBIT NO. SE040

◆Tibial Plateau Abrasion in Mobile Bearing Knee System During Walking Gait: A Finite Element Study

Edward A. Morra, MSME, *Cleveland, OH (n)*
Paul D. Postak, BSc, Cleveland, OH (n)
A. Seth Greenwald, D Phil (Oxon), Cleveland, OH (n)

INTRODUCTION: The damage observed in UHMWPE total knee arthroplasty component retrievals is the result of high cycle fatigue loads, which act on the tibial insert during daily ambulation. Mobile bearing knee (MBK) designs have been advanced as a means of reducing damaging contact stresses by increasing component conformity. This study reveals the contact areas and stresses that are associated with tibial insert damage in four, contemporary MBK designs during three highly loaded points in the walking gait cycle. METHODS: A three-dimensional, finite element model was created for each design studied. Average loading conditions for the heelstrike (0 degrees, 2.5 x BW), midstance (20 degrees, 2.0 x BW) and toeoff (15 degrees, 3.0 x BW) portions of the stance phase were simulated. Contact areas and stresses on the tibial insert were calculated and their magnitudes and locations imaged photorealistically allowing visual comparisons of the different designs for each loading condition. RESULTS: All of the MBK designs maintained similar conformity at each position investigated. The average contact area was 420mm2 with an average peak contact stress of 12.2MPa. The increased contact area and corresponding decreased peak contact stresses for these systems suggest a reduction in UHMWPE damage potential when compared to fixed plateau designs. DISCUSSION AND CONCLUSIONS: Currently, the FDA is considering the down classification of MBK designs, which would make them generally available in the US. Their potential for increased longevity is in part design dependent and information describing specific system characteristics is essential in appreciating their anticipated in vivo performance.

SCIENTIFIC EXHIBIT NO. SE041

Minimally Invasive Total Knee Arthroplasty

Peter M. Bonutti, MD, *Effingham, IL*
(e - Stryker Howmedica Osteonics)
Margot McMahon, BA, Effingham, IL
(b - Stryker Howmedica Osteonics)
Michael A. Mont, MD, Baltimore, MD
(a - Stryker Howmedica Osteonics)

INTRODUCTION: There has been tremendous interest in minimally invasive total knee arthroplasty. This exhibit will review the background, indications, techniques and early results of these techniques. METHODS: The standard minimally invasive approach includes use of a small incision (6 to 10 centimeters), minimal disruption of the quadriceps mechanism, as well as no patellar eversion. The primary purpose of this exhibit is to review the technique as well as its indications. Secondary goals of the exhibit will include; (1) a summary of the background anatomic studies related to this technique, (2) a comparison of this technique to results of standard approach total knee arthroplasties, (3) an introduction and comparison to another minimally invasive method, the Suspended Leg Technique, and (4) early results of a multicenter prospective study comparing this technique to standard approaches. RESULTS: The early results of this technique at one center have shown 98% clinical and radiographic success at minimum 2-year (mean 3 years) follow-up. There have been minimal early complications. This has warranted prospective multicenter evaluation to assess the safety and efficacy of this procedure. DISCUSSION: Patients have been pleased with this approach which merits further evaluation. This exhibit will lead to a thorough knowledge of the indications, techniques, and early results with a comparison to standard approaches for total knee arthroplasty.

SCIENTIFIC EXHIBIT NO. SE042

◆ Computer Simulation of Bone Cutting for Knee Replacement Surgery With Freehand Navigation

Hani Haider, PhD, *Omaha, NE (n)*
Peter S. Walker, PhD, New York, NY (n)
O. Adres Barrera, BS, Omaha, NE (n)
Hesham H. Ali, PhD, Omaha, NE (n)
Todd D. Sekundiak, Omaha, NE (n)
Kevin L. Garvin, MD, Omaha, NE (e – Smith & Nephew)

Introduction: Most surgical navigation systems help in the alignment of jigs for bone cutting, but do not offer direct feedback on the cutting itself. We demonstrate that bone cutting can be modeled 3-dimensionally and simulated in real time intraoperatively. Our goal was to investigate the possibility of cutting freehand by navigation without cutting jigs. Methods: A standalone application in C/C++ was developed on a standard PC running Windows. Position, orientation and changing shape of a patient-specific bone based on CT data and motion of the cutting tool were measured with an infrared tracker and rendered continuously in 3D. Surface modeling was used to render the instruments and bones except the one being cut. The volumetric (voxel) based model was used to represent the bone being incrementally cut by an oscillating saw. The routines were programmed to give real time feedback of tool alignment. Results: Testing with synthetic bones, incremental change of bone shape due to cutting took 140ms total tracking, cutting and rendering time using a hybrid of volumetric (voxel) and surface modeling. With advanced PC hardware and switching during run time between volumetric and surface rendering, a rendering

rate of over 20 frames per second was achieved with realistic feedback on cutting. Discussion and Conclusion: With the cutting and position tracked in 3D on the screen, exposure of bones to monitor cutting can be reduced. Such a freehand navigation system could eliminate the need for cutting jigs and allow the use of reduced incision sizes.

SCIENTIFIC EXHIBIT NO. SE043

A New Cost-Effective and Customized Knee Device for Knee Flexion Contractures

Anil Bhave, PT, *Baltimore, MD*
(b – DePuy Casting, BSN Medical)
Scott Tennis, PT, Baltimore, MD
(b – DePuy Casting, BSN Medical)
Michael Mont, MD, Baltimore, MD (n)
Carla Brown, OTC, Woodlawn, MD
(b – DePuy Casting, b, e - BSN Medical)
Dror Paley, MD, Baltimore, MD (n)

INTRODUCTION: Treatment of knee flexion contractures (KFC) can be problematic. Conservative treatment includes a variety of physical therapy modalities, serial casting, and low-load prolonged stretch with commercially available splinting systems. Commercially available splints can be expensive and time consuming. The authors have used a new polyester synthetic casting material to create a custom molded, low-cost, custom knee device (CKD) in an innovative way to treat KFC. The CKD is made using 3 rolls of casting material, 2 hinges, and an elastic band wrapped in a figure of eight. METHODS: A standard treatment protocol included maximal knee extension positioning for 30-minute stretch using CKD, followed by therapy and electrical stimulation of the quadriceps muscle. Patients used the CKD for 2 to 3 times a day for 30 to 45 minutes. RESULTS: Sixteen patients with KFC treated with this protocol were followed for a mean of 2 years. The etiology of KFC was total knee arthroplasty in 12, limb lengthening in 2 and high tibial osteotomy in 2. The mean preop KFC was 15 degrees (range: 12 to 40). Fifteen out of 16 patients achieved full extension at a mean of 7.8 weeks (range: 6 to 15) of treatment. CONCLUSION: This custom molded knee device utilized with new casting materials is less expensive than other commercially available splints, is easier to customize for individual patients, and was effective. This low cost; viable approach should be incorporated into the daily treatment for contracture management.

SCIENTIFIC EXHIBIT NO. SE044

Biomechanical Investigation of Total Knee Arthroplasty (TKA) Using Robotic Technology

Guoan Li, PhD, *Boston, MA (n)*
Ephrat Most, MS, Boston, MA (n)
Ramprasad Papannagari, MS, Boston, MA (n)
Harry E. Rubash, MD, Boston, MA (c, e – Zimmer)

INTRODUCTION: An objective evaluation of the ability of Total Knee Arthroplasty (TKA) to restore normal knee function is necessary for the improvement of TKA designs and surgical techniques. We developed an in-vitro experiment model using robotic technology to quantify the biomechanical functions of various TKA designs. METHOD: Thirty cadaveric human knee specimens were tested using a robotic testing system. The intact knee kinematics under combined quadriceps (400N) and hamstring (200N) load was measured. The knee was then reconstructed using various TKA designs (cruciate-retaining (CR), posterior-stabilized (PS), fixed-bearing and mobile-bearing TKAs) and tested using the same protocol described above. The capability of TKAs to restore knee flexion beyond 120˚ was evaluated. RESULTS: Our data demonstrated that 1) the posterior cruciate ligament (PCL) in a CR TKA contributes to posterior femoral translation but only with 50% capacity of the PCL in the intact knee; 2) the cam-spine mechanism in a PS TKA does guide the knee after engagement. Loading had little effect on knee position after cam-spine engagement. Cam-spine disengagement was observed after 135˚; 3) mobile-bearing TKA showed similar kinematics to fixed-bearing TKA; 4) when flexed close to 150˚, similar kinematics was observed for all implants. DISCUSSION: These data showed that the robotic technology is an invaluable tool for the evaluation of the biomechanical functions of various TKAs where the intact knee functions can be used as its own control. This robotic system also provides a testing platform for improvement of current surgical techniques in TKA to optimally restore normal knee function.

SCIENTIFIC EXHIBIT NO. SE045

Cementless LCS Total Knee Artrhoplasty After 9 Years In-Situ: Articular and Backside Wear on Retrieved Meniscal and Rotating Platform Polyethylene Bearings

George D Markovich, MD, *Fort Myers, FL (n)*
Melinda K. Harman, MS, West Palm Beach, FL (n)
Scott A. Banks, PhD, West Palm Beach, FL (n)
W Andrew Hodge, MD, West Palm Beach, FL (*)

The perceived advantages of mobile bearing knee prostheses are 1) reduced polyethylene wear associated with large tibial-femoral contact areas, and 2) low shear stresses at the bone interface due to relatively unrestrained bearing motion. However, abrasive polyethylene wear remains a concern, especially considering the high incidence (47%) of osteolysis recently reported in an 8.5 year follow-up study of LCS mobile bearing prostheses. Smaller particulate debris associated with the more conforming tibial-femoral articulation and additional wear associated with the mobile "backside" articulation may be contributing factors. This study evaluates polyethylene wear on retrieved LCS mobile bearing prostheses. Meniscal bearing and rotating platform inserts from uncemented LCS prostheses were retrieved from 29 and 13 knees, respectively. The mean age and time in-situ was 74+11 years and 9+5 years, respectively. Reasons for removal included bearing wear(15), patella wear(9), pain and/or stiffness(5), autopsy(3), loosening(2), osteolysis(1), and other(7). The original femoral and tibial components were left in-situ in 85% of the knees at revision, such that only the polyethylene articulations were exchanged. Forty of 52 (77%) meniscal bearings analyzed were delaminated, including 20 (38%) bearings with fractured articular surfaces. Three (23%) of the rotating platforms had delamination. Twenty of 25 (80%) patellas had delamination, including 6 (24%) with fractured articulations. Scratching was the dominant backside wear mode. Despite severe wear on many of the polyethylene components, the incidence of osteolysis noted at revision was low (5%) and the need for complete revision of the metal tibial and femoral components was rarely deemed necessary.

SCIENTIFIC EXHIBITS

SCIENTIFIC EXHIBIT NO. SE047

Placebos in Orthopedic Medicine

Jack Drogt, MD, *White Bear Lake, MN (n)*
Jack M. Bert, MD, Saint Paul, MN (n)
Richard Smith, BS, Saint Paul, MN (n)

Over 100 articles from the past 50 years were reviewed which compared placebos to established treatments for arthritis and orthopedic conditions. Multiple studies consisted of comparisons pre and post treatment using various subjective pain evaluations for the treatment of arthritis and/or pain using placebos versus topical creams, intrarticular injections of saline versus steroids, nerve blocks using saline versus anesthetic drugs, oral analgesics versus. anti-inflammatories versus. placebos, and sham procedures versus joint lavage and debridement for the treatment of arthritis. In 72% of the articles reviewed, placebo treatment resulted in a minimum of 30% up to 70% improvement in pain symptoms when measured by pre and post treatment subjective pain evaluations. Recent articles have reported that placebo treatment is equivalent to established, recognized treatment for pain associated with arthritis. Oral, injectable, and topical placebos as well as various surgical procedures all improved pain scores in the majority of patients with pain associated with orthopedic conditions and arthritis. Whether placebo treatment is appropriate care in patients with established pathology is not substantiated or clarified in this literature review. However, it is clear that there is a wide variability of success in these patient groups regardless of the type of placebo treatment rendered to the patient.

SCIENTIFIC EXHIBIT NO. SE048

Therapeutic Effects of Osteoprotegerin on Periprosthetic Osteolysis in a Rat Model

Kang-Jung Kim, MD, *Tokyo, Japan (n)*
Kenji Kaneko, MD, Tokyo, Japan (*)
Miho Iwase, MD, Tokyo, Japan (*)

Introduction: Osteoprotegerin (OPG) has been reported to be a novel protein that can suppress osteoclast differentiation and activation. This study examined the therapeutic effects of OPG on established periprosthetic osteolysis in a rat model. Materials and Methods: A bone cement prosthesis was inserted into the rat femur and polyethylene particles were continuously infused into the knee joint using an osmotic pump. After osteolysis was established in four weeks, rats were intravenously injected with vehicle (control group) or 1 mg/kg of OPG (OPG-1 group) or 10 mg/kg of OPG (OPG-10 group) every week until they were sacrificed at 8 weeks. Effects of direct injections of OPG into the knee joint were also investigated. Periprosthetic bone resorption was evaluated with bone mineral density and histomorphometric analysis of membranes composed of total area and inflammatory grading. Radiographs were evaluated for focal osteolysis with a blind manner. Results: Periprosthetic bone resorption was significantly suppressed in OPG-10 group compared to the other groups ($p<0.05$). Histomorphometric analyses showed less total area as well as less inflammatory grading of the interface membrane in OPG-10 group compared to other groups ($p<0.01$). Radiographic osteolysis appeared to decrease in number in OPG-10 group. Direct injections of OPG into the knee joint appeared to be more effective compared to intravenous injections. Discussion: The present study demonstrates that OPG has significantly restored the established periprosthetic osteolysis in our animal model. OPG may be a possible agent to retain the bone stock before revision surgery for failed prostheses.

SCIENTIFIC EXHIBIT NO. SE049

The Compartments of the Foot: a 3-Telsa MRI Study With Clinical Correlates for Needle Pressure Testing

Norman S. Turner III, MD, *Rochester, MN (n)*
Kimberly K. Amrami, MD, Rochester, MN (n)
Joel P. Felmlee, PhD, Rochester, MN (*)
David W. Stanley, BS, RT, Rochester, MN (*)
Stephen W. Carmichael PhD, DSc, Rochester, MN (n)
John S. Reach, Jr, MD Rochester, MN (n)

Introduction: Reliable measurement of subfascial pressures represents an essential part of compartment syndrome management. To date, there is neither consensus on the number and location of foot compartments, nor standardized protocol for needle placement. The purpose of this study was to devise a new system using 3-Tesla MRI that assessed the number and location of these compartments more accurately. Methods: To document the specific location of foot compartments, high resolution 3-Tesla MRI (General Electric) was coupled with a specifically designed high signal-to-noise foot/ankle coil (GE). This system accentuated the chemical shift artifact generated by volume averaging at tissue boundaries. Highlighted individual compartments were then mapped to T1 weighted MR images. Further analysis progressed on AW Workstation (Sun Microsystems) and allowed standardized needle placement recommendations. To maximize image quality we coordinated various image planes with fixed surface bony anatomical landmarks, providing site and depth recommendations for the evaluation of each compartment. Results: Six feet from healthy volunteers were imaged. From these, 10 compartments were described: (1) Medial, (2) Central Superficial, (3) Central Deep, (4) Lateral, (5-8) Interossei, (9) Calcaneal, and (10) Skin. Optimal needle placement and depth were identified. Conclusions: The proposed system allowed us to assess the number and location of foot compartments. Computer image analysis enabled us to define exact points for needle insertion and depth of penetration for accurate pressure monitoring.

SCIENTIFIC EXHIBIT NO. SE050

In Vivo Determination of Normal and Anterior Cruciate Ligament Deficient Knee Kinematics

Mohamed R. Mahfouz, PhD, *Knoxville, TN*
(a – National Science Foundation)
Richard D. Komistek, PhD, Knoxville, TN
(a – National Science Foundation)
Douglas A. Dennis, MD, Denver, CO
(a – National Science Foundation)
William A. Hoff, PhD, Denver, CO (*)

INTRODUCTION: The objective of this study was to determine the three-dimensional, in vivo, weightbearing kinematics of normal and ACL deficient knees using fluoroscopy. METHODS: Fifteen subjects were divided into two groups, 10 normal and 5 ACLD knees. Each subject was CT scanned (0.3mm interval) and 3D

computer models of each subject's femur and tibia were recreated from the scan data. Each subject performed a weightbearing deep knee bend under fluoroscopic surveillance. The 3D models of the subject's femur and tibia were registered to 2D fluoroscopic images using a 3D-to-2D registration algorithm. Two methods were used to analyze the motion of the joint: Helical Axis of Motion (HAM) and contact path tracking of the femur on the tibia. RESULTS: All normal knees experienced posterior femoral translation of their lateral condyle and minimal motion in the medial condyle. The average amounts of posterior femoral translation for the lateral and medial condyles were 21.07mm and 1.86mm, respectively. All ACLD knees experienced considerable motion of the medial condyle. The average amounts of posterior femoral translation of the lateral and medial condyles were 17.01mm and 4.65mm, respectively. A substantial difference was found between the Center of Rotation locations of the normal and the ACLD subjects from the HAM analysis. DISCUSSION: ACLD subjects experienced more variable motion patterns and more motion of the medial condyle, at times in the opposite direction compared to the normal knee. ACLD kinematic patterns were more similar to posterior cruciate retaining total knee arthroplasties.

SCIENTIFIC EXHIBIT NO. SE051

Tendon Reattachment With a Porous Metal Prosthesis: an In-Vivo Canine Study

John S. Reach, Jr, MD, *Rochester, MN (a – Zimmer)*
Ian D. Dickey, MD, Rochester, MN (n)
Robert Talac, MD, PhD, Rochester, MN (n)
Mark E. Zobitz, MS, Rochester, MN (n)
Julie E. Adams, MD, Rochester, MN (n)
Hiroshi Minagawa, MD, Rochester, MN (n)
Sean P. Scully, MD, PhD, Rochester, MN (n)
David G. Lewallen, MD, MS, Rochester, MN
(a, b, c – Implex, Zimmer)

Background: Tendon attachment to metallic prostheses has applications throughout Orthopaedics. A soft-tissue attachment device was created to exploit the theoretical advantages offered by the new family of porous metals: allowing immediate fixation strength and long-term biologic in growth. Methods: 40 skeletally-mature canine supraspinatus tendons were reattached between two washers of porous tantalum. Fixation strength, clinical function and morphological changes were evaluated at four time points. Results: Tendon-implant strength as percent of normal rose significantly ($p<0.0014$) from 39% at surgery, to 67% at three weeks, 99% at six weeks, and 140% at twelve weeks (standard deviations 13, 19, 18 and 35). Stiffness of construct approached normal tendon ($p<0.0299$): 47% at surgery, 62% at three weeks, 94% at six weeks, and 132% at twelve weeks (standard deviations 27, 19, 18, and 38). Gait analysis demonstrated resumption of preoperative function. The percent of total body weight at mid-stance did not differ at three, six or twelve weeks ($p = 0.062$). The supraspinatus muscle atrophied significantly ($p<0.015$) from 97 (% of normal) at surgery, to 77% at three weeks. By six weeks, the muscle had recovered 81% of normal volume ($p<0.02$). Twelve week muscle volume hypertrophied to 92% of normal ($p<0.02$). Histomorphometry showed collagen fibers attaching to the metal surface and increased cellular density within the metal trabeculae. Conclusions: Robust tendon attachment to a metallic prosthesis was achieved. Tendon strength and stiffness as well as gait parameters returned to normal. Sharpey's fiber surface attachment and cellular in growth were observed.

SCIENTIFIC EXHIBIT NO. SE052

An Overview of the Use of the Bone Marphogenetic Protein, OP-1, for Musculoskeletal Applications

Michael A. Mont, MD, *Baltimore, MD*
(b – Stryker-Biotech)
Gracia Etienne, MD, Baltimore, MD (*)
Tushar Patel, MD, Arlington, VA (a – Stryker Biotech)
Gary Friedlaender, MD, New Haven, CT
(a, e – Stryker Biotech)
Stephen Cook, PhD, New Orleans, LA
(a, e – Stryker Biotech)
Andrew Shimmin, MD, Windsor, Victoria Australia (*)

Osteogenic Protein-1 (OP-1) is a bone morphogenetic protein that has been found to have oteoinductive activity in a variety of clinical situations. It has been available worldwide since 1997 with clinical experience encompassing over 2,500 patients. Recently, it has been approved by the FDA for use in difficult to heal long-bone fractures and spinal fusions. The primary goal of this exhibit will be to describe the present clinical use, actual application, and early results of the use of OP-1 in seven different musculoskeletal conditions. Secondary goals of the symposium will be to provide background about this device including: (1) an historical look at this and other BMP's, (2) a summary of animal and laboratory work, and (3) a review of safety issues. The specific clinical situations that will be reviewed will include the use of OP-1 in; (1) nonunions and/or difficult to heal fractures, (2) spinal fusions, (3) other arthrodesis situations, (4) revision hip and knee arthroplasties, (5) osteonecrosis of the femoral head and distal femur, (6) bone loss or defect scenarios, and (7) early experience with other applications. The educational benefits of this exhibit will be to provide a complex overview of present indications and contraindications for use. A look to the future with possible other applications will be also reviewed.

SCIENTIFIC EXHIBITS

SCIENTIFIC EXHIBIT NO. SE070

Musculoskeletal Tumor Society - COMSS Society

The Hazards of Biopsy: An Unresolved Problem

Henry J. Mankin, MD, *Brookline, MA (n)*
Carole Mankin, Brookline, MA (n)
Francis J. Hornicek, MD, Boston, MA (n)
Michael A. Simon, MD, Chicago, IL (n)

The essentials of the successful and safe biopsy of musculoskeletal lesions are based on understanding of the behavior of tumors and, more specifically, knowledge of orthopaedic oncology, diagnostic radiology, connective tissue pathology, and cytopathology. Open biopsy has been the conventional procedure for obtaining adequate and representative samples of tissue for the diagnosis of musculoskeletal lesions for many years. The procedure, however, has the risk of significant complicaton, particularly when done outside the definitive treatment center. On a study performed in 1982, the Musculoskeletal Tumor Society reported on the hazards of biopsy, including errors, complications, and changes in the course of treatment and outcome that were significantly higher when the biopsy was done in the referring institution. A second study performed 10 years later showed almost identical findings. Unfortunately, the rate of unnecessary amputation did not appear to change and it did not appear that the anticipated degree of learning hoped for was obtained in the general orthopaedic community in the 10-year span between publications of the two articles. Currently the percutaneous biopsy and fine needle aspiration biopsy have become frequent routine radiologic procedures and the complication rate is relatively low. Most treatment centers advocate core biopsy of bone tumors and those soft tissue tumors not palpable be performed uncer CT-guidance (MSTS 1992 study). Recent advances in imaging techniques and the availability of various cutting and trephine needles have made it easier to perform biopsies safely and accurately, even in difficult locations. The procedure obviates surgery in many instances and facilitates appropriate surgical planning in others. The overall accuracy was determined to be 71% in the authors reported series. The accuracy for fine needle aspirations was 63% and for CT-guided core biopsies was 74%. The open biopsy may still be required if the percutanelus biopsy results are in doubt or they vary from what is suspected clinically. These procedures remain the logical and safe choice for diagnostic studies of most patients with lesions of the musculoskeletal system.

SCIENTIFIC EXHIBIT NO. SE071

Pediatric Orthopaedic Society of North America - COMSS Society

Current Trends in Orthopedic Trauma in Children

David L. Skaggs, MD, *Los Angeles, CA (n)*
Laurel C. Blakemore, MD, Ann Arbor, MI (n)
John M. Flynn, MD, Philadelphia, PA (n)
Karl E. Rathjen, MD, Dallas, TX (n)
Susan A. Scherl, MD, Omaha, NE (n)
David S. Weismann, MD, East Brunswick, NJ (n)

Introduction: This scientific exhibit is sponsored by the Pediatric Orthopedic Society of North America Committee on Trauma and Prevention. The treatment of children with orthopedic trauma has undergone significant advances. Orthopedic surgeons who have completed their training in the past may not have had the opportunity to become familiar with these advances. Methods and Results: The use of flexible elastic nails in femoral shaft fractures is minimally invasive, allows early mobilization, and is associated with few re-fractures or other serious complications. This technique has been widely adopted by centers previously using other treatment methods. Slipped capital femoral epiphyses can usually be treated with a single cannulated screw through a 1 cm incision. In the immature patient, there is a trend towards treating some forearm fractures not amenable to closed reduction and casting with intramedullary fixation. This avoids the need for an extensive exposure and complications associated with plate fixation. Urgency of treatment of supracondylar fractures has been recently questioned. In the treatment of supracondylar humerus fractures lateral entry pins used correctly provide adequate fixation for the great majority of fractures. This technique is associated with minimal complications and prevents iatrogenic injury to the ulnar nerve. Pitfalls of placement of supracondylar pin placement include nerve injury and failure of fixation; helpful techniques for avoiding these complications are reviewed. Discussion: There have been significant advances in the treatment of certain common fractures in children, which may be well within the capabilities of most orthopedic surgeons treating these fractures.

SCIENTIFIC EXHIBIT NO. SE073

Orthopedic Trauma Association - COMSS Society

William T. Obremsky, MD, *Nashville, TN (n)*

Please come by the Orthopaedic Trauma Association (OTA) Booth and ask current members for advice on difficult fracture or reconstruction cases. In addition, the OTA would like to invite all attendees* to consider applying for membership. Patients with severe multiple injuries are usually treated in level I trauma centers, but over 90% of musculoskeletal injuries receive definitive diagnosis and treatment in community orthopaedic surgeon offices and community hospitals. The OTA would like to more fully engage orthopaedic surgeons who provide the majority of the care of musculoskeletal injuries in North America as members of the OTA. Orthopaedic surgeons who meet the following requirements are eligible for associate membership in the OTA.

- Board certification
- Membership and in good standing of the American Academy of Orthopaedic Surgeons or American Osteopathic Association or Canadian Orthopaedic Association
- Majority of practice related to injuries of the soft tissue and bony musculoskeletal system
- Licensed to practice medicine
- Citizenship in United States or Canada

These requirements are the same as for active membership but no authorship requirements exist. Benefits of membership include:

- Subscription to *The Journal of Orthopaedic Trauma*
- Subscription to OTA newsletter *Fracture Lines*
- Access to OTA website to obtain opinions/advice on difficult cases
- Use of OTA Web-based or PC-based Database
- Reduced registration fee for the OTA Annual meeting
- Access to OTA research funding

*International, Research and Resident Memberships are also available. See the OTA web-site for details: www.ota.org
The OTA welcomes your membership application.

SCIENTIFIC EXHIBIT NO. SE074

American Society for Surgery of the Hand - COMSS Society

◆3D Carpal Imaging and Animation

Michael J. Sandow, FRACS, *Adelaide, Australia (d, e – True Life Anatomy)*
Sam Papas, MAPS, Adelaide, Australia (n)
Michael Kerylidis, Bdes, Adelaide, Australia (n)

The wrist has a complex anatomical structure. The scaphoid is the critical lateral column link between the proximal and distal rows of the carpus. During radial deviation the lateral column must shorten. It does this by scaphoid flexion, however the apparent differential rotation and relationships between the scaphoid, lunate and trapezium is not well explained by existing kinetic theories. By obtaining true 3D CT scans of the normal and abnormal wrist in various positions of coronal and sagittal deviation, and then creating motion sequences using a step frame animation technique, the dynamic relationships between the various carpal bones can be demonstrated, ligamentous constraints inferred and pathological reconstructive option evaluated. Based on the specific patient anatomy, proposed surgical interventions can be tested in the virtual environment, and the end-user driven GUI design provides an intuitive interface to enhance its clinical usefulness. The motion of the carpus can be demonstrated in a clinically applicable format to aid anatomical understanding, diagnosis and reconstructive planning. The motion of individual bones of the patient's wrist can be seen in isolation, and specific dynamic abnormalities demonstrated. An understanding of the fixed constraints within the carpus allows for the development of more logical reconstructive interventions that attempt to replicate normal kinetics. With the availability of more user-friendly and powerful imaging software, the complex anatomy and mechanics of the carpus are being unravelled and potential treatment solutions developed and tested, based on a more precise and individualized appreciation of the unique pattern of injury in the individual patient.

SCIENTIFIC EXHIBIT NO. SE075

Ruth Jackson Orthopaedic Society – COMSS Society

Gender and Other Risk Factors for Bone Stress Injury and Recovery in Track Athletes

Sharon L. Hame, MD, *Los Angeles, CA (n)*
Aurelia Nattiv, MD, Los Angeles, CA (n)
Ashraf Abdelkerim, BS, Los Angeles, CA (n)
Suzanne Hecht, MD, Los Angeles, CA (n)
Julie Casper, MD, Los Angeles, CA (n)
James Puffer, MD, Lexington, KY (n)

The purpose of the study was to assess gender and other risk factors for stress injury and prolonged return to competition in collegiate track athletes. All athletes on the track /cross country teams at our institution from June 1996 to March 2001 (N=211) were prospectively evaluated for bone stress injury. Radiographs were obtained if an injury was suspected. Magnetic resonance imaging (MRI) was obtained when radiographs were negative. MRIs were graded by the severity of the bone stress injury. For risk factor assessment, 95 athletes completed a medical questionnaire annually. Athletes underwent dual energy absorptiometry (DEXA) and body composition, 4 day food diary analysis, hormonal and biochemical laboratory testing, muscle strength and flexibility testing. Incidence was determined and regression analysis performed. Thirty athletes sustained 55 stress injuries. Forty (73%) were negative on initial radiographs and subsequently positive on MRI. The incidence rate of stress fractures for female athletes was 10.7% of total years of participation in the study, and 5.1% for males athletes ($p<0.038$). The incident rate ratio was 2.1. Factors associated with prolonged return to full competition include: lower bone mineral density of the whole body ($p<0.0002$), lumbar spine ($p<0.001$), femoral neck ($p<0.002$), total hip ($p<0.0003$) and radius ($p<0.002$), disordered eating ($p<0.001$), Caucasian ethnicity ($p<0.05$) and higher grade injury on MRI ($p<0.002$). Female track athletes are at higher risk for sustaining a stress fracture compared to male athletes. Risk factors in track athletes associated with longer recovery include low bone density, more severe MRI grading, disordered eating, and Caucasian ethnicity. Knowledge of these risk factors can potentially prevent injury and help predict outcome.

SCIENTIFIC EXHIBIT NO. SE076

Orthopaedic Research Society – COMSS Society

Current Hot Topics in Orthopaedic Research

Tony Keaveny, PhD, *Berkeley, CA (n)*

Orthopaedic research continues to progress rapidly as new methodology becomes available. Members of the Orthopaedic Research Society conduct investigations on a wide range of topics relevant to improving our knowledge of the etiology, diagnosis, and treatment of musculoskeletal disease. Many different areas of expertise contribute to current orthopaedic research, including biochemistry, molecular biology, biomaterials, biomechanics, and advanced imaging. Some of the current exciting areas of investigation include tissue engineering using stem cells, adipose-derived cells, and muscle cells; studies examining the effects of mechanical forces (stress and strain) on cells and tissues; newly-identified mediators of bone resorption (osteoprotegerin) and bone formation (PTH) that may play important roles in osteolysis and osteoporosis; gene expression in healing bone, ligament, and tendon; novel imaging techniques such as Fourier-transform infrared (FTIR) and double-quantum-filtered NMR; new biomaterials that may be used for implants and tissue regeneration, and gene therapy methods to induce expression of key molecules in healing bone, cartilage, ligament, tendon, meniscus, nerve, and muscle.

SCIENTIFIC EXHIBIT NO. SE077

American Shoulder and Elbow Surgeons – COMSS Society

Tendon Gene Therapy Modulates the Local Repair Environment in the Shoulder

Daniel A. Grande, PhD, *Manhasset, NY (n)*
David M. Dines, MD, New Hyde Park, NY (*)
James Mason, PhD, Manhasset, NY (d – Tissue Genesis)
Pasquale Razzano, MS, Manhasset, NY (n)

Introduction: Tears of the rotator cuff are a common soft-tissue injury of the musculoskeletal system. These tears heal with by formation of inferior repair tissue, which may lead to severe joint dysfunction. This report demonstrates the feasibility of using a tissue engineered gene therapy platform for shoulder tendon repair. In this study, tendon fibroblasts were transfected with a gene specific for augmenting repair, confirmation of active peptide was assessed, and then ability of the peptide to upregulate metabolism in an adjacent, local environment is demonstrated. Methods: Tendon fibroblasts were serially cultured, expanded and transduced with the genes for either platelet-derived growth factor [PDGF] or insulin-like growth factor-1 [IGF-1] by retroviral vector. These cells were tested for their ability to modulate the metabolism of surrounding cells in an in vitro model for 24 or 48 hours and then labeled with tritiated

proline and thymidine to assess collagen and DNA synthesis by scintillation counting respectively. Results; RTF constructs incubated alone exhibited a baseline level of collagen synthesis and was not significantly stimulated by placement of a similar RTF construct. By 24 hours PDGF transduced cells stimulated adjacent RTF cells to increase collagen synthesis threefold. IGF-1 stimulated collagen synthesis by approximately 30%. In contrast to PDGF, IGF-1 also stimulated DNA synthesis by almost 100%. By 48 hours PDGF also stimulated DNA synthesis by almost threefold and continued to stimulate collagen synthesis. Discussion: These results suggest a role for local PDGF tissue engineered gene therapy for rotator cuff repair.

SCIENTIFIC EXHIBIT NO. SE079

The Knee Society – COMSS Society

Minimally Invasive Knee Replacement

Richard Sheldon Laskin, MD, *New York, NY*
(e – Smith & Nephew)
Alfred J. Tria, Jr, MD, Princeton, NJ (c – Zimmer, IMP)
Steven B. Haas, MD, New York, NY (*)
Russell E. Windsor, MD, New York, NY (c, e – Zimmer)

To properly perform a knee replacement the surgeon must have adequate visualization to permit the bony resections and to balance the soft tissues. Knee replacement has traditionally been performed through large incisions with involvement of large portions of the quadriceps and disruption of the suprapatellar pouch. Such large incisions, often necessitated by large instrumentation, enabled surgeons to perform the surgery with eventual excellent long-term results. The rehabilitation, however, has often been difficult, tedious, and painful primarily because of the extensive soft-tissue dissection required by these large incisions. In all facets of surgery, there has been an attempt to minimize soft-tissue trauma in an attempt to facilitate rehabilitation and minimize functional loss after the operation. Over the past 3 years surgical techniques and instrumentation have been developed which enable the performance of both unicomaprtmental and total knee replacement though smaller, tissue sparing incisions. These have progressed in tandem with the development of smaller instrumentation. Several exposure techniques have been developed including the mini mid vastus and the medial quad sparing to facilitate this exposure. It is this deep exposure, rather than the absolute length of the skin incision which is felt to be crucial. Results of minimally invasive, or more properly smaller incision surgery, have included a more rapid return of flexion, less pain, and a more rapid mobilization program in physical therapy. These types of surgical approach have been shown not to be applicable to the patient with a heavily muscled leg, or the morbidly obese patient.

SCIENTIFIC EXHIBIT NO. SE080

American Association of Hip and Knee Surgeons – COMSS Society

Medicare Reimbursement of Arthroplasty Surgery: A Time Analysis

Carlos J. Lavernia, MD, *Coral Gables, FL*
(a, d, e – Zimmer, d – Johnson & Johnson)
Thomas P. Vail, MD, Durham, NC
(a, c, e – Johnson & Johnson, a – Smith & Nephew, Wright Medical, e – Zimmer)
Clifford J. Colwell, Jr, MD, La Jolla, CA (n)

Introduction: Arthroplasty surgery is one of the most cost-effective surgical interventions in the field of medicine. Surgeon reimbursement for this surgical intervention has decreased significantly over the last 10 years. The objective of this paper will be to present information on the historical reimbursement of primary arthroplasty of the hip and knee. Methods: Reimbursement for primary arthroplasty of the hip and knee was researched utilizing the Medicare databases and private reimbursement databases. Economic indices for Overall Inflation, services and products inflation were also analyzed. Graphical representation of reimbursement versus time was performed. Discussion: The research based relative value scale was introduced in 1988 by Dr. Hsiao et al. The reimbursement of joint replacement has suffered multiple devaluations in the last 10 years when compared to the inflation index, surgeon payment has also suffered significantly when compared to the services and products overall. Arthroplasty surgery has been devalued at an alarming rate. Access to care is directly related to the ability of physician to deliver services. The current malpractice crisis combined with the devaluation of this procedure, will make access to this procedure extremely difficult for the average patient.

PAPERS

PAPER NO. 111

Effects of Intra- or Peritendinous Injections of Steroids on Biomechanics of Rabbit Achilles Tendons

Jason L Pennypacker, MD, *Harrisburg, PA (n)*
Ronald R Hugate Jr, MD, Rochester, MN (*)
Paul J Juliano, MD, Hershey, PA (n)
Marnie Saunders, PhD, Hershey, PA (n)

This study compares the biomechanical effects of corticosteroid injections both intratendinously and into the retrocalcaneal bursa of rabbit Achilles tendons. Systemic effects of bilateral steroid injections were also studied. Methods: Rabbits were divided into three treatment groups: (1) intratendinous steroid injected in the left Achilles tendon and intratendinous saline injected in the right, (2) steroid injected in the left retrocalcaneal bursa and intratendinous saline in the right and (3) intratendinous steroid injected in the left and intrabursal steroid in the right. Harvested tendons were biomechanically tested for failure load, mid-substance and total strain, modulus of elasticity, failure stress and total energy absorbed and were compared by injection location, steroid versus saline and total systemic load of steroid. Results: Intratendinous steroid injected tendons showed significantly decreased failure stress (P=0.008) compared to saline injected tendons. Intrabursal steroid injected tendons had significantly decreased failure stress (P=0.05), total energy absorbed (P=0.017) and increased total strain (P=0.049) compared to placebo. Intratendinous and intrabursal steroid injected tendons were biomechanically equivalent. Tendons receiving steroid injections regardless of location demonstrated significantly weaker biomechanical properties than saline injected tendons. Tendons in rabbits receiving bilateral steroid injections demonstrated significantly decreased failure load (P=0.011), modulus of elasticity (P=0.015), failure stress (P=0.03) and total energy absorbed (P=0.015) compared to unilateral steroid injected tendons. Conclusions: Intratendinous and retrocalcaneal bursal steroid injections adversely effect the biomechanical properties of rabbit Achilles tendons. Tendons in rabbits injected bilaterally with steroids demonstrated additive significantly adverse biomechanical effects than tendons injected unilaterally.

PAPER NO. 112

Early Results of Autologous Chondrocyte Implantation in the Talus

John-Paul Whittaker, MRCS, *Clwyd, United Kingdom (n)*
Nilesh Makwana, FRCS ORTH, Shropshire, United Kingdom (*)
P W Laing, MD, Liverpool, United Kingdom (n)
James Richardson, MD, Oswestry, United Kingdom (n)

Patients with osteochondral lesions of the talus have traditionally been difficult to treat. Autologous chondrocyte implantion (ACI) may provide predictable repair through restoring an articular surface.We reviewed our results of Ankle ACI in 12 patients with an average age of 40 years performed over four years. The patients were assessed with a Mazur ankle score, Patient satisfaction score and Lysholm knee score, pre- and post-operatively. Ankle arthroscopic assessment was performed in patients at 12 months post surgery.The average time to follow up was 21 months (range 12 to 56). The osteochondral lesions were post traumatic in nine cases, with six lesions situated medially, five anterolaterally and one central talar lesion. The average size of the talar defects at surgery was 1.95cm2 (range 1 to 4 cm2). Patient satisfaction scores in eleven patients were either 'extremely pleased' or 'pleased' with the operation. The mean Mazur scores increased by 26 points at mean 21 months follow up. The Lysholm knee scores at one year, returned to the preoperative level in four patients, with the remaining eight patients showing a reduced score (mean 9 points), suggesting early donor site morbidity. Eleven had ankle arthroscopy at one year and were shown to have filled defects and stable cartilage. A biopsy taken from the graft site, showed hyaline like cartilage and fibrocartilage to be present. These early results suggest that ankle ACI is an appropriate treatment for large symptomatic osteochondral lesions in the talus.

PAPER NO. 113

◆Mid Term Results of the First 98 Consecutive Salto Total Ankle Arthroplasty

Michel Bonnin, MD, *Lyon, France (c – Tornier SA)*
Thierry Judet, MD, Saint-Ismier, France (*)
Jean Colombier, Toulouse, France (*)
Philippe Piriou, MD, Garches, France (*)
Nicolas Graveleau, MD, Boulogne Billancourt, France (*)
Florent Buscayret, MD, Montpellier, France (n)

INTRODUCTION : The Salto® Total Ankle Arthroplasty (TAA) , is non cemented with mobile bearing and anatomical design. This study describes mid-term results since first implantation in 1997. METHOD: Between 1997 and 2000, 98 consecutive Salto TAA were implanted: 69 Osteo-Arthritis (OA) and 29 Rheumatoid Arthritis (RA). At last FU, 2 were deceased, 1 was lost and 2 prosthesis were removed. 93 implants were available with a mean FU 35 months (24-68). At FU evaluation was based on AOFAS scoring scale and XR. RESULTS: AOFAS score was 32.3 preoperatively and 83.1 at FU (p 0.0005). 72 patients are pain free, 54 walk unlimited distances, 25 more than 1 km, 67 have no limp but 7 needs aid. 58 can walk on tiptoes, 49 can walk on uneven ground, 14 can run, 76 ascend and 63 descend stairs normally. Range of Motion on XR (dorsal and plantar flexion) improved from 15.2 degrees preoperatively to 28.3 at FU (p 0.0005). AOFAS score in OA group is 82.5 and 84.16 in RA (not significant).At FU, 2 prosthesis were removed, 2 had loosening on XR and 2 more had revision (Synovectomy and resection of medial calcifications). Survivorship at FU was then 98 percent (best scenario) or 94.9 percent (worst scenario) with endpoint implant removal, but 93.8 (best scenario) or 91.8 (worst scenario) with end point removal, XR loosening or revision. CONCLUSION: Preliminary results of Salto TAA are promising. Its anatomic design helps recovering good function and its precise instrumentation increases accuracy in positioning.

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

PAPER NO. 114

◆Mobile Bearing Ankle Replacement: Clinical and Radiographic Comparison of Two Designs

Peter L R Wood, MB BS FRCS, *Cheshire, United Kingdom (a – Wright-Cremescoli, Waldemar Link)*
Timothy M Clough, MD, Lancashire, United Kingdom (a – Wright-Cremescoli, Waldemar Link)

We report a prospective randomised series of 100 ankle replacements using either Buechel-Pappas (B-P-Endotec) or Scandinavian Total Ankle Joint Replacement (STAR-Link). The STAR is uncemented cobalt-chrome with a dual coating of plasma sprayed titanium and electrochemically deposited calcium phosphate. The B-P is uncemented nitrided titanium alloy with porous coating. Both incorporate a congruent mobile bearing of ultra-high molecular weight polyethylene (UHMWPE).There were 56 men and 44 women (mean age 64 years; 31- 83). 31 patients had inflammatory arthritis and 69 osteo-arthritis. Seven patients had died and their replacements were satisfactory at last review. 87 surviving patients had a good clinical result (mean follow-up 28 months 24-37). The AOFAS score for pain (maximum 40) improved from 0 to 34 and the functional score (maximum 60) from 29 to 42. Four replacements required revision (early deep infection; subluxation; broken B-P tibial implant; broken STAR UHMWPE insert). Two more, one with aseptic loosening and one with unimproved pain, are unsatisfactory but have not had further surgery. The radiographs of 10 ankles (5 B-P and 5 STAR) including the one revised for subluxation (B-P) showed loss of full contact between the component surfaces. This we describe as 'edge loading'. It is more likely ($p<0.01$) when the pre-operative varus or valgus deformity is greater than 20 degrees (6 of 15 compared with 4 of 85). Even asymptomatic 'edge-loading' could lead to eventual failure because of polythene wear. We recommend ankle replacement only when the pre-operative deformity is mild. No difference is shown between B-P and STAR. .

PAPER NO. 115

Agility Total Ankle Arthroplasty: A 7 to 16 Year Follow-up Study

Charles L Saltzman, MD, *Iowa City, IA (n)*
Stephen L Knecht, MD, Iowa City, IA (*)
John J Callaghan, MD, Iowa City, IA (a, e – DePuy)
Mira Estin, BA, Iowa City, IA (n)
Franklin G Alvine, MD, Sioux Falls, SD (a, c, d – DePuy, Johnson & Johnson)

The purpose of this study is to report intermediate-term results of Agility total ankle replacement. METHODS: The first 132 consecutive Agility Total Ankle replacements were prospectively evaluated independent of the surgeon. RESULTS: 132 ankles were performed in 126 patients. At a mean follow-up of nine years, 33 patients (36 implants) were deceased, fourteen implants (11%) had been revised or fused, and one was amputated for an unrelated cause. Clinical follow-up of 67 (86%) of the remaining 78 living patients (69 of 81 ankles) was performed. Of these patients, over 90% reported decreased pain, were satisfied with their surgery, and would do it again. 19% (22/117) ankles had progressive subtalar arthritis; 15% (17/117) had progressive talonavicular arthritis. 8% (9/111) ankles had syndesmosis nonunion. 76% (89/117) ankles had some evidence of peri-implant radiolucency, but many of these were stable and had no clinical implications at the time of this follow-up study.

PAPER NO. 116

Correlation of Hallux Valgus Surgical Outcome with AOFAS Forefoot Score and Radiological Features

David B Thordarson, MD, *Los Angeles, CA (n)*
Murali Moorthy, MD, Glendale, CA (*)
Edward Ebramzadeh, PhD, Los Angeles, CA (*)
Sally A Rudicel, MD, Boston, MA (n)

Introduction: The purpose of this multi-center prospective study by the AOFAS was to evaluate the outcome of hallux valgus surgery with a validated survey instrument, and compare this to their AOFAS forefoot scores and radiological measures, pre- and postoperatively. Conclusions/Significance: Outcome research focuses on the patient's perception of the results independent of the physician's interpretation of the results. This study demonstrated the improved function and perception of a patient's condition, increasing at 6, 12, and 24 months after surgery. Outcome did not vary when compared to the AOFAS forefoot score, preoperative degree of deformity, residual deformity or type of surgery. Methods: A multi-center study by the members of the AOFAS was undertaken to determine the effect of hallux valgus surgery and the patient's perception of function. 328 patients were enrolled and completed a baseline AAOS outcome questionnaire with the foot and ankle module, with the patients' physicians completing a pre- and postoperative questionnaire regarding range of motion, limp, and radiologic parameters. Pre- and postoperative AOFAS forefoot scores for each patient from the physician questionnaire were available for 136 patients. Radiographic data on 205 patients allowed for stratification of results based upon preoperative hallux valgus and intermetatarsal angles versus postoperative hallux valgus and intermetatarsal angles versus the change in these angles. Results were stratified by the type of operation performed. Results: 4 of 10 SF-36 scales changed more than 5 points (physical function-75.1 to 82.6, role-physical-68.5 to 79.9, bodily pain-56.5 to 72.7, role-emotional-83.2 to 89.4). Physical health and pain (66.7 to 78.3), satisfaction with symptoms (1.7 to 3.5), global foot and ankle scale (76.1 to 85.8), and shoe comfort (33.4 to 47.5) all increased significantly. Surprisingly, whether results were compared by absolute magnitude of the angular change in the hallux valgus or intermetarsal angle or comparing mild to moderate to severe deformities, patients were noted to have a similar improvement in their AOFAS and individual SF-36 and lower extremity scores. Magnitude of preoperative deformity, postoperative residual deformity, and magnitude of correction did not significantly change improvement in any of these scores. Additionally, simultaneous forefoot procedures had no impact upon outcome, and no significant difference between outcome scores between the three different operations was noted consistently when the multiple scores were evaluated. Patients who had a Chevron osteotomy, although having similar hallux valgus angles postoperatively, had a lower overall correction which one would expect if properly selecting patients for this procedure. Surprisingly, patients who underwent a first tarsometatarsal fusion (Lapidus procedure) in this series had a lower overall change in the intermetatarsal angle and a higher postoperative intermetatarsal angle (14.2 degrees) versus 6.6 degrees for Chevron and 9.6 degrees for basilar first metatarsal osteotomy (p less than 0.05).

PAPER NO. 117

Minimally Invasive Reduction and Fixation of Tongue-Type Calcaneus Fractures

Bruce J Sangeorzan, MD, *Seattle, WA (n)*
Stephen K Benirschke, MD, Seattle, WA (*)
Sean E Nork, MD, Seattle, WA (*)
Sara K Holt, MPH, Seattle, WA (n)

Introduction: We evaluated the outcome of tongue-type calcaneus fractures treated with a minimally invasive reduction technique and small fragment fixation. Methods: We retrospectively assessed 36 patients who had tongue-type calcaneus fractures treated at a level-1 trauma center with use of a minimally open reduction technique and small fragment fixation over a 7-year period. Data collection included: length of stay, complications, preoperative and postoperative calculations of Bohler's angle, and foot function index. Results: The duration of follow-up averaged 25.5 months (range, 8 to 48). Time from injury to surgical treatment averaged 9.1 days, and the LOS averaged 3.2 days (range, 1 to 13). The average postoperative duration of stay decreased to 2.2 days if two patients who had prolonged hospitalizations secondary to other medical problems were excluded. There were no infections or implant failures. Complications included three cases of sural nerve irritation. Eleven patients reported discomfort related to implants, 10 of whom underwent implant removal. There was one talocalcaneal fusion. The average Bohler's angle was 3.26 degrees (range, -30 to 30 degrees) preoperatively, fixation 27.6 degrees (range, 11 to 41 degrees) postoperatively, 26.6 degrees after union. Reduction was not lost during healing. The average score on Foot Function Index was 21 (range, 5 to 36) with approximately equal reductions to individual subscales for pain, disability, and activity. Conclusions: This technique is effective for fixation of tongue-type calcaneus fractures without an extensile approach. Compared with historical controls, the risk profile is lowered and length of stay is reduced.

PAPER NO. 118

Percutaneous, Arthroscopically-Assisted Ostheosynthesis of Joint-Depression Type Calcaneal Fractures

Alexander Nehme, MD, *Toulouse, France (n)*
Philippe Chiron, MD, Toulouse Cedex, France (*)
Jean Louis Tricoire, Toulouse, France (*)
Bruno Chaminade, Toulouse, France (n)
Ghassan Maalouf, MD, Beirut, Lebanon (n)
Jean L Puget, MD, Toulouse Cedex 4, France (n)

Introduction: Some major wound complications that may occur after open reduction and internal fixation of intra articular calcaneal fractures are behind the trend of percutaneous fixation. But indications of percutaneous methods are limited to tongue-type,Sanders type II fractures. The aim of this study is to present a new percutaneous, arthroscopically assisted screw synthesis that was developed to extend their indications to joint-depression type fractures. Materials and methods: The patient is operated in a supine position. The injured limb is stabilized with a Steinman pin inserted in soft tissues of the upper face of the calcaneal tuberosity. Axial traction is realized in valgus to reduce automatically the horizontalization and varus of the greater tuberosity. Reduction of the thalamic portion of subtalar joint is then realized percutaneously under fluoroscopic and arthroscopic control. After anatomic reduction is achieved, the fragments are fixed with three to four cancellous screws via stab incisions. Between March 2000 and March 2001, 24 joint-depression type fractures were treated according to this method. Results: The functional results of 20 patients with at a minimum of 18 months follow-up are good to excellent; with an average AOFAS ankle-hindfoot score of 94.5 (range 82-100). Overall patient satisfaction and comfort were superior to open reduction for similar fracture patterns, and the in-hospital time could be reduced. Conclusions: Stabilization of the injured limb with axial traction, allows percutaneous arthroscopically and fluoroscopically assisted synthesis of joint-depression type calcaneal fractures even with deep impaction. The short term results of this minimally invasive surgery are excellent.

PAPER NO. 119

Prospective Comparison of Minimally Invasive and Extensile Treatment of Tongue Type Calcaneus Fractures

Sean E Nork, MD, *Seattle, WA (n)*
Bruce J Sangeorzan, MD, Seattle, WA (n)
Stephen K Benirschke, MD, Seattle, WA (n)
Sara K Holt, MPH, Seattle, WA (n)

Introduction: The purpose of this paper is to prospectively compare a minimally invasive reduction and internal fixation (group1) of tongue type calcaneus fractures with screws alone against ORIF using an extensile lateral approach (group2). Methods: 20 patients with isolated, closed, tongue type calcaneus fractures were surgeon randomized to treatment with small incision (n equals 7) or extensile open reduction (n equals 13). AOFAS hindfoot score and the MFA were recorded every three months to one year. We tracked time to FWB, LOS, and secondary complications. Comparisons were done using student's t-test. Results: At one year out, mean AOFAS in group 1 was 76.0, versus 73.3 in the group 2. Mean MFA in group 1 was 16.0 (SD 13.7) as compared to 32.7 (SD 20.6) for group 2 (p equals 0.07). Average MFA for uninjured subjects is 9.3. Average MFA score for patients with foot injuries at 1 year out is 22.1. Length of stay averaged 1.6 (SD 0.92) days for group 1 versus 3.5 (SD 1.05) days for the group 2 (p less than 0.001). Group 1 time to full, unencumbered weight bearing was 11.2 weeks (SD 3.18) versus 20.3 weeks (SD 12.5) for group 2 (p equals 0.007). Complications included superficial thrombophlebitis in one patient in the group 2. There were no infections in either group. Discussion: Minimally invasive reduction technique for fixation of tongue-type calcaneus fractures appear to have a faster recovery time, shorter length of stay and a trend to improved functional outcome at one-year post injury.

PAPER NO. 120

Intermediate to Long-term Results of a Treatment Protocol for Calcaneal Fracture Malunions

Michael Patrick Clare, MD, *Omaha, NE (n)*
Roy W Sanders, MD, Tampa, FL (n)

The purpose of this study was to report the results of a treatment protocol based on the Stephens-Sanders classification of calcaneal fracture malunions.We reviewed the results of 70 malunions in 64 patients who had previously undergone nonoperative management of a displaced calcaneal fracture elsewhere. Type I malunions (n equals 11) underwent lateral wall exostectomy and peroneal tenolysis; type II malunions (n equals 48) a lateral wall exostectomy, peroneal tenolysis, and subtalar autograft arthrodesis; type III malunions (n equals 11) a lateral wall exostectomy, peroneal tenolysis, subtalar autograft arthrodesis, and calcaneal osteotomy. The average interval between fracture and surgery was 16.4 months. Twenty-five patients (28 malu-

nions) were deceased or lost to follow-up; 42 malunions (60 percent) in 39 patients were evaluated at an average of 5.3 years. Assessment included the Maryland, AOFAS ankle and hindfoot, and SF-36 scores. Fifty-four of 59 arthrodeses (91.5 percent) achieved initial union. The average Maryland and AOFAS scores were 79.1 and 73.8, respectively. Statistical analysis revealed no difference in outcome scores between the malunion types, likely due to sample size. Twenty-six of 39 (66.7 percent) had mild residual pain, nineteen (73.1 percent) in the lateral ankle. Twenty-five of 29 (86.2 percent) workers compensation patients returned to work at an average of 8.7 months post-operatively; twenty-three (92 percent) required retraining. The protocol proved effective in relieving pain, re-establishing a plantigrade foot and improving patient function. Because of the difficulty in restoring calcaneal height following malunion, patients with displaced calcaneal fractures may benefit from operative treatment acutely.

POSTERS

POSTER NO. P431

Biomechanical Testing of Mitek GII Anchors & Arthrex Bio-Tenodesis Screws for Ankle Stabilisation

Lee Jeys, FRCS, *Birmingham, United Kingdom (n)*
Sortiris Korrosis, PhD, Holmfirth, United Kingdom (*)
Todd Stewart, PhD, Holmfirth, United Kingdom (*)
Nicholas J Harris, MD, Sheffield, United Kingdom (*)

Introduction: Autograft stabilisation of the lateral ankle ligament is a new technique for ankle stabilisation which utilises a free Semitendinosis tendon graft to anatomically reconstruct the anterior talar fibular ligament (ATFL). The aim of this study was to evaluate the biomechanical properties of a bone anchor and an interference screw for free tendon fixation of the ATFL. Materials and Methods: A fresh-frozen porcine talus and tendon model was used with 10 specimens for each fixation type. Load was applied at 70 degrees to the long axis of the talus to recreate the line of pull of the ATFL. Results: The mean load to failure of the bone anchor group was 114N +/- 9.9N, with a mean elongation of 37% +/- 13%. The mean load to failure for the interference screw group was 227N +/-18.26N, with a mean elongation of 22% +/- 7%. In comparison, studies of human ATFL have shown strengths of 139N and elongation of less than 4mm (20%) for good stability(1,2,3). Conclusion: The interference screw fixation technique produced a significantly greater failure strength and less elongation at failure than the bone anchor technique. From the two clinical products evaluated the results suggest that interference screws may provide better biomechanical properties than bone anchors, and may be more suited to providing a stable lateral ankle ligament reconstruction. References 1. Ataarian et al, Foot Ankle, 6(2), pp54-58,1985. 2. Gould et al, Foot Ankle, 1, pp84-89,1980. 3. Anderson and Lecocq, JBJS, 36A, pp825-832, 1954.

POSTER NO. P432

Achilles Tendon Healing in iNOS Gene Knockout Mice

George A C Murrell, MD, *A/Prof, Kogarah Sydney, Australia (n)*
Wei Xia, PhD, Sydney, Australia (n)
Yao Wang, PhD, A/Prof, Sydney, Australia (*)
Richard Charles Appleyard, PHD, St Leonards, NSW, Australia (*)
George A Smythe, PhD, A/Prof, Sydney, Australia (n)

INTRODUCTIONNitric oxide (NO), a diatomic free radical, regulates many functions of mammalian cells. We have previously reported that nitric oxide synthases (iNOS, eNOS and bNOS) are induced during rat tendon healing and inhibition of nitric oxide synthases (NOS) inhibited rat tendon healing. The aim of this study was to evaluate the effects of deleting the iNOS gene on Achilles tendon healing in mice. METHODSThe methods we used in this study included: setting up the Achilles tendon healing on the iNOS gene knockout (iNOS-/-) mice and their wild type (iNOS+/+) mice and administering NOS inhibitor, aminoguanidine (AG), to the iNOS-/- mice via an intraperitoneal mini-osmotic pump checking the cross-sectional areas of the tendons testing the biomechanical properties of the tendons measuring the serum nitrate level of the miceRESULTSA significant reduction in cross-sectional area of the healing Achilles tendon was observed in iNOS-/- with AG group compared with the iNOS-/- group, but no significant difference was found between iNOS+/+ group and iNOS-/- group. iNOS gene deletion and inhibition of NOS did not affect failure load, maximum displacement, stiffness, energy, modulus or maximum stress of the healing tendon constructs. The serum nitrate level in both iNOS-/- group and iNOS-/- with AG group were significantly lower than that in iNOS+/+ group, but no significant difference was found between iNOS-/- group and iNOS-/- with AG group. DISCUSSION AND COUCLUSIONNo is important in tendon healing, but the iNOS gene is not solely responsible for the beneficial effects of NO on tendon healing.

POSTER NO. P433

Shock Wave Therapy Induces Neovascularization at the Tendon-Bone Junction. A Study in Rabbits

Ching-Jen Wang, MD, *Kaohsiung, Taiwan (n)*
Feng-Shen Wang, MD, Kaohsiung Hsien, Taiwan (*)
Kuender D Yang, MD, Kaohsiung Hsien, Taiwan (*)
Chun-Shun Huang, Kachsiung, Taiwan (*)
Chia-Chen Hsu, MD, Kaoshiung Hsien, Taiwan (n)
Lin-Hsiu Weng, MD, Kaoshiung Hsien, Taiwan (n)
K. Y. Yang, MD, London, ONT Canada (*)

Introduction: Despite the success in clinical application, the mechanism of shock wave therapy remains unknown. Clinical observations revealed the effect of shockwave therapy appeared dose dependent and progressive improvement with time, and approximately 60% of calcium deposits in calcifying tendonitis of the shoulder dissolved completely after shockwave therapy. We hypothesized that shock wave therapy may induce the ingrowth of neovascularization and improve tissue blood supply. The purpose of this study was to investigate the effect of shock wave therapy on neovascularization at the Achilles tendon-bone junction. Methods: Fifty New Zealand white rabbits with body weight ranging from 2.5 to 3.5 Kg were used in this study. The right limb (the study side) received shock wave therapy to the Achilles tendon near the insertion to bone; whereas the left limb (the control side) received no shock wave

therapy. Biopsies of the tendon-bone junction were performed in 0,1, 4, 8 and 12 weeks. The neo-vessels were examined microscopically with hematoxylin-eosin stain. The angiogenesis-related markers including vessel endothelial growth factor (VEGF) and endothelial nitric oxide synthase (eNOS) expressions, and endothelial proliferation by proliferating cell nuclear antigen (PCNA) expression were examined microscopically with immunohistochemical stains. Results: Shock wave therapy produces a significantly higher number of neo-vessels and angiogenesis-related factors including eNOS, VEGF and PCNA than the control. The eNOS and VEGF began to rise at one week and lasted for 8 weeks, then declined at 12 weeks; whereas the increases of neo-vessels and PCNA began at 4 weeks and persisted for 12 weeks or longer. Discussion and Conclusion: Shock wave therapy induces the ingrowth of neovascularization at the Achilles tendon-bone junction in rabbits. The neovascularization may play a role to improve blood supply and tissue regeneration.

POSTER NO. P434

A Radiographic Review of the Adult Ankle: What Constitutes Normal?

Joseph DeAngelis, MD, *Hartford, CT (n)*
Nicola DeAngelis, MD, Natick, MA (n)
Richard Coveney Anderson, II, MD, Worcester, MA (n)

Introduction/Purpose: To quantify the normal radiographic relationships of the adult ankle. Methods: Digital radiographs of 564 ankles were retrospectively reviewed. Of these, 191 were deemed 'normal' by an attending radiologist, had no evidence of trauma, surgery, or degenerative disease, and were completed with good radiographic technique. Measurements were taken from the three standard ankle trauma views and normal values were calculated to quantify the relationship of the bones in the ankle. Results:Mortise View 1. Medial Clear Space: 2.7 mm (SD 0.5, range 1.3-4.3) 2.Superior Clear Space: 3.6 mm (SD 0.6, range 2.0-5.3) 3. Talo-Crural Angle: 11.3° (SD 3.0, range 3.5-17.6) 4. Tibio-fibular overlap: 4.3 mm (SD 2.2, range 0-10.5) 5. Tibio-fibular clear space: 4.3 mm (SD 1.2, range 1.0-7.9) AP view 1. Tibio-fibular overlap: 8.5 mm (SD 2.5, range 1.9-14.9) 2. Tibio-fibular clear space: 4.1 mm (SD 1.6, range 0-8.5) Discussion/Conclusion: 1) These results are consistent with the current standard measurement used for the medial clear space.2) These results are roughly consistent with the current standard measurements used for talocrural angle, tibio-fibular overlap, and tibio-fibular clear space. However, the ranges associated with each of these values make their clinical usefulness questionable.3) In 92 of 94 mortise views (98%), the superior clear space was found to be greater than or equal to the medial clear space on a mortise radiograph.4) Given the above conclusions, the best standard of comparison for an injured ankle is a radiographic trauma series of the contralateral uninjured ankle.

POSTER NO. P435

Supplementary K-Wire Fixation for Crescentic and Ludloff Osteotomies: A Biomechanical Study

Hong-Geun Jung, MD, *Baltimore, MD (n)*
Lew C Schon, MD, Baltimore, MD (n)
Gregory P Guyton, MD, Baltimore, MD (n)
Brent G Parks, MSC, Baltimore, MD (n)
Craig I Title, MD, New York, NY (n)
Karl Dom, Baltimore, MD (*)
Augustine Nguyen, BSc, Baltimore, MD (n)

INTRODUCTION: Crescentic and Ludloff proximal metatarsal osteotomies are two common procedures for correction of hallux valgus. Although screw fixation is used for stability, loss of reduction can occur. The purposes of this study were to compare the sagittal plane stability of the standard Ludloff proximal metatarsal osteotomy (PMO) with 2-screw fixation with that of the Ludloff PMO fixed with 1 proximal screw and 2 supplemental axial K-wires, and also to compare the stability of the conventional crescentic PMO fixed with a single screw with that of the crescentic PMO fixed with 1 screw and 2 supplemental K-wires. METHODS: Eleven and ten matched pairs of cadaveric foot specimens were used for the Ludloff and crescentic osteotomies, respectively. For the Ludloff PMO, the osteotomy was fixed with 4-mm long-threaded cannulated screw proximally and a fully threaded 2.7-mm screw distally. For the matched pair specimen, the same Ludloff osteotomy was fixed with 1 proximal 4-mm screw and two supplemental axially placed 0.062-inch K-wires. For the crescentic PMO group, the matched pair was prepared by adding two axial 0.062-inch K-wires to the conventionally placed 4.0-mm screw. The extensometer was used to measure the gap as the metatarsal head was loaded continuously until failure using a servohydraulic MTS Mini Bionix test frame. The strength of fixation was normalized with the bone mineral density (BMD) of the paired specimen (N*cm2/gm). RESULTS: The average strength of the standard Ludloff and the Ludloff with proximal one-screw and two axial K-wire fixation specimens corrected with BMD were 858.5 N*cm2/gm (S.D. 791.5) and 692.3 N*cm2/gm (S.D. 680.8), respectively, without statistically significant difference ($p>0.05$). The average strength of the crescentic PMO with axial K-wire fixation (458.8 N*cm2/gm, S.D. 434.3) was significantly higher than the standard crescentic PMO (367.5 N*cm2/gm, S.D. 397.9) ($p=0.05$). CONCLUSION: Supplemental fixation with two axial K-wires can be added to the standard Ludloff and the crescentic PMO to enhance the initial fixation stability to prevent the loss of reduction or dorsal malunion.

POSTER NO. P436

Complications in Silastic Implant Arthroplasty of Great Toe

Biing Yann Ng, MRCS, *Manchester, United Kingdom (n)*
Ali Rameto, MD, Wigan, United Kingdom (n)
Manoj Basu, Wigan, United Kingdom (*)
Brian Livnigstone, FRCS, Wigan, United Kingdom (*)
M S Bell, Wigan, United Kingdom (*)

Introduction: There is relatively little data in the literature regarding the frequency of complications. This study summarises the complications encountered in over 100 silastic implant arthroplasty of great toe at a single institution Methods: Over a 11 year period between April 1991 and November 2002, we reviewed retrospectively 140 patients with Hallux rigidus (179 great toes) who had undergone double-stem, hinge, and flexible silastic implant arthroplasty of hallux at our institution.

Inpatient and outpatient complications were recorded on patients' case notes in addition to regular patient follow-up for minimum 24 months. The main indications for surgery were hallux rigidus (80), hallux valgus with radiographic changes (54) and others (6). The cohort study included 124 females and 16 males with a mean age of 57.8 years (range 35 to 82). 60 procedures were performed on the right side and 41 on the left side. 39 were bilateral cases. Results: We identified 8 complications (5.7%) in 179 silastic implant arthroplasties. The complications included metatarsalgia (7%), superficial wound infection (7%), deep infection (1.6%), FHL rupture (0.5%), EHL rupture (0.5%), stitch granuloma (1%), EHL adherence to scar (0.5%) and DVT (0.5%). All the deep infection cases required removal of implants and conversion to Keller's procedure. 2 cases of metatarsalgia required removal of implants and conversion to Keller's procedure. Discussion: The low incidence of early complications would suggest that silastic implant arthroplasty of hallux can be safely performed. However, long-term follow-up is needed to evaluate the effect of inflammatory reaction of silicone and occurrence of silicone-rubber synovitis.

POSTER NO. P437

The Structure of the Anterior Talofibular Ligament of the Ankle

Tsukasa Kumai, MD, *Cardiff Wales, United Kingdom (n)*
Yoshinori Takakura, MD, Kashihara, Nara, Japan (n)
Kazuya Sugimoto, MD, Nara, Japan (*)
Arminu Rufai, MD, Cardiff, United Kingdom (*)
Michael Benjamin, Cardiff, S Glam, United Kingdom (*)

Purpose: We know little of the structure of the anterior talofibular ligament (ATFL) of the ankle - in comparison with the ACL of the knee. To understand the pattern of injuries in vivo, we need to know more about the ligament in situ. The purpose of the study is to show its histopathology and molecular composition in relation to the injury pattern. Methods: Samples of the entire ATFL, including both attachment sites were removed from 8 dissecting room cadavers (64-88 years of age) for routine histology and 5 fresh cadavers (29-44 years of age, within 48h of death) for immunohistochemistry. Differences in the structure of its two attachments were evaluated with quantitative, morphometric techniques, and regional differences in the distribution of collagens, glycosaminoglycans and proteoglycans were determined qualitatively by immunolabelling. Results: Morphometric analysis showed that bone density was less at the fibular attachment. Immunohistochemistry revealed the presence of a fibrocartilage (containing type II collagen and aggrecan) at the site where the ligament wraps around the lateral talar articular cartilage near its talar end: the fibrocartilage is an adaptation to resisting compression. Conclusions: We propose that avulsion fractures are less common at the talar end of the ligament because (1) bone density is greater here than at the fibular enthesis (2) stress is dissipated away from the talar attachment site by the _gwrap-around_h fibrocartilaginous character of the ligament. We believe our description of the anatomical characteristics of the ATFL provides an important foundation for understanding the basic mechanism of injury.

POSTER NO. P438

Posterior Tibial Tendon Pathology in Acquired Adult Flatfoot Deformity

Vincent A Fowble, MD, *Brooklyn, NY (n)*
Vincent J Vigorita, MD, Amagansett, NY (n)
Andrew K Sands, MD, New York, NY(*)
Eli Bryk, MD, New York, NY (n)

Introduction: Posterior tibial tendon insufficiency (PTTI) causes acquired flatfoot and morbidity. The histopathology and etiology remain unclear. We evaluated the microscopic pathology involved in PTTI. Materials and Methods: Twenty-eight PTT surgical specimens were obtained and fixed in formalin. Specimens were paraffin embedded, sectioned and stained with H&E and Masson trichrome stains, viewed in plain and polarized light, and analyzed for abnormalities including collagen orientation. Observations were made of the tenosynovial layer, the "subintimal" zone, and tendon proper. Results: All specimens displayed pathologic processes with varying severity. The overall microscopic appearance showed longitudinally oriented finger-like projections of neovascular infiltration causing collagen fibril disruption: 13 cases very pronounced. Other findings include: increased mucin content (8), chondroid metaplasia (10), tenosynovial hyperplasia (8), "subintimal" zone thickening and neovascularization (22). Only one specimen showed inflammatory cells. Tendon bundles on cross-section revealed a "ropiness", i.e. neovascular fibrotic bands encircling tendon collagen bundles. Discussion and Conclusion: Neovascular infiltration into the tendon was the most dramatic and prevalent finding. All specimens showed this change. Grossly abnormal specimens had diffuse neovascular infiltration derived from tenosynovial and "subintimal" proliferation, resulting in collagen bundle disruption, and associated with: 1) scarring (fibrosis and collagen bundle circumscription) and/or 2) degeneration (increased mucin and chondroid metaplasia). Findings may be secondary to either a reparative and/or degenerative process.We found no consistent evidence of ischemic change and only one specimen showed an inflammatory process, thus providing little histopathologic evidence supporting either's origin in PTTI. The etiology of this angiogenesis, the only substantive and consistent pathologic marker, is still unclear. It may have resulted from a traumatic, transient ischemic, or a remote inflammatory event. Contrary to previously reported studies, we believe the fundamental pathology is angiogenic, manifested as arborizing neovascularity throughout the tendon.

POSTER NO. P439

Plafondplasty for Increased Exposure in Osteochondral Autograft Transplantation to the Talar Dome

William Butcher, MD, *Milwaukee, WI (n)*
Mohsen Makhsous, PhD, Milwaukee, WI (n)
Valerie S Harder, Chicago, IL (n)
Greg Lee, MD, Milwaukee, WI (n)
Armen S Kelikian, MD, Chicago, IL (n)

INTRODUCTION:Osteochondral autograft transplantation is now an established treatment option for localized articular cartilage defects of the talar dome. Exposure during this procedure can sometimes be a problem however, especially with posterior medial lesions, thus necessitating a medial malleolar osteotomy. Reaming a semicircular trough in the anterior tibial plafond or "plafondplasty" has been described as an alternative to an osteotomy. The purpose of this study is to determine if a plafond-

plasty adversely effects the articular contact characteristics of the tibiotalar joint. Our hypothesis is that a plafondplasty causes no change in contact characteristics. METHODS:Using a digital pressure sensor and pressure-sensitive film, the contact area and pressure distribution within the tibiotalar joint before and after plafondplasty were compared. Ten fresh cadaver ankles were placed in a static axial loading apparatus. The loads simulated normal gait at four different ankle positions. The plafondplasty was standardized using a 10mm reamer centered on the anterior articular margin, 9mm from the medial edge of the talus. RESULTS:This study found no significant difference in the peak pressure, average pressure, or contact area of the tibiotalar joint after the plafondplasty (p 0.05, â 0.05). It was also noted that the area of articular cartilage sacrificed was smaller than expected. DISCUSSION AND CONCLUSION:The results of this study suggest that a plafondplasty does not disrupt the contact area or pressure distribution within the tibiotalar joint and therefore can be used as an alternative to a medial malleolar osteotomy in certain situations.

POSTER NO. P440

Tuberculosis of the Ankle Joint

Shih-Hao Chen, MD, *Kaohsiung Hsien, Taiwan (n)*
Yeung-Jen Chen, MD, Taipei, Taiwan (*)
Jih-Yang Ko, Niao Sung Hsiang, Taiwan (*)
Steve Wen-Neng Ueng, MD, Keelung, Taiwan (*)

Although chemotherapy is the first step in the management of skeletal tuberculosis, surgical debridement, biopsy, synovectomy or arthrodesis may be needed for definite diagnosis and treatment of the symptomatic ankle. Twenty-six cases of osteoarticular tuberculosis around the ankle joint were enrolled over 16 years period and followed up 52.3 months. Radiographs showed localized osteoporosis as stage I in 1 case, one or more erosion as stage II in 4 cases, destruction of the whole joint as stage III in 5 cases, and anatomic disorganization and subluxation as stage IV in 5 cases. Progression of staging was noted in the remaining 11 cases (42.3%) during the management course. Perioperatively sinus formation was found in 14 cases (53.8%) with mixed pathogens infection in 6 cases (23%). Accuracy rates of diagnosis were 4/17 (23.5%) in aspiration of synovial fluid, 17/25 (68%) in histology and 8/26 (30.7%) in bacteriology.Among 34 surgical procedures performed in 24 cases, the failure rate of incision-drainage was 3/4 (75%), and that of synovectomy was 6/12 (50%) with eventual arthrodesis. Except 2 generalized dissemination, 1 unrelated decease and 1 loss of follow-up, complete resolution was seen in 22 cases, revealing good result in 16 cases and fair result in 6 cases with sequelae of stiffness, joint pain and rocker-buttom deformity. Tuberculosis of the ankle joint is easily misdiagnosed and ultimately involves the neighboring joints and talar bone collapse. A success of treatment depends upon the accurate staging, optimal surgical management and duration of adequate chemotherapy.

POSTER NO. P441

◆Perioperative Complication Rate of Total Ankle Arthroplasty is Reduced by Surgeon Experience

Andrew Haskell, MD, *San Francisco, CA (n)*
Roger A Mann, MD, Oakland, CA (e – Link Orthopaedics)

Introduction: Recent studies suggest the perioperative complication rate of total ankle replacement decreases after surgeon familiarization with the procedure. This study tests the hypothesis that the perioperative complication rate decreases with increasing surgeon experience with total ankle replacement. Methods: A retrospective review of 189 cases of the Scandinavian Total Ankle Replacement was performed. Ten surgeons reviewed the first 10 cases they performed (Group A) and an additional 10 cases an average of 12.8 cases after the first group (Group B). Not all surgeons completed 10 cases in the allotted time periods resulting in 95 cases in Group A and 94 cases in Group B. Results: Patient age, sex, etiology of arthrosis, and preoperative coronal plane alignment were similar between the groups. The number of cases with complications (51 Group A, 35 Group B) and wound complications (24 Group A, 12 Group B) decreased ($p<0.05$). Fractures more often were treated closed in Group A (10 Group A, 3 Group B) and by internal fixation in Group B (5 Group A, 8 Group B) ($p<0.05$). There is a trend toward decreased number of secondary surgeries (24 Group A, 14 Group B) ($p=0.08$). Discussion/Conclusions: This study shows a 31 percent decrease in overall complications and 50 percent decrease in wound complications after a period of surgeon familiarization with total ankle replacement. This information is important for planning how to train surgeons new to total ankle replacement and for patient counseling regarding the potential risks of the procedure.

POSTER NO. P442

Radiographic Indicators of Deltoid Ligament Injuries in Ankle Fractures

Jeffrey A Kazaglis, MD, *San Antonio, TX (n)*
John F Kragh Jr, MD, San Antonio, TX (*)

Introduction: Since lateral malleolus fractures with complete deltoid injury usually require operative fixation, surgeons should understand the radiographic indicators of medial ankle instability. No report comparing the sensitivities of these parameters exists. The purpose of our study is to measure the sensitivities of eight radiographic indicators of ankle instability. Methods:We reviewed radiographs of thirty-eight patients with unstable ankle fractures without medial malleolus fractures We included only cases deemed unstable with a documented abnormal examination under anesthesia, i.e., fluoroscopic Cotton's test. The independent variables were eight radiographic parameters. Five of the parameters (parallel, perpendicular, top, corner, and maximum) were numeric. Three of the parameters (gestalt, lateral, and plumb) were binomial (normal or abnormal). The dependent variable was sensitivity. We measured the numeric distances manually with a ruler and compared them to published thresholds. We rank ordered the sensitivity of each variable, calculated 95% confidence intervals, and plotted sensitivity as a function of threshold. Results: For the numeric values, the most sensitive test was the maximum medial clear space with a sensitivity of 0.95 (95% C.I., 0.50 to 1.0) at a threshold of 4 mm. The least sensitive indicator was the medial clear space minus the tibio-talar joint space at 0.32 (95% C.I., 0 to 1.0). The binomial sensitivities for plumb line, lateral crescent, and gestalt were 0.45, 0.55, and 0.40 respectively. Our data indicated that binomial assessments of medial instability were not sensitive. Discussion: We measured the sensitivities of eight commonly used parameters of medial ankle instability in ankle fractures. We found that the maximum medial clear space is the most sensitive radiographic parameter to determine the presence of a true bimalleolar-equivalent injury requiring operative fixation and that binomial assessments of ankle radiographs were not sensitive.

POSTER NO. P443

Quality of Life in Hallux Surgery: A Prospective Study Comparing SF-36 and AOFAS-Hallux-Score

Lukas Karamat, MD, *Vienna, Austria (n)*
Wolfgang Schneider, MD, Wien-Vienna, Austria (n)
Karl Knahr, MD, Wien, Vienna, Austria (n)

Introduction:Health related quality of life after forefoot surgery has been assessed in only a few publications. We evaluated the quality of life in patients undergoing hallux surgery and compared the results with a well established clinical score (AOFAS-hallux-score). Patients and methods:150 patients were included in our study prospectively. We obtained complete pre- and postoperative SF 36 questionnaires in 124 cases (114 female, 10 male). The pre- and postoperative AOFAS-hallux-scores were also evaluated and all patients had standard weight-bearing radiography. Mean follow-up was 18,2 months (range 12,1-30,4). Results:The mean AOFAS-hallux-score improved statistically significant from 52,7 preoperatively to 81 points postoperatively. The mean results in the SF 36 subscales "Physical Function" and "Bodily Pain" also showed significant postoperative improvement from 70,3 to 76,6 points and 45 to 65 points respectively. We did not detect any significant changes in the remaining 6 scales of the SF 36. Conclusion:The pre- and postoperative results of the SF 36 scales "Physical Function" and "Bodily Pain" correlate with the results of the AOFAS-hallux-score subcategories pain and function. The remaining SF 36 scales (mostly mental health scales) are probably not influenced by hallux surgery.

POSTER NO. P444

Patient and Physician Based Outcomes Following the Brostrom-Gould Procedure

Adam R Brodsky, MD, *New York, NY*
(a – Hospital for Special Surgery)
John Kennedy, MD, New York, NY
(a – Hospital for Special Surgery)
Jonathan T Deland, MD, New York, NY (n)
Martin J O'Malley, MD, New York, NY (n)

Introduction. Physician based outcomes following the Brostrom-Gould procedure have been uniformly excellent. The current study investigates the hypotheses that outcomes following this procedure should weighted towards a quality of life questionnaire, rather than physician based outcomes scores. Methods 73 consecutive patients with unilateral Brostrom-Gould repairs were evaluated Mean follow-up was 64 months. Patients were evaluated with the AOFAS hind-foot score in addition to the SF-36. Results The overall AOFAS hind-foot score was 94.7. The overall percentage SF-36 score was 81.6 . No correlation was found between the two scores. Sixty-nine patients would have the procedure again. Of the two patients who would not have the procedure again, the AOFAS scores were 86 and 90 respectively, while the SF-36 scores were 62 and 68. Conclusion. The Brostrom-Gould procedure remains an effective surgical treatment in the management of lateral ankle instability. However, conventional AOFAS hind-foot scores may not identify those patients with an unsatisfactory outcome. Validity of outcome interpretation using contemporary physician based hind-foot scores, may be questioned in the absence of a patient based outcome module in future studies.

POSTER NO. P445

Peroneal Tendon Pathology in Sporting Activity

James Keith DeOrio, MD, *Jacksonville, FL (n)*

Introduction: Contrary to previously published reports, patients undergoing surgery for peroneal tendon pathology only have a 50 percent chance of returning to their former activity level. Methods: 28 patients with peroneal tendon pathology were reviewed. This included 14 peroneus brevis tendon tears, 9 peroneus longus tears (1 combined), 3 aberrant tendons, and 3 degenerative tendons. For the frank tears, 4 were repaired, 8 had a portion excised (1 complete), and 10 underwent both. Follow up was from 6 months to 5.5 years and averaged 25 months in 22 of the 28 patients. Sudden injuries resulted in 62 percent of the patients' pathology. The average delay from the time of injury to surgery was 10 months. Results: Postoperatively, 91 percent indicated they had residual pain, 29 percent at rest and 57 percent with activity. 48 percent indicated scar tenderness and swelling, 33 percent numbness, 33 percent decreased range of motion, and 48 percent had an inability to wear high heel shoes. Only 11 had unlimited function and 7 limited recreational activity. 12 were satisfied without reservation and 7 were satisfied with reservation. MRI scan was positive in all patients with peroneal tendon pathology identifying correctly the tear in the peroneus brevis or peroneus longus 88 percent of the time. Conclusion: Only - of the patients operated on for peroneal tendon pathology will be able to return to a high level of sporting activity.

POSTER NO. P446

Fresh Ankle Osteochondral Allografting (Transplantation) for Tibiotalar Joint Arthritis

Robert E Meehan, MD, *Detroit, MI (n)*
Michael E. Brage, MD, San Diego, CA (n)
William Bugbee, MD, La Jolla, CA (n)
William L Tontz, MD, San Diego, CA (*)
Sarah McFarlin, MD, San Diego, CA (*)

Introduction Conventional treatment of tibiotalar joint arthritis relies on arthrodesis or prosthetic arthroplasty. We propose the use of fresh osteochondral allografting as an alternative procedure. Methods Eleven patients, average age 43; range 18-65, underwent fresh osteochondral grafting of the tibiotalar joint. Seven patients had posttraumatic arthritis, two osteoarthritis, and two an osteochondral defect. Cuts were made with ankle arthroplasty jigs. Results At a minimum follow-up of 24 months, average 31; range 24-43, eight patients, 72% were satisfied. The average AOFAS score improved from 55 to 76, p=0.02. The patient's pain, gait and walking surface scores were all significantly improved, p<0.05. Additional surgery included four talofibular joint debridements, two regrafting for early failure, and one conversion to a prosthetic replacement. Radiographs revealed graft collapse of greater than 3mm in five patients. Poor results occurred in patients with a size mismatch, or graft thickness < 7mm. Conclusion Fresh osteochondral allografting offers a viable alternative for tibiotalar joint arthritis. Early results demonstrate successful outcomes. Summary: Fresh osteochondral allografting (transplantation) for tibiotalar joint arthritis provides a viable alternative to arthrodesis and prosthetic replacement.

POSTER NO. P447

Syndesmotic Instability in Weber B Ankle Fractures: A Clinical Evaluation

Paul Tornetta III, MD, *Boston, MA (n)*
William R Creevy, MD, Boston, MA (n)
Erik Stark, MD, Boston, MA (*)

Introduction: Syndesmotic instability may coexist with Weber B lateral malleolar fractures. This study evaluated syndesmotic stability with respect to current recommendations for syndesmotic fixation in Weber B lateral malleolar and bimalleolar fractures. Materials Methods: 291 patients with unstable SE pattern Weber B ankle fractures were evaluated (115 bimalleolar injuries, 176 lateral malleolar injuries with deltoid ligament incompetence). Fractures were treated by standard ORIF. After fixation, syndesmotic stability was evaluated using stress radiograph or direct observation. Any subluxation of the talus or more than 2 mm of syndesmotic widening or posterior translation were used as criteria for the diagnosis of syndesmotic instability and trans-syndesmotic fixation was added to the construct. Results: Syndesmotic instability was found in 36 percent of fractures after bony stability was restored. Lateral malleolar fractures associated with deltoid injury had a 40 percent rate of syndesmotic instability compared with 30 percent for bimalleolar SE4 fractures. The vast majority of the bimalleolar fractures that had associated syndesmotic instability were anterior colliculular fractures (94 percent) rather than supracollicular fractures (6 percent). Discussion: We found syndesmotic instability to be common after anatomic and stable bony fixation in Weber B, SE type unstable ankle injuries. We recommend individual examination of the syndesmosis after ORIF performed by stress radiograph or direct examination. Conclusions: Previously published criteria for syndesmotic instability based on cadaveric studies are not representative of the clinical situation. Syndesmotic instability is common after bony fixation in unstable Weber B, SE type ankle fractures and must be sought out and treated.

POSTER NO. P448 – ORS

The Mechanism Of Pain Relief In Extracorporeal Shock-Wave Therapy

Norimasa Takahashi, MD, Chiba, Japan (n)
Seiji Ohtori, MD, Chiba, Japan (n)
Takashi Saisu, MD, Chiba, Japan (*)
Yuiti Wada, MD, Chiba, Japan (*)
Kenji Takahashi, MD, La Jolla, CA (*)
Nobuyasu Ochiai, MD, Chiba, Japan (*)
Hideshige Moriya, MD, Chiba, Japan (*)

INTRODUCTION: There have been many reports on the use of extracorporeal shock-waves (ESW) for the treatment of chronic plantar fasciitis. However, the mechanism of pain relief from this therapy has not yet been clarified. We evaluated the analgesic properties of ESW application using animal. METHODS: 1) ESW were applied to the planter skin of 15 rats. Skin and dorsal root ganglia (DRGs) innervating the skin were harvested, sectioned, and processed immunohistochemically using antibodies to PGP9.5 and CGRP which are involved in pain perception. 2) In another group, repeated ESW were applied at interval of 14 days. The numbers of PGP9.5 and CGRP- immunoreactive (IR) were also evaluated. RESULTS: The number of PGP9.5- or CGRP-IR nerve fibers on days 2 and 7 were significantly less than in non-treated skin. However, re-innervation of these nerve fibers occurred on days 14 and 21. Furthermore, the ratio of CGRP-IR DRG neurons in the ESW group was significantly less than that in the non-treated group. We also showed significant decrease of CGRP-IR nerve fibers in repeated application group. The number of these nerve fibers at day 42 in repeated treatment group was significantly less than in the single treatment group. DISCUSSION: ESW application may lead to the destruction of the CGRP- and PGP9.5-IR nerves, and depression in CGRP levels in DRG. Re-innervation in the skin commenced, however, its re-innervation depressed after second ESW application. In clinical, ESW have been applied two or three times. The observation in the current study may explain the clinical analgesic effect of repeated ESW therapy.

SCIENTIFIC EXHIBITS

SCIENTIFIC EXHIBIT NO. SE024

What's New in Surgical Options for Hallux Rigidus? Guidelines Based on Review of 104 Consecutive Cases at 4-Year Follow-Up

Sandro Giannini, MD, *Bologna, Italy (n)*
Francesco Ceccarelli, MD, Bologna, Italy (n)
Cesare Faldini, MD, Bologna, Italy (n)
Roberto Bevoni, MD, Bologna, Italy (n)
Gianluca Grandi, MD, Bologna, Italy (n)
Francesca Vannini, MD, Bologna, Italy (n)

Introduction: Hallux rigidus (HR) is a limitation of dorsiflexion of the first metatarsophalangeal joint associated with pain, and its treatment remains a debated topic in orthopaedic surgery. Most authors have recommended resection arthroplasty of the first metatarsophalangeal joint in the past, but others, more recently have presented good results with cheilectomy, various types of osteotomies and arthrodeses or bioreabsorbable implant. The aim of this paper is to present guidelines of treatment of HR based on the review of our series of 111 consecutive feet. Methods: 86 patients (67 female and 19 male) were treated between 1992 and 2002. Labelling factors of each HR were considered for classification. In 7 cases without arthritis, surgical treatment consisted in plantar release. In 18 cases with a grade I HR treatment consisted of distal decompressive osteotomies. In 33 cases with a grade II HR treatment consisted of cheilectomy. In 53 cases with a grade III HR treatment consisted of arthrodesis or resection arthroplasty using bioreabsorbable implant. Immediate weightbearing was allowed with gauze bandage and talus shoes for 4 weeks. All patients were clinically (AOFAS score) and radiographically checked at an average follow-up of 4 years. Results: The clinical preop score was 42+14 and at follow-up was 81+9. The preop mean metatarsophalangeal ROM was 27+17, while at follow-up was 75+8 ($p<0.001$). Discussion and conclusion: Surgical treatment of HR depends on the patho-anatomy, and the precise evaluation of labelling factors, is the key point to obtain optimal results.

PAPERS

PAPER NO. 041

Microsurgical 2nd Toe-Metatarsal Transfer for Congenital Radial Club Hand with Absence of Thumb

Yuan-Kun Tu, MD, *Keelung, Taiwan (n)*
Steve Wen-Neng Ueng, MD, Keelung, Taiwan (n)
Ying-Chao Chou, MD, Keelung, Taiwan (n)

IntroductionThe goal of surgery for Bayne type 4 radial club hand without thumb (Blauth type 3-5) is to achieve a better functioning and cosmetic hand. However, the parents often find it difficult to sacrifice a Blauth type 3B thumb, and refuse pollicization due to culture causes. We report using free toe transfer for reconstruction of these congenital deformities. Materials and MethodsFrom 1996 to 2000, 11 patients received ¡§ free 2nd toe-metatarsal transfer¡¨ for the reconstruction of radial club hands without thumb. The average age was 3 years old, with average follow up 4 years. There were 5 patients with Blauth type 4, 4 with type 5, and 2 with type 3B deformity. The first case was a 2 years old girl with 3 digits on her radial club hand. Parents worried about the pollicization would turn their kid into an ¡§ET¡¨ hand. Therefore we performed the first 2nd toe-metatarsal transfer in our series. After the first successful reconstruction, we continued our microsurgical works in the following 10 cases. ResultsAll the vascular anastomosis were successful, with an average operation time of 8 hours. The postoperative function of grip and range of motion were acceptable, as well as the S2PD. Our patients obtained rather satisfactory clinical results, and their parents were pleased with these reconstruction procedures. ConclusionsBased on our preliminary report, free 2nd toe-metatarsal transfer seems to be an acceptable alternative method for the reconstruction of radial club hand without thumb.

PAPER NO. 042

Management of Recurrent Carpal Tunnel Syndrome with Microneurolysis and Hypothenar Fat Flap

Scott Furm Mofford Duncan, MD, *Phoenix, AZ (n)*
Anthony Smith, MD, Scottsdale, AZ (n)
Kevin J Renfree, MD, Scottsdale, AZ (n)

Introduction:Failure of open carpal tunnel decompression occurs in 3 to 19% of cases. Common causes include incomplete release, tenosynovitis, postoperative adhesions, and intraneural fascicular scarring. Different authors have advocated repeat carpal tunnel release with neurolysis, hypothenar fat flaps, vein wrapping, ulnar nerve release, transverse carpal ligament reconstruction, and other surgical interventions to relieve recurrent symptoms. Methods:We report on 16 consecutive cases of recurrent carpal tunnel syndrome treated with microneurolysis and hypothenar fat flaps. The average interval between the original carpal tunnel release and the re-release was 22 months (6-58 months). Average age of the patients was 56 years (32-78 years). Average follow up was greater than 2 years and ranged from 13- 62 months. Results:Pain completely disappeared in 75% of patients with improvement in sensation and strength. The remaining 25% had disappearance of nocturnal symptoms but continued to have persistent dysesthesias. Electromyographic studies showed improvement in 81% of patients at one-year post-operative testing. All 16 patients were satisfied with their results and said they would have the procedure again. Scar pain dissipated at 6-9 months in all patients. There have been no recurrences. Discussion and Conclusion:The results of this study suggest that the combination of using a microscope for neurolysis and a hypothenar fat flap, can restore median nerve gliding and provide soft tissue coverage improving symptoms in the patient with recurrent carpal tunnel disease. This is an efficient technique for salvaging the patient with recurrent carpal tunnel syndrome.Introduction:Failure of open carpal tunnel decompression occurs in 3 to 19% of cases. Common causes include incomplete release, tenosynovitis, postoperative adhesions, and intraneural fascicular scarring. Different authors have advocated repeat carpal tunnel release with neurolysis, hypothenar fat flaps, vein wrapping, ulnar nerve release, transverse carpal ligament reconstruction, and other surgical interventions to relieve recurrent symptoms. Methods:We report on 16 consecutive cases of recurrent carpal tunnel syndrome treated with microneurolysis and hypothenar fat flaps. The average interval between the original carpal tunnel release and the re-release was 22 months (6-58 months). Average age of the patients was 56 years (32-78 years). Average follow up was greater than 2 years and ranged from 13-62 months. Results:Pain completely disappeared in 75% of patients with improvement in sensation and strength. The remaining 25% had disappearance of nocturnal symptoms but continued to have persistent dysesthesias. Electromyographic studies showed improvement in 81% of patients at one-year post-operative testing. All 16 patients were satisfied with their results and said they would have the procedure again. Scar pain dissipated at 6-9 months in all patients. There have been no recurrences. Discussion and Conclusion:The results of this study suggest that the combination of using a microscope for neurolysis and a hypothenar fat flap, can restore median nerve gliding and provide soft tissue coverage improving symptoms in the patient with recurrent carpal tunnel disease. This is an efficient technique for salvaging the patient with recurrent carpal tunnel syndrome.

PAPER NO. 043

27-Year History of Malpractice Lawsuits for Surgical Treatment of Carpal Tunnel Syndrome in NY State

Carter B Lipton, MD, *New York, NY (*)*
Benton E. Heyworth, BA, New York, NY (*)
Brian W Su, MD, New York, NY (*)
Andrew H Patterson, MD, Bronxville, NY (n)
Melvin Paul Rosenwasser, MD, New York, NY (*)

Purpose: The purpose of this study was to investigate the hypothesis that malpractice lawsuits associated with treatment of carpal tunnel syndrome (CTS) are more common in cases involving endoscopic techniques. Methods: The legal records of closed cases in New York State from Medical Liability and Mutual Insurance Company (MLMIC), the U.S.'s largest medical malpractice insurance company, were reviewed for claims related to CTS between 1975 and 2002. Additionally, all cases with the ICD-9 code for CTS from inpatient and outpatient surgery between the years 1984-2002 from the Statewide Planning and Research Cooperative System (SPARCS) data were analyzed. Results: 73 lawsuit claims were identified related to surgical management of CTS, with 67 percent resulting in indemnity payments to the plaintiff (mean: $166,000). Common causes for claims included: nerve laceration (49 percent), development or exacerbation of reflex sympathetic dystrophy (RSD) (12 percent) and wrong operation or operative side (7 percent). RSD cases resulted in the

highest mean indemnity payments ($410,000). Since 1992, 15 percent of CTS procedures were performed endoscopically, but 46 percent of nerve laceration claims were endoscopic cases ($p < .01$). Mean indemnity payments for endoscopic cases were $252,000, compared to $157,000 for open cases over this time. Five of the six claims involving complete transection of the median nerve were endoscopic procedures. Conclusions: Surgical treatment of CTS is associated with a relatively large number of malpractice lawsuits in New York. These result in high payments to the plaintiff. In cases involving nerve injuries, endoscopic technique has resulted in significantly more lawsuits than open technique.

PAPER NO. 044

Articular Surgery for the Hand in Systemic Sclerosis (Scleroderma)

Andrew Derek Thomas, *New York, NY (n)*
Charles P Melone Jr, MD, New York, NY (n)
Steven Beldner, MD, New York, NY (n)

INTRODUCTION Debilitating hand deformity characterized by interphalangeal (IP) flexion and metacarpophalangieal (MCP) extension contractures is a hallmark feature of diffuse cutaneous systemic sclerosis (dSSc). This study analyzes the results of articular reconstruction employing arthrodesis and arthroplasty for 80 patients with painful, disabiling dSSc of the hand. METHODS Eighty dSSc patients who demonstrated advanced IP flexion and MCP extension contractures underwent articular hand surgery. 266 joints were reconstructed; 221 by IP arthrodesis and 45 by MCP silicone arthroplasty. For staged reconstruction, arthrodeses, as a first stage, were secured with K-wires until union; arthroplasties, as a second stage, were managed with early motion and dynamic splinting. A tension-free wound closure was essential for uncomplicated healing and for 55 joints no skin sutures were used. RESULTS Follow-up ranging from three to twelve years (average 5.25 years) revealed: 1) uncomplicated wound healing by primary or secondary intention 2) eradication of painful ulcers, 3) radiographic union of 203 (92%) arthrodeses within eight weeks of surgery, 4) a forty-eight degree average arc of motion for MCP arthroplasties without evidence of implant failure, 5) considerable functional and aesthetic improvement, and 6) uniform patient satisfaction. CONCLUSION This study, the first reported series of combined arthrodeses and arthroplasty for the dSSc hand, substantiate the efficacy of articular surgery for the hand in systemic sclerosis. Both arthrodesis and arthroplasty have demonstrated a predictable, favorable healing process consistently resulting in prevention of tissue loss, improved function, enhanced aesthetics and high levels of patient satisfaction

PAPER NO. 045

Metacarpophalangeal Joint Arthroplasty in Rheumatoid Arthritis: A Long- Term Assessment

Charles A Goldfarb, MD, *Saint Louis, MO (n)*
Peter D Stern, MD, Cincinnati, OH (n)

Many rheumatoid arthritis patients at longterm followup after metacarpophalangeal joint arthroplasty have a less than ideal outcome. Fractured implants, recurrent deformity, and decreased motion are commonly seen. The purpose of this investigation was to comprehensively evaluate patient outcome at longterm followup. Methods: A total of 208 arthroplasties in 52 hands of 36 patients were evaluated at an average of 14 years postoperatively. Active motion, ulnar drift, and radiographs were assessed. The Michigan Hand Outcomes Questionnaire was administered. Results MCP motion improved immediately after surgery but declined with time. Mean arc of motion improved from 30 degrees preoperatively to 46 degrees after surgery but decreased to 36 degrees at final followup. Mean ulnar drift improved from 26 degrees preoperatively to neutral but recurred to an average of 16 degrees at final follow up. 63% of implants were broken and 22% more were severely deformed. Significant bone shortening was noted in most patients and bony erosions were seen in 29% of patients. The MHQ averaged 48 of 100 points. Only 40% of patients were satisfied with function and only 27% of hands were painfree at final followup. Conclusions The outcome after silicone MCP joint arthroplasty in rheumatoid arthritis worsens with long- term follow up. A large percentage of implants are fractured with a loss of motion and recurrent deformity commonly seen. Bony changes are commonplace adjacent to implants.

PAPER NO. 046

Vascular Changes of the Hand in Professional Baseball Players: Digital Ischemia in Catchers

Thomas Adam Ginn, MD, *Winston-Salem, NC (n)*
Adam M Smith, MD, Rochester, MN (*)
Jonathan Snyder, Winston-Salem, NC (*)
L Andrew Koman, MD, Winston-Salem, NC (n)

Introduction: This study prospectively investigates the incidence of neurovascular hand pathology in professional minor league baseball players. Methods: Thirty-six players on active minor league rosters underwent examination of both hands with doppler ultrasound, timed Allen test, digital brachial pressure monitoring, and ring sizing of fingers. Data was analyzed to compare positions and hitters versus non-hitters: catchers(9), outfielders(7), infielders(5), and pitchers(15). Results: Digital brachial indices in the ring and index fingers in catchers were significantly diminished compared to all other players. Measurement of the timed Allen test demonstrated no significant difference between groups. Doppler testing demonstrated a significant incidence of abnormal flow in catchers along the path of the ulnar artery when compared to other position players ($p<.05$). Doppler abnormalities were significantly more common in the gloved hand compared to the throwing hand ($p<.05$). Catchers demonstrated significant index finger hypertrophy in the gloved hand in 7/9 players (average increase of 5mm in circumference when compared to the contralateral hand). Only catchers were found to have index finger hypertrophy ($p<.05$). 5/9 catchers complained of resting glove-hand pain, weakness, tingling or numbness, and all (9/9) complained of similar intermittent symptoms during games. Discussion/Conclusions: The effect of repetitive microtrauma to the hands of athletes is well-documented. This study is significant because it confirms the presence of microvascular changes in the hands of otherwise healthy players prior to the development of significant ischemia. Gloves used by professional catchers do not adequately protect the hand from microvascular trauma.

PAPER NO. 047

Comparison of Spontaneous Recovery and Nerve Surgery in Brachial Plexus Injury

Jin Soo Park, MD, *Kangwon-Do, Korea, Republic of (n)*
Moon Sang Chung, MD, Seoul, Korea, Republic of (n)
Goo Hyun Baek, MD, Seoul, Korea, Republic of (n)
Yung Khee Chung, MD, Seoul, Korea, Republic of (n)
Jung-Han Yoo, MD, Seoul, Korea, Republic of (n)

There has been no general agreement about optimal time for nerve surgery in closed brachial plexus injury. From our early experiences, we knew by chance that spontaneous recovery in BPI patients may begin even later than 8 months after injury.

From 1985 to 2000, we observed 103 patients with BPI who did not any operation until 8 months after injury. Ninety five were male and 8 were female with a mean age of 29 years. Whole plexus types were observed in 56 patients (54%), upper plexus types in 29 (28%), lower plexus types in 3 (3%), and infraclavicular types in 15 (15%). Electromyographies were performed in all patients and repeated every three months. Results were evaluated by authors' criteria, a modification of the American Medical Association system. Duration of follow-up was 50 months in average. Forty seven patients (46 %) showed spontaneous improvement which was assessed by electromyography and detected 7.8 months (range, 3-16 months) in average after trauma. The average score of these 47 patients improved from 14.8 points preoperatively to 39.8 points postoperatively. Thirty one patients (30%) had nerve surgery (nerve graft, neurotization or neurolysis). The interval from injury to nerve surgery was 10 months in average. Among 31 patients who had nerve surgery, 16 patients improved from 21.5 points to 36.3 points in average. Because spontaneous recovery began 7.8 months after injury in average, it would be reasonable to 'wait and see' until at least one year in expectation of spontaneous recovery.

PAPER NO. 048

Capsulodesis for Chronic Scapholunate Dissociation

Steven Moran, MD, *Rochester, MN (n)*
William P Cooney III, MD, Rochester, MN (n)
Richard A Berger, MD, PhD, Rochester, MN (n)

Capsulodesis for Chronic Scapholunate DissociationChronic scapholunate instability remains a therapeutic challenge. Ligament repair and capsulodesis is our first line of treatment for all but fixed deformities. In this study, we examined the results of two different capsulodesis used to treat chronic scapholunate instabilityStudy: We reviewed 398 wrist procedures and identified 31 with long-term follow-up average 4.5 years who had isolated chronic S-L instability treated by ligament repair and dorsal capsulodesis. Results were evaluated clinically and radiographically and assessed with Mayo wrist score. Time to presentation for evaluation and surgery average 20 months. We compared the Blatt capsulodesis with the Mayo dorsal intercarpal ligament capsulodesis. Results: All patients improved in pain with no patient requiring a re-operation. Grip strength averaged 83% and motion 70% of the uninjured side. The Mayo wrist score averaged 73, range 60-90 representing fair to good results, with no excellent results. Patients with the Mayo capsulodesis not crossing the radiocarpal joint (dorsal capsulodesis) had the better results than with the Blatt capsulodesis.We observed that patients with chronic S-L dissociation had fairly consistent pain relief with most activities, but were not totally pain free. Perhaps late surgical intervention contributed to inability to completely restore wrist function. Improved techniques of capsulodesis and longer stabilization of the scapholunate interval may improve the long-term outcomes of chronic ligament injuries of the wrist. Conclusion: Capsulodesis is a reliable procedure for relief of pain associated with chronic scapholunate instability, but it does not restore normal kinematics nor close the scapholunate diastasis. Correction of the rotary instability of the scaphoid appears sufficient for pain relief and to prevent radiocarpal arthritis.

PAPER NO. 049

Fragment Specific Fixation of Distal Radius Fractures

Leon S Benson, MD, *Glenview, IL (b- Trimed, Inc)*
David Flanigan, MD, Madison, WI (*)
Laura D Stern, Glenview, IL (*)
Craig S Williams, MD, Des Plaines, IL (n)
Jeffrey L Visotsky, MD, Des Plaines, IL (*)

Purpose: To examine the use of fragment specific internal fixation for comminuted distal radius fractures. Methods: A retrospective review was performed on 93 comminuted intra-articular distal radius fractures (in 89 patients) treated with fragment specific internal fixation. Fractures were classified according to both the Frykman and AO systems. Range-of-motion recovery and functional outcomes were documented by data collected in office and occupational therapy environments. Data was also collected with respect to wound healing problems, infections, hardware removal, and malunion. Results: Average patient age was 50 years (range 17 to 79 years) with an average follow-up of 18 months (range 12 to 38 months). Frykman Types 7 and 8 accounted for 92% of the fractures; according to the AO system, 94% were Types C2 or C3. There were no wound infections. Hardware removal was warranted in ten patients. Tourniquet times for the entire patient group averaged 97 minutes (range 71 to 125). Most patients were splinted for three days after surgery and then allowed to pursue occupational therapy for wrist motion. Recovery of wrist motion and function was predictable and usually achieved within the first six weeks after surgery. Discussion and Conclusion: While major complications were few and consisted mainly of loosened K-wires requiring removal, the learning curve for this technique is quite steep and operative times are significantly longer than those for external fixator application. Fragment specific fixation, however, did allow early wrist motion after surgery, often within the first week, even for patients with severe distal radius fractures.

PAPER NO. 050

Functional Outcome and Complications after Dorsal Plating for Unstable Fractures of the Distal Radius

Tamara D Rozental, MD, *Philadelphia, PA (n)*
Pedro K Beredjiklian, MD, Philadelphia, PA (n)
David J Bozentka, MD, Wallingford, PA (n)

Introduction: The purpose of this study is to determine the complications and functional outcome of patients treated with dorsal plating for dorsally displaced, unstable distal radius fractures. Methods: The records of all patients treated at our institution with internal fixation using dorsal plates for dorsally displaced, comminuted distal radius fractures were reviewed. Patients with follow-up less than 12 months were excluded from the study. Outcomes were evaluated at latest follow-up using the DASH and the Gartland and Werley scoring systems. Results: 28 patients (19 women, 9 men), with an average age of 41.6 years form the basis of this study. Average follow-up: 21months (12 months to 3.2 years). Patients were treated with Synthes pi (n=19) or low-profile plates (n=9). There were no instances of loss of reduction, malunion or non-union. The average score on the DASH questionnaire was 14.5 (range 10-28.5). All patients had excellent (61.5%) or good (38.5%) results on the Gartland and Werley scoring system. Results continued: A total of 9 patients experienced post-operative complications requiring repeat surgical treatment for hardware removal or tendon reconstruction. All re-operations occurred in patients treated with Synthes pi plates (n=9, 47.3%), while no patients treated with low profile plates (n=0, 0%) required hardware removal ($p < 0.025$). We identified four complications in patients treated with titanium plates and five complications in

patients treated with stainless steel plates regardless of plate design. (p=0.71) Conclusions: There is a paucity of data in the literature documenting functional outcomes of patients treated with dorsal plates for distal radius fractures. Patients treated with titanium or stainless steel Synthes pi plates have a significantly increased risk of complications compared to those treated with low profile plates. Regardless of the type of plate used, all patients had good or excellent functional long-term outcomes.

POSTERS

POSTER NO. P449

Diphyseal Nonunion of the Forearm

David Ring, MD, *Boston, MA (a – AO Foundation)*
David Rind, MD, Boston, MA (a – AO Foundation)
Kourosh Jafarnia, MD, Houston, TX (a – AO Foundation)
Christian Allende, Boston, MA (n)
Jesse B Jupiter, MD, Weston, MA (b – AO Foundation)

Introduction: With current plate and screw fixation techniques, diaphyseal nonunions of the radius and ulna are unusual. Methods: Thirty-nine ununited diaphyseal fractures of the forearm were treated with plate and screw fixation and autogenous cancellous bone grafting. Thirty fractures were the result of high-energy trauma, 24 were associated with open wounds, and 14 patients had instability of the distal radioulnar joint. Nineteen nonunions involved the radius alone, 11 the ulna alone, and 9 both bones. All but 2 patients had previous surgical treatment. Fifteen patients had plates of inadequate size or length. Fifteen patients had prior infections. All but two of the nonunions were atrophic, the other 2 were hypertrophic. In 25 patients there was an absolute bony defect averaging 3.2 centimeters in length. Results: One patient required a second procedure to gain union. Another had a second fracture at the proximal limit of the plate successfully treated with internal fixation. At an average follow-up of 38 months, all of the fractures were healed. All patients had decreased or no pain, improvement in strength, stability, function and aesthetics, but five patients were rated unsatisfactory due to stiffness and pain. Discussion: With current treatment of diaphyseal forearm fractures, failure to heal is uncommon and is often associated with open fractures (61.5%), fracture-dislocation of the forearm (36%), infection (38%), inadequate plates (38%) and absolute bony defects (64%). Nonetheless, healing can be obtained with the provision of a well-vascularized soft-tissue envelope, autogenous cancellous bone grafting, and stable internal plate fixation.

POSTER NO. P450

Pitfalls in the Treatment of Volar Shearing (BartonFs) Fractures of the Distal Radius

David Ring, MD, *Boston, MA (a – AO Foundation)*
Neil G Harness, MD, Somerville, MA (n)
Jesse B Jupiter, MD, Weston, MA (b – AO Foundation)

Introduction: While the results of plate fixation of volar shearing fractures are good in most cases, there are several pitfalls. Modifications of standard volar buttress plating may help limit problems. Methods and ResultsPart 1: During an 8-year period, 44 consecutive patients with a volar shearing fracture of the distal radius were treated with standard volar buttress plating. During this period two pitfalls were noted: four patients with a comminuted volar articular margin had subluxation of the carpus with a small volar lunate facet fragment; and three patients had dorsal translation and angulation of the articular fragments due to an unrecognized dorsal metaphyseal fracture line. Part 2: During a subsequent 3-year period, 33 consecutive patients with a volar shearing fracture of the distal radius were treated with a modified technique that accounted for a dorsal metaphyseal fracture line, radial styloid fracture, small volar lunate facet fragments. During this period none of the patients had volar subluxation of the carpus or dorsal translation of the articular fragments. Conclusions: Fractures of the volar articular margin of the distal radius are best treated with volar plate and screw fixation. Pitfalls such as loss of control of a small volar lunate fragment with carpal subluxation and overreduction of the articular fragments or radial styloid can be limited through awareness of these common, but often unrecognized injury components and modification of the plating technique when needed.

POSTER NO. P451

Computed Tomography of Suspected Scaphoid Fractures

David Ring, MD, *Boston, MA (a – AO Foundation)*
Lauren P Adey, MD, Roslindale, MA (n)
Seth Levitz, BA, Boston, MA (n)
Jesse B Jupiter, MD, Weston, MA (b – AO Foundation)

Introduction: The use of computed tomography (CT) for triage of suspected scaphoid fractures is commonplace in Europe, but few data have been presented supporting its use. Methods: Using an IRB-approved prospective protocol and after informed consent, 20 patients with suspected scaphoid fractures were evaluated with CT scans. These 20 CT scans were compared with CT scans obtained from 16 patients with non-displaced fractures of the scaphoid. The scans were evaluated by five blinded observers. Results: Only one patient with a suspected scaphoid fracture had a true fracture. CT identified an alternative source for the radial sided wrist pain (fracture of the radial styloid or trapezium) in seven of the remaining 19 patients (43%). Among the five blinded reviewers sensitivity for fracture of the scaphoid averaged 94% (range 88 to 100%), specificity 90% (range 86 to 100%). The Kappa values for agreement between observers were excellent (> 0.75) for five comparisons but only fair to good (between 0.40 and 0.75) for the remaining five. Conclusions: Computed tomography proved safe and effective for the triage of suspected scaphoid fractures and often disclosed an alternative, less worrisome, source of the radial side wrist pain. Nonetheless, caution is advised when using computed tomography for the diagnosis of a fracture of the scaphoid because nondisplaced fractures of the scaphoid can be very subtle on CT and may be difficult to distinguish from vascular foramina and other linear opacities.

POSTER NO. P452

Surgical Approaches to the Scaphoid Bone: An Anatomic Study of the Radial Artery

Steve K Lee, MD, *New York, NY (n)*
Alexis Chiang, MD, New York, NY (*)
Ericka Ann Lawler, MD, New York, NY (*)
Sacha D Matthews, MD, Portland, ME (*)
Steven Marshall Green, MD, New York, NY (*)
Martin A Posner, MD, New York, NY (n)

PURPOSE: To determine safe surgical approaches to the scaphoid bone relative to the radial artery. METHODS: Eleven embalmed wrists were dissected and the scaphoid was exposed through three different approaches: snuffbox, palmar, and dorsal. The radial artery was localized to specific anatomic land-

marks. RESULTS: The radial artery had a highly variable course around the scaphoid bone. The mean distance of the radial artery from the mid-waist of the scaphoid bone was 1.7 mm. CONCLUSIONS: Anatomic Snuffbox: Due to anatomic variability, there is no absolute safe zone in the anatomic snuffbox, but rather a relative safe zone, which is just distal to the radial styloid, equidistant in the dorsal and palmar planes. We define this as the Optimal Entry Point (OEP), which is both a relatively safe entry point with regards to adjacent structures and an optimal entry point in the scaphoid for intercarpal fixation. Palmar Approach: The superficial branch of the radial artery has a variable course around the scaphoid tubercle, either ulnar or radial to it and as close as 5 mm from its center. For closed fixation of scaphoid fractures, we recommend a limited incision and blunt spreading. Dorsal Approach: The radial artery is closely associated with the scaphoid waist, with a mean distance of 1.7 mm. The extracapsular radial artery may not be visualized from within the capsule, but an awareness of its proximity to the scaphoid waist should reduce the risk of iatrogenic injury.

POSTER NO. P453

Intramedullary Fixation of Proximal Pole Scaphoid Fractures: Does Screw Size Matter?

John F Dalton, MD, *Doraville, GA (n)*
Gary R McGillivary, MD, Atlanta, GA (n)
Andrew P Gutow, MD, Ann Arbor, MI (b – Acumed, Inc)

INTRODUCTION: The purpose of this study was to investigate the biomechanical properties of the Acutrak (Acumed, Inc., Beaverton, OR) Standard and Mini screws in fixation of proximal pole scaphoid fractures. METHODS: Seven matched pairs of scaphoids were harvested from cadaveric wrists. Paired bones were randomized to either Acutrak Standard or Mini screw fixation. Proximal pole fractures were created and retrograde screw placement was performed. Three-point bending loads were applied to each scaphoid. Failure was defined as fragment displacement of 1.0 mm, loosening of fixation, or cortical fracture. RESULTS: The mean load-to-failure was 362.28 N (range: 168.21 to 495.69 N) for the standard screw and 286.03 N (range: 65.83 to 454.67 N) for the mini screw. This difference was shown to be statistically significant ($p<0.015$). In addition, all specimen in the Mini group failed secondary to proximal fragment displacement, while all specimen in the Standard group failed secondary to cortical fracture. DISCUSSION AND CONCLUSION: The smaller diameter of the Mini screw places it entirely within the cancellous bone of the scaphoid. With bending loads, the Mini screw "cuts through" the cancellous bone leading to fracture displacement. In contrast, the Standard screw provides better "fill" of the proximal fragment with subcortical contact creating a more stable construct resulting in greater resistance to bending loads as seen by the significantly higher load-to-failure and negligible fragment displacement. In light of this data, we recommend fixation of proximal pole scaphoid fractures with the Standard, rather than the Mini, Acutrak screw.

POSTER NO. P454

◆Preoperative Assessment of Distal Radius Fractures using the Instability Score

Etsuji Shiota, MD, *Fukuoka, Japan (n)*
Akio Matsuzaki, MD, Fukuoka, Japan (n)
Teruaki Izaki, MD, Fukuoka, Japan (n)
Takamasa Koga, MD, Fukuoka, Japan (n)
Naoto Kozaki, MD, Fukuoka, Japan (*)

INTRODUCTION: The usefulness of Lafontaine's instability score (Acta Orthop Belg 55:203,1989) which assesses the stability of distal radius fractures, was evaluated. METHODS: The evaluation of 128 patients (80 females, 48 males, average age 52.4 years), treated with only the intra-focal fixation method between July 1993 and February 2001 and followed up for over 2 years. Fixation materials used were the threaded Kirschner in 63 patients (K group) and the conehead wedging screw in 65 patients (C group). Fracture types were classified according to Frykman. The instability score (0-5points) was allotted from the radiograph at injury (4 points) - dorsal angulation of more than 20 degrees, dorsal comminution, intra-articular radiocarpal fracture and associated ulnar fracture, and from age over 60 years (1 point). The postoperative results were evaluated according to the modified Gartland and Werley demerit point system. The correlation of the instability scores and demerit points, the contribution of each items and the difference of the results according to the fixation materials were analyzed. RESULTS: The entire results were: 42, excellent; 80, good; 6, fair. A strong correlation was observed between the instability scores and the demerit points ($R=0.863$). All items contributed strongly ($P<0.0001$), except age ($P=0.2067$). The results of patients with instability scores of 5 were slightly poorer than others and the C group was better than the K group ($P=0.0321$). DISCUSSION AND CONCLUSION: It was suggested that the instability score can estimate prognoses preoperatively and can be one of the valuable and simple indices in the planning of treatments.

POSTER NO. P455

Hand Injuries Due to Domestic Animal Bites

Sara Edwards, MD, *Chicago, IL (n)*
Leon S Benson, MD, Glenview, IL (n)
Adam Schiff, BS, Glenview, IL (*)
Craig S Williams, MD, Des Plaines, IL (n)
Jeffrey L Visotsky, MD, Des Plaines, IL (*)

Purpose: To assess the demographic patterns, clinical morbidity, and treatment costs associated with domestic animal bites to the hand. Methods: A retrospective review was performed on 90 patients who suffered either a dog or cat bite to the hand.Data was collected not only for the injury presentation and treatment course, but also for the circumstances culminating in a bite incident. Results: The patient population consisted of 57 dog bites and 33 cat bites. Almost one third of the bite victims were the animals' owner, more than half of the victims were bitten by an animal with which they were familiar. Bite injuries ranged from relatively minor wounds to major injuries that included open fractures, persistent deep infection, nerve and tendon lacerations, or tissue loss. Fifty-five percent of bite victims required hospital admission. Thirty-two percent of bite victims required at least one surgical procedure. Twenty-one percent of patients suffered significant permanent impairment, such as loss of tissue (fingertip), loss of joint motion, or major sensory impairment. Ten percent of patients required long-term intravenous antibiotics and/or multiple operations and incurred medical expenses in excess of $75,000. Discussion and Conclusion: Domestic

animal bites to the hand can produce significant morbidity and are common enough to represent a public health issue. Bite prevention strategies should focus upon careful handling of animals that are fighting or injured. The potentially high cost of an animal bite is represented not only by the direct expense of medical care, but also by the days lost from work and the permanent impairment of hand function that can result.

POSTER NO. P456

Treatment of Mucous Cysts of the Fingers: Review of 134 Cases with Minimum Two-Year Follow-up

Marco Rizzo, MD, *Durham, NC (n)*
Robert D Beckenbaugh, MD, Rochester, MN (n)

Purpose. The purpose of this study is to evaluate the results of a single surgeon's treatment of mucoid cysts comparing outcomes between injection and surgery. Methods. One hundred and thirty-four cysts were treated, with a minimum 2-year follow-up. Sixty-two females and 54 males were affected. Seventy digits were in the right upper extremity, while 64 left upper extremity digits were involved. The average age of the patients was 57 years (range 38 to 89 years).). The distribution of cyst involvement included: thumb (30), index (32), long (41), ring (18), and little finger (13). The average duration of cyst presence prior to presentation was 10.5 months. The average cyst size was 7.2 mm in diameter (range 3 to 18 mm). Thirty-one patients had nail ridging or deformity at presentation. Eighty patients underwent multiple soft-tissue punctures into the cyst with a 25-guage-needle and injection with local anesthetic and steroid. Fifty-four patients underwent surgical excision and joint debridement. Results. In the injection group complete resolution of the cyst was occurred in 48 cases (60%). Among the 32 that recurred, repeat injections were performed in eight cases with three resolving. No recurrences were noted in the surgery group. Nail ridging resolved following surgery in 25 digits; the remaining six digits had partial improvement or persistent ridging. Five infections occurred, treated successfully with antibiotics (4) and/or debridement (1). Conclusions. Aspiration and injection was convenient, but had a 40% recurrence rate. Surgery provided definitive treatment with no significant long-term problems.

POSTER NO. P457

Emergency Room Care For Open PIP Dislocations

David Guelich, MD, *Chicago, IL (n)*
Brian J Hartigan, MD, Glenview, IL (n)
Leon S Benson, MD, Glenview, IL (n)
Jeffrey L Visotsky, MD, Des Plaines, IL (*)
Craig S Williams, MD, Des Plaines, IL (n)

Introduction: Acute management for open dislocations of the proximal interphalangeal joint has included immediate debridement in an operating room environment, ostensibly to avoid subsequent infection or incomplete reduction. It is our hypothesis that open PIP dislocations can be safely irrigated and reduced in the emergency room. Methods: A retrospective review was undertaken to identify patients who had sustained open dorsal PIP dislocations. All patient had been treated with initial wound debridement and reduction in the emergency room. The study population consisted of 10 patients, representing 13 dorsal PIP. Specific attention was focused upon post-injury infections, persistent instability, motion, and need for reoperation. Results: In all 13 affected PIP joints, definitive emergency room care was not associated with subsequent infection or instability. Final range of motion data did not suggest that these patients were significantly stiffer than the usual patient recovering from a closed PIP dislocation. Discussion/Conclusion: Although our patient population is small, previous studies, which have endorsed immediate operative debridement for open PIP dislocations, have been of similar size. Open dorsal PIP dislocations usually produce a "tearing" wound of the palmar skin, and the open joint is contaminated by incidental exposure through this wound. Out data would suggest that immediate debridement and reduction of this injury in the emergency room is safe and reliable. Emergency room management is much more timely and economical, since a trip to the operating room is not only very expensive, but also typically mandates several hours of delay until an operating room is available.

POSTER NO. P458

Comparison of Clinical Results of Minimal Incision versus Endoscopic Carpal Tunnel Release

Hong-Moon Sohn, MD, *Kwangju, Korea, Republic of (n)*
Sang-Ho Ha, MD, Kwangju, Korea, Republic of (n)
Jae Won You, MD, Kwangju, Korea, Republic of (*)
Sang-Hong Lee, MD, Cheolanam-do, Korea, Republic of (*)
Jun Young Lee, MD, Gwangju, Korea, Republic of (*)
Young Lae Moon, MD, Gwangju, Korea, Republic of (*)

Purpose: The purpose of our study was to compare the clinical results of minimal incision carpal tunnel release with those of endoscopic release. Materials and Methods: We retrospectively analyzed 27 patients(41 cases) who had been treated by minimal incision carpal tunnel release and 20 patients(29 cases) by single portal endoscopic carpal tunnel release. The minimal incision was done within a midpalmar crease and the incision was 2Cm long. The minimal follow up period was 8 months. The results were compared between the two groups by assessing subjective satisfaction, postoperative symptoms, grip and pinch strength, two point discrimination and time to recovery. Results: According to Cseuz's criteria, the results were excellent or good in 38 cases(93%) in minimal incision carpal tunnel release group and 27 cases(93%) in the endoscopic carpal tunnel release group. Subjective symptoms, pillar pain, grip power, pinch strength, two point discrimination test and recovery time did not show statistically significant difference between the two groups($P<0.05$). There was no neurovascular injury in both group. Conclusion: We suggest that minimal incision carpal tunnel release and endoscopic carpal tunnel release are equally efficient methods in the treatment of carpal tunnel syndrome.

POSTER NO. P459

◆Biomechanical Strength of Rabbit FDP Tendons Repaired and Supplemented with Octyl-2-Cyanoacrylate

Eric Spencer, MD, *Harrison, NY (n)*
Pamela M Levine, MD, Brooklyn, NY (*)
George T F Rahilly, MD, Cumberland Foreside, ME (*)
Steven Marshall Green, MD, New York, NY (n)

We investigated the ultimate strength to failure, and the patterns of failure of flexor tendon repairs using standard suture technique alone, compared with standard suture technique supplemented with octyl-2-cyanoacrylate (Dermabond, Ethicon Inc), in the rabbit model. Twenty-six rabbit hindpaw Flexor Digitorum Profundus tendons in thirteen rabbits were iatrogenically lacerated and repaired using standard suture technique. One of the repaired tendons from each animal was supplemented with octyl-2-cyanoacrylate. All of the tendons were harvested at 3 weeks, and tested on the tensile testing machine

(Instron Mini 44). Ultimate strength averaged 4.05 N for the suture repair group, and 7.95 N for the suture repair group supplemented with octyl-2-cyanoacrylate. (p equals 0.019) The repair group supplemented with octyl-2-cyanoacrylate had an ultimate strength to failure that was significantly higher than the suture only group. All repairs failed at the repair site. The results indicate that flexor tendon repair supplemented with octyl-2-cyanoacrylate increases the ultimate strength to failure as compared to suture repair alone at 3 weeks post repair. We conclude that flexor tendon repair supplemented with octyl-2-cyanoacrylate has greater tensile strength than flexor tendon repair with suture alone in the early post operative period, in the rabbit model. This may be a more effective method of flexor tendon repair allowing early passive, and active motion, minimizing adhesion formation, and increasing ultimate range of motion. This work is meant to be a model for a novel approach to primary hand flexor tendon repair in human subjects.Biomechanical strength

POSTER NO. P460

Bridging/Non-Bridging External Fixation For Extra-Articular Distal Radius Fractures

Anthony Frank Infante, DO, *Ruskin, FL*
(a – Smith&Nephew)
Michael Swords, DO, Sun City Center, FL (*)

Purpose Displaced, extra-articular distal radius fractures are difficult to treat with optimum results. This study is to show that a combination of the non-bridging and bridging external fixation techniques is the ideal treatment option for distal radius fractures. Materials and MethodsThe study is a prospective, consecutive study on fixation of extra-articular distal radius fractures (23A2&3), from June, 1999 to December 2002, performed at a Level 1 trauma center and a community hospital. All of the patients were treated with a bridging/non-bridging technique by a single surgeon. 25 patients are currently in the study. Twenty of the patients had isolated extra-articular distal radius fractures and five were polytrauma patients. The patient is seen in the office at 2 weeks for suture removal and distal pin removal. At 6 weeks, new x-rays are taken and the external fixator is removed if the fracture is healed. If not, the patient returns in two weeks for follow-up x-rays and removal of the external fixator. The patient is then seen in follow-up at 3 months, 6 months and 1 year after external fixator removal. ResultsAll 25 of the fractures treated to completion healed within 8 weeks. There wasn't any loss of reduction on AP or lateral views. Twenty-four of the twenty-five regained full hand motion and grip strength averaged 90% of the uninvolved hand. Those same twenty-four regained approximately 90% their original supination, pronation, flexion and extension at four months. The average flexion lost was 10 degrees compared to the normal side and average extension lost was 5 degrees compared to the normal side. Twenty-four of the patients returned to their previous activities, including four patients who perform manual labor with the involved wrist. Conclusion/SignificanceA bridging/non-bridging external fixator can be used effectively to treat extra-articular distal radius fractures. Motion of the fingers and wrist are restored early while the fracture is healing.

POSTER NO. P461

The Reverse Radial Forearm Fascial Flap with Radial Artery Preservation

Scott Furm Mofford Duncan, MD, *Phoenix, AZ (n)*
Anthony Smith, MD, Scottsdale, AZ (n)
Alexander Yong Shik Shin, MD, Rochester, MN (*)
Allen T Bishop, MD, Rochester, MN (n)
Edward W Buchel, MD, Phoenix, AZ (n)

Introduction: Soft tissue reconstruction using the reverse radial forearm is problematic in patients with an abnormal Allen test. A vein graft can reconstruct the radial artery, but this procedure is technically demanding. An alternate approach in these patients is a distally based fascial perforator flap that allows for preservation of the radial artery. Methods: The radial artery and the perforators are identified with Doppler. The fascial island is centered along the perforator axis to the antecubital fossa with a distal pivot point 4 cm proximal to the radial styloid. The fascia is completely exposed and a 4-cm-wide flap is raised by incising the fascia and continuing the dissection distally beneath the fascia, preserving the perforators. The flap is rotated 180 degrees to reach the defect in the hand. We describe three cases using this flap. Results: Case 1: A 53-year-old female who required coverage and nerve grafting after wide excision of a volar hand tumor. Case 2: A 37-year-old female who required soft tissue coverage of the dorsal ulnar sensory nerve and carpal bones. Case 3: A 33-year-old female with segmental loss of ulnar artery and nerve, and a 8 centimeter by 4 centimeter wound. All three patients are over 2 years post-operative and have not required any further reconstruction. Discussion and Conclusion:This technique preserves the radial artery basing the flap on the radial artery perforators. These cases demonstrate the use of this fascial flap for palmar and dorsal hand soft tissue coverage. Introduction: Soft tissue reconstruction using the reverse radial forearm is problematic in patients with an abnormal Allen test. A vein graft can reconstruct the radial artery, but this procedure is technically demanding. An alternate approach in these patients is a distally based fascial perforator flap that allows for preservation of the radial artery. Methods: The radial artery and the perforators are identified with Doppler. The fascial island is centered along the perforator axis to the antecubital fossa with a distal pivot point 4 cm proximal to the radial styloid. The fascia is completely exposed and a 4-cm-wide flap is raised by incising the fascia and continuing the dissection distally beneath the fascia, preserving the perforators. The flap is rotated 180 degrees to reach the defect in the hand. We describe three cases using this flap. Results: Case 1: A 53-year-old female who required coverage and nerve grafting after wide excision of a volar hand tumor. Case 2: A 37-year-old female who required soft tissue coverage of the dorsal ulnar sensory nerve and carpal bones. Case 3: A 33-year-old female with segmental loss of ulnar artery and nerve, and a 8 centimeter by 4 centimeter wound. All three patients are over 2 years post-operative and have not required any further reconstruction. Discussion and Conclusion: This technique preserves the radial artery basing the flap on the radial artery perforators. These cases demonstrate the use of this fascial flap for palmar and dorsal hand soft tissue coverage.

POSTER NO. P462

Palmer IB TFCC Tears: A Biomechanical Comparison Between Repair Techniques

Steven Lee, MD, *New York, NY (n)*
David P Rudman, MD, Englewood, CO (*)
Stephen J. Nicholas, MD, New York, NY (*)
Malachy P McHugh, PhD, New York, NY (*)
Ian Kremenic, MD, New York, NY (*)

Purpose: To test the properties of horizontal versus vertical mattress repairs for Palmer IB TFCC tears. Hypothesis: Vertical mattress would yield stronger repairs. M&M: 9 fresh frozen wrists were dissected leaving the radius, ulna, and TFCC. Horizontal and vertical mattress repairs were performed on the ulnar TFCC using 2-0 PDS. The ulna was secured to a MTS and a linear tensile force was applied on the suture. Parameters studied: Failure force, stiffness, elongation, and mode of failure. Results: Vertical mattress were stronger(79.4N)and stiffer (1.7N/mm) than horizontal mattress (26.6N) and (1.3N/mm). Elongation prior to failure was not different between groups. All vertical mattress failed thru the suture itself, while horizontal mattress pulled thru the TFCC. Conclusion: Vertical mattress repairs are significantly stronger and stiffer than horizontal repairs. The vertical mattress strength was limited to the suture material strength. The repair strength difference likely reflects the more abundant collagen fibers found circumferentially than radially, similar to that in knee menisci.

POSTER NO. P463

Central Slip Tenotomy for the Treatment of Chronic Mallet Finger: An Anatomic Study

Jerome Donald Chao, MD, *New York, NY (n)*
Robert J Strauch, MD, Scarsdale, NY (n)
Vishal Sarwahi, MD, New York, NY (*)
Yong Sing Da Silva, BA, New York, NY (*)
Melvin Paul Rosenwasser, MD, New York, NY (*)

Mallet finger often results in chronic DIP extensor lag, due to lengthening of the healed tendon. Tenotomy of the central slip can improve chronic DIP extensor lag by allowing the extensor mechanism to slide proximally - reducing terminal tendon 'slack'. No anatomic or biomechanical study has studied the amount of lag correctable with Fowler tenotomy. The goal of this study is to evaluate the potential of Fowler tenotomy to restore DIP extension. Fourteen fresh cadaver fingers were used. A suture-anchor was placed into the bony insertion of the extensor tendon, which was then sectioned, producing a mallet deformity. The suture-anchor suture was secured to the extensor tendon to simulate lengthening of the tendon. A weight attached to the proximal extensor tendon provided a uniform traction force. Fowler tenotomy was performed by lifting the extensor tendon from the ulnar side and completely sectioning its insertion. Extensor lag pre- and post-tenotomy were measured. Several clinical studies have demonstrated that Fowler's tenotomy is effective treatment for chronic mallet finger, but may not fully restore DIP extension. In this study, an extensor lag of up to 46° was fully correctable, but the average degree of correction was 36°. Patients with pre-existing extensor lags of greater than 36° may not achieve full correction.

POSTER NO. P464

A New Technique for Treatment of Complex Metacarpo-Phalangeal Dislocations

Samir C Sodha, MD, *Philadelphia, PA (n)*
Benjamin Chang, MD, Philadelphia, PA (*)

INTRODUCTION: Historically, complex MCP dislocations have necessitated open surgical management by either a volar or dorsal approach. This is the first description of a technique employing a percutaneous solution to these rare injuries. METHODS: From 1996 – 2002, three patients with irreducible dislocations of the metacarpo-phalangeal joint of the thumb and one of the index finger were identified after failing closed reduction. All patients had lateral radiographs suggesting volar plate interposition blocking reduction. Utilizing a dorsal stab incision adjacent to the extensor tendon, an 11-blade scalpel was directed through the dorsal retinaculum and capsule onto the dorsum of the metacarpal neck just proximal to the base of the dislocated proximal phalanx. The volar plate was divided longitudinally under the skin and reduction was achieved. Total procedure time averaged 5 minutes and the stab incision was closed with a single steri-strip. The first three procedures were performed in the operating room, the fourth one in the emergency room. Patients were followed for a minimum of 6 months. RESULTS: Successful reduction was attained on first attempt in all 4 patients without complications. All dislocations were stable following reduction. Full, painless range of motion was achieved and there were no cases of recurrent instability. CONCLUSION: The described procedure represents a relatively simple and reliable solution to complex MCP dislocations with results comparable to open surgical reduction. This minimally invasive technique can be performed in the emergency room setting avoiding the cost and time associated with an open procedure in the operating room.

POSTER NO. P465

Rotatory Malunion of Distal Radius Fractures

William H Seitz Jr, MD, *Cleveland, OH (n)*

Introduction: Rotational malalignment following fracture of the distal radius results in subluxation of the distal radioulnar joint with alteration of the normal contact area of the ulnar head in the sigmoid notch of the radius, arthrosis, pain, limited pronation and supination, and dysfunction. Materials and Methods: Eleven cases of derotational osteotomy of the distal radius with low profile plate fixation have been performed for correction of rotational malalignment with restoration of appropriate articular tilt, length and alignment. In eight cases the articular surface of the distal ulna was found to be too degenerated to salvage the distal radioulnar joint and resection of the distal ulna with soft tissue reconstruction was performed. Results: Healing of the osteotomy of the distal radius was achieved in all 11 patients. None of the patients undergoing distal ulnar resection demonstrated instability of the distal radioulnar joint but one demonstrated distal radioulnar impingement. Preoperative pronation/supination arc was 40 degrees and postoperative arc was 130 degrees. In 8 of the 11 pain was rated as 0 on a 10 point scale while the other 3 ranged between 2 and 5 on the same scale. At two year follow-up grip strength measured 80% of the contralateral side while total range of motion measured 76% of the contralateral side. All 11 patients were functional at daily household activities, 5 out of 7 previously working patients were back to work. Conclusions: Rotatory malpositioning following distal radius fracture provides significant disability. Derotational osteotomy can be effective in restoring pronation and supina-

tion, diminishing pain and increasing function. Late treatment may also require resection of the distal ulnar articular surface due to posttraumatic arthrosis.

POSTER NO. P466 – ORS

Extensor Tendon Tension In Zone Vi At Maximal Isometric Contraction

Brian M Keech, MD, Farmington, CT (n)
Mary L Newport, MD, Farmington, CT (n)
Vilmaris Diaz-Doran, MD, Farmington, CT (a – University of Connecticut Health Center)
Douglas J Adams, MD, La Jolla, CA (a – University of Connecticut Health Center)

Inappropriate management of injuries to the extensor mechanism of the hand can lead to significant hand dysfunction. Understanding force magnitudes that are normally transmitted through extensor tendon mechanisms is critical for appropriate selection of repair technique and post-operative rehabilitation. Metacarpophalangeal (MP) torque generated during maximal isometric MP extension was measured directly in 15 subjects (23-58 years old, average 34) at five combinations of wrist and MP joint flexion / extension for all four fingers. Five cadaver forearms were subjected to the same protocol, measuring tendon tension proximal to the MP joint (in zone VI) to determine the relationship between tendon tension and resultant MP joint torque. Average maximal isometric reaction force at midspan of the proximal phalanx ranged from 1700 to 3500 grams, depending on finger and test position ($p<0.05$). Across all fingers, reaction force increased with progressive wrist flexion. Cadaver experiments revealed tendon tension generated in zone VI significantly larger than a reaction force applied perpendicular to the proximal phalanx at midspan (average 2.1 times larger, range 1.0 to 4.9). This relationship established a conservative estimate of approximately 1 gram of extensor tendon tension generated in zone VI for each 5¥10-5 N·m (5 g·mm) of MP joint torque generated. The newly-modified Bunnel suture technique affords the greatest post-operative repair strength, failing at approximately 2200 grams of applied tensile force. Our results demonstrate that tendon tension developed in zone VI during maximal exertion far exceeds tendon repair strength, rendering current repair techniques inadequate to withstand maximum extension in the early post-operative period.

SCIENTIFIC EXHIBITS

SCIENTIFIC EXHIBIT NO. SE025

Use of the Swanson Trapezium Implant for Basil Thumb Arthritis

Homer C. House, MD, *Baltimore, MD (n)*
Hugh House, MD, Sherwood Forest, MD (*)
Robert W. Eberle, PhD, Apex, NC (n)

For the past 30 years the author has been using the Swanson Trapezium Implant for Basil Thumb Arthritis. It is believed that using the technique described to hold the implant in place and not allowing subluxation, prevents destruction of the implant and result in synovial synovitis. The technique is demonstrated and the last 100 implants reviewed. We have found that in the event that there is a fracture between the implant and the stem, and the implant becomes painful, simple removal of the implant 5 or 10 years after it has been implanted allows one to simply remove the implant and close the wound and a secondary suspension is not necessary to maintain the 10 or 11 millimeters of height between the first metacarpal and scaphoid. We have had in this study one case of sever acute allergy to the silicone and three broken stems. There has been no global wrist evidence of synovial synovitis. There have been occasional capitate and scaphoid single cysts that were asymptomatic and did not grow in time. It is believed that the long-term postop results with this technique maintain the normal scaphoid first metacarpal space so that the thinear muscle are optimized in maintaining their functional length and excursion, and that the late pinch strength pressures are significantly improved over pressures taken in the preoperative phase even after novacaine block of the first metacarpal trapezial joint and trapezial scaphoid joint.

SCIENTIFIC EXHIBIT NO. SE026

Scaphoid Fracture Repair: A Biomechanical Comparison of Contemporary Cancellous Bone Screws

Thomas R. Hunt III, MD, *Cleveland, OH (a, b-Stryker/Leibinger, a – Acumed, Zimmer, Synthesis)*
Paul D. Postak, BSc, Cleveland, OH (n)
Adam R. Ratzel, BSc, Cleveland, OH (n)
William H. Seitz, Jr, MD, Cleveland, OH (n)
Brian A. Pinsky, BA, Cleveland, OH (*)
A. Seth Greenwald, D Phil(Oxon), Cleveland, OH (n)

INTRODUCTION: Scaphoid fractures are common, but often challenging to treat. Internal fixation designed to provide stability and promote healing, is predicated on both compression generation and retention under physiologic loading. Intraosseous cancellous bone screws of differing geometries and thread configurations avoid articular impingement associated with the use of headed bone screws. This study compares the ability of four contemporary designs to generate and maintain sufficient, interfragmentary compression under simulated in vivo fatigue loading. METHODS Using synthetic foam blocks approximating scaphoid bone density (15lb/ft3), transverse osteotomies were created and washer load cells interposed at the fracture sites. Concurrent with surgeon insertion of the screws, per manufacturers' instructions, the maximum compression for each screw design (n=10) was measured with failure defined as a sudden loss of compression. With this baseline, fatigue testing (n=10) was performed using a four-point bending test fixture cyclically loaded for 500 cycles with a maximum bending moment of 1300N-mm. Each design's ability to retain compression during this dynamic, physiologic loading sequence was measured. RESULTS: The four designs evaluated all achieved maximum compression ranging between 33N and 56N. Statistically significant differences ($p<0.05$) were found between the retention ratios (compression after cycling/compression before cycling), which varied between 0% and 81%. DISCUSSION AND CONCLUSION: This study determined that contemporary, intra-osseous cancellous bone screw designs advocated for scaphoid fracture repair differ dramatically in their ability to retain compression under physiologic loading. These findings suggest that device selection plays an important part in promoting fracture healing and the avoidance of nonunion.

PAPERS, POSTERS & SCIENTIFIC EXHIBITS HAND/WRIST

PAPERS

PAPER NO. 021

The Most Frequent Traumatic Orthopaedic Injuries from a National Pediatric Inpatient Population

Michael Vitale, MD, *New York, NY (n)*
Mark A Vitale, New York, NY (n)
Greg J. Galano, BA, New York, NY (n)
Joshua E Hyman, MD, New York, NY (n)

Introduction: Pediatric trauma is a leading cause of death and disability in children in the United States. The overall death rate of children has decreased, but death rates from trauma have actually increased in recent years. Understanding the patterns of injury and treatment for common pediatric musculoskeletal trauma will help focus policy aimed at preventing injury and optimizing treatment. The purpose of this study was to provide a current description of traumatic pediatric orthopaedic injuries. Methods: The Healthcare Cost and Utilization Project Kids' Inpatient Database, which provides data on all pediatric discharges was analyzed. We focused on the most common traumatic pediatric orthopaedic conditions requiring admission in 1997. Incidence rates for these conditions were generated using census data. Descriptive statistics for age, hospital charges, and length of stay were conducted for the top ten traumatic orthopaedic injuries. Results: Over 84,000 children were admitted for orthopaedic trauma in 1997. These patients accrued an estimated 932.8 million dollars in hospital charges. Femur fracture was the most frequent injury (22 percent), followed by tibia and/or fibula fracture, humerus fracture, radius and/or ulna fracture, and vertebral fracture. Practice patterns varied for certain groups of patients, depending on the type of hospital where the child was treated. Discussion and Conclusions: Pediatric orthopaedic trauma represents a sizeable proportion of all pediatric hospitalizations and was responsible for nearly a billion dollars in hospital charges in 1997. Trends in the incidence and treatment of these common injuries will be discussed with an emphasis on differences in care in children's versus non-children's hospitals.

PAPER NO. 022

Articular Cartilage Defects in Young Patients: Treatment with Autologous Chondrocyte Implantation

Lyle J Micheli, MD, *Boston, MA (n)*
Bruce Moseley, MD, Houston, TX (n)
Allen F Anderson, MD, Nashville, TN
(b – Genzyme Biosurgery)
Jon E Browne, MD, Kansas City, MO
(a, c – Genzyme Biosurgery)
Christoph Erggelet, MD, Freiburg, Germany (*)
Robert A Arciero, MD, Farmington, CT
(a – Arthrex, Smith & Nephew, b – Gruppo)
Freddie H Fu, MD, Pittsburgh, PA (n)
Bert Mandelbaum, MD, Santa Monica, CA
(e – Member Genzyme Articular Cartilage Registry Board)

Introduction: Procedures aimed at biologically repairing cartilage injuries may have the greatest potential benefit in young patients due to their life expectancy and functional demands. Most cartilage procedure outcome studies, however, focus on older patient populations. This study seeks to assess the long-term multicenter outcomes of ACI treatment in juvenile patients, less than 18 years of age. Methods: 39 juvenile patients had at least one full-thickness lesion on the distal femur and were implanted at least 2-years ago. Information on adverse events and subsequent operations were captured. Treatment outcomes were measured using the 10-point modified Cincinnati Knee Rating System. Results: Mean age was 15 years; approximately half were male. 25 patients underwent at least one cartilage repair procedure prior to cartilage harvest, including 13 who had a marrow stimulation procedure. 17 patients were diagnosed with OCD lesions. 37 patients had single defects, mean size: 5.3 cm2. 37 patients completed self-evaluations at a minimum of 2-years after implantation. The overall condition score improved 3.6 points for the 37 patients, ($p<0.0001$) and 4.3 points for 32 patients who improved from baseline, ($p<0.001$). Pain and swelling scores improved 4.0 ($p<0.0001$) and 3.5 points ($p<0.0001$), respectively. There were no treatment failures at follow-up. Discussion: Results highlight statistically significant and marked clinical improvements from baseline to follow-up and support the use of ACI as an effective option for treatment of large chondral lesions in the Juvenile patient.

PAPER NO. 023

Nonunion of Fractures in Pediatric Patients: A 15-year Experience at a Level 1 Trauma Center

Michael Wade Shrader, MD, *Rochester, MN (n)*
Anthony A Stans, MD, Rochester, MN (n)
William J Shaughnessy, MD, Rochester, MN (n)
George John Haidukewych, MD, Rochester, MN (n)

Introduction: Because of its rarity, there is little data evaluating nonunions in the pediatric population. Previous literature has reviewed time periods before contemporary techniques of internal fixation and management of open injuries were available. This retrospective review evaluates a large consecutive series of pediatric nonunions treated at a Level 1 Trauma Center. Methods: Between 1985 and 2000, 43 nonunions in 42 patients with a mean age of 9+9 years (3-14 years) were identified. Congenital pseudarthroses and nonunions of osteotomies were excluded. There were 32 males and 10 females. Eleven of the original 43 fractures were open and 5 presented with active infection. The average time to diagnosis of nonunion was 21 months. Results: Twenty of 43 nonunions (47%) were located about the elbow, with 16 initially treated at community hospitals. 17 of 43 nonunions were diaphyseal (39%). All fractures treated with secondary attempts to achieve union had united at last follow-up, requiring a mean of 3.6 (range 1-19) surgeries. One patient was lost to follow-up. The remaining 41 patients were followed until union or a minimum of one year with a mean follow-up of 50 months. Discussion and Conclusion: The number of diaphyseal nonunions in this series was lower than an earlier report from this institution. Concerningly, nearly half of the nonunions occurred about the elbow. This study underscores the importance of careful evaluation and treatment of pediatric elbow fractures and describes the demographics, risk factors, and treatment of pediatric nonunions in an era of modern orthopedic fracture management.

PAPER NO. 024

Management of Femoral Shaft Fractures in Children, Ages 6-10: National Practice Patterns & Trends

Michael Vitale, MD, *New York, NY (n)*
Benton E. Heyworth, BA, New York, NY (n)
Greg J. Galano, BA, New York, NY (n)
Mark A Vitale, New York, NY (n)

Introduction: There is continued variability and controversy regarding the appropriate treatment of femur fractures in children of intermediate ages. This study examined national practice patterns and longitudinal trends in order to investigate the hypothesis that management of these fractures is changing and may be different at children's (CH) compared to non-children's hospitals (NCH). Methods: The Kids' Inpatient Database (KID), which reflects all inpatient pediatric admissions in the U.S., was reviewed for 1997 and 2000. Closed femoral shaft fracture cases for patients 6-10 years old were identified using ICD-9 codes. Hospital type (CH, NCH) and treatment method (spica casting, internal fixation, external fixation, traction) were determined using the National Association of Children's Hospitals and Related Institutions and ICD-9 procedure codes, respectively. Case volumes, frequencies, and descriptive results were compared using t-tests and chi-squared analyses. Results: Between 1997 and 2000, the percentage of cases treated with internal fixation increased from 39 percent to 57 percent at CH and from 28 percent to 41 percent at NCH, while cases treated with spica casting decreased from 29 percent to 23 percent at CH and from 39 percent to 31 percent at NCH. For all treatments, length of stay was significantly shorter at CH than NCH. Mean charges were also less and decreased at CH, while increasing at NCH over this time period. Discussion and Conclusion: Children aged 6-10 with femur fractures are increasingly treated with internal fixation, perhaps due to recent evidence demonstrating the benefits of flexible intramedullary rod fixation. Sixty percent of cases are treated at NCH, at which there is a higher rate of treatment with spica casting, higher charges and longer length of stay than at CH. These findings have implications for the ongoing debate regarding the need for sub-specialization of pediatric care.

PAPER NO. 025

Prevalence of Meniscal and Chondral Injuries with ACL Tears in Skeletally Immature Patients.

Mininder S Kocher, MD, *Boston, MA (n)*
Rahul Mandiga, MD, Boston, MA (*)
Peter G Gerbino II, MD, Boston, MA (*)
Lyle J Micheli, MD, Boston, MA (n)

Introduction: The purpose of this study was determine the prevalence of meniscal and chondral injuries associated with anterior cruciate ligament (ACL) tears in skeletally immature patients. Methods: 102 skeletally immature patients with complete ACL tears who underwent ACL reconstruction were reviewed. Results: The prevalence of associated chondral injury was 6% (6/102). The prevalence of associated meniscal injury was 45% (46/102). Meniscal tears involved the medial meniscus (16/46), lateral meniscus (26/46), or both (4). Tear patterns were bucket-handle displaced (10/46), longitudinal (17), radial (7), and complex (8). Discussion: Meniscal injury associated with ACL tears in skeletally immature patients is relatively common.

PAPER NO. 026

Anterior Cruciate Ligament Reconstruction in the Pediatric Population: A Survivorship Analysis

Theodore J Ganley, MD, *Philadelphia, PA (n)*
Eric Lee Cain, MD, Fremont, CA (n)
John R Gregg, MD, Valley Forge, PA (n)
Robert B Carrigan, MD, Philadelphia, PA (*)

Introduction: The Kaplan-Meier method is an established technique to track survivorship over time. Little is published regarding longevity of anterior cruciate ligament (ACL) reconstruction in athletic children. Our purpose was to perform a survivorship analysis of a single surgeon's 10-year experience with anterior cruciate ligament replacement in children. Methods: All primary ACL reconstructions performed over ten years by a single surgeon in patients skeletally older than 13 years (female)/ 14 years (male) and chronologically younger than 18 years old were reviewed via chart review plus phone and mail contact of patients. Failure was defined as the onset of symptomatic knee instability and/or revision ACL surgery. All patients underwent ACL reconstruction with Achilles tendon allograft. Patients were excluded with multiple ligament injuries, other significant knee injuries, or follow up of less than 2 years. Results: 276 patients younger than 18 years old were identified. Follow-up averaged 6.3 years (range 2-10 years). 29 patients (10.5%) were excluded or lost to follow-up. There were a total of 17 (7.8%) failures of reconstruction. 9 (4.1%) occurred in less than one year and the balance by 3 years. Most failures occurred with a second knee injury during the resumption of high level competitive athletics. Kaplan-Meier method survivorship curves were generated for the entire cohort as well as by stratification by sex. Discussion: The Kaplan-Meier method is useful to track anterior cruciate ligament reconstruction longevity. In children, anterior cruciate ligament reconstruction failures occurred early, within three years after reconstruction.

PAPER NO. 027

Pediatric Spinal Cord Injury without Radiographic Abnormality

Franck Launay, MD, *Marseille, France (n)*
Arabella I Leet, MD, Baltimore, MD (a – National Institute of Health)
Paul D Sponseller, MD, Baltimore, MD (n)

Introduction: The SCIWORA syndrome, or spinal cord injury without radiographic abnormality, is uncommon yet it has a major impact on trauma protocols. The purpose of this meta-analysis of the current literature is to underline the features of SCIWORA in order to optimize management of this injury in children. Methods: A Medline search was carried out of reported cases of SCIWORA. We found 392 published cases. From these articles we noted epidemiologic data such as prevalence, incidence, age and gender, as well as pathophysiology, mechanisms of injury, and clinical and radiological features. Results: The incidence of all reported SCIWORA cases is higher in children (87%). Spinal cord injuries represent 2% of all pediatric spine trauma and SCIWORA represents about 20% of all reported pediatric spinal cord injuries. The mechanism was a flexion injury in 54% of cases, distraction in 21%, extension in 18% and crush syndrome in 7%. The usual clinical picture is a child under 8 years of age who presents a partial (55%) or a complete (27%) cervical (74%) cord syndrome after a motor vehicle accident (45%). Children under 8 years of age have a worse prognosis than older children.In addition to the clinical exam findings, injury to the spinal elements seen on MRI can be predictive of

the outcome. Findings indicative of cord transection and major hemorrhage are correlated with poor outcome, minor hemorrhage or "edema only" is associated with moderate to good recovery, and the absence of any abnormal cord signal suggests the patient will make a complete recovery. Treatment is essentially conservative, but rigid external immobilization is needed to avoid a recurrent SCIWORA which occurs in 16% of the cases. Discussion: The anatomic features of the pediatric spine make it more susceptible to SCIWORA in contrast to the adult spine and explain the high rate of flexion mechanism involved in the pathogenesis of the syndrome. As SCIWORA has a relatively poor prognosis, but that can be improved if diagnosed, our recommendation is to include SCIWORA in spine injury protocols. Thus, if the neurologic examination of an injuried child is abnormal or if it is normal but with initial transient symptoms, the child should be treated as a spinal cord injury and should be immobilized appropriately. If plain radiographs and CT scans tomography do not show any vertebral damage, MRI should be obtained to rule out SCIWORA.

PAPER NO. 028

Pediatric Thoracolumbar Flexion-Distraction Injuries: Operative versus Non-Operative Management

Paul J Moroz, MD, *Boston, MA (n)*
Paul Benoit, MD, Marstons Mills, MA (*)
Timothy Hreska, MD, Boston, MA (*)
John B Emans, MD, Boston, MA (n)
John E Hall, MD, Brookline, MA (n)

Introduction and Methods: In this retrospective review of thoraco-lumbar flexion-distraction spine fractures at a paediatric level 1 trauma center we compared outcomes (fusion and loss of reduction) of operatively and non-operatively managed children. Twenty cases of thoraco-lumbar and lumbar region flexion-distraction fractures were identified. Patients were grouped by non-operative versus operative and three Cobb angles for each patient taken over time were recorded: one taken at the time of fracture, one at initiation of treatment, and the last at final follow-up. Union rate of fractures and changes in angular deformity was analyzed by Fisher's exact test. Results: Patients included 11 males and 9 females (average age 13.9 years; range 6 - 17). Average follow-up was 5.4 years. Eighty-five percent of cases involved motor-vehicle crashes with seventy percent wearing some form of seatbelt. Twenty percent had a neurological injury, all having surgery as initial management. All patients initially treated surgically healed with an average loss of lordosis of 7.5 degrees. Five of the seven in the non-operative group developed non-union with instability and an average loss of 33 degrees of reduction over time. All five non-unions went on to successful surgical fusion. Flexion-distraction fractures were 30 times more likely to heal with initial surgery (odds ratio = 30, 95% CI 2.1 - 410, $p<0.001$). Conclusion: Non-operative management leads to an unacceptably high rate of non-union and we recommend primary surgical management of all paediatric thoraco-lumbar flexion-distraction injuries.

PAPER NO. 029

Acute Traumatic Compartment Syndrome of the Leg in Children: Diagnosis and Outcome

John M Flynn, MD, *Philadelphia, PA (n)*
Ravi K Bashyal, Philadelphia, PA (n)
Franck Launay, MD, Marseille, France (n)
Paul D Sponseller, MD, Baltimore, MD (n)

Introduction: The purpose of this study was to analyze acute traumatic compartment syndrome (ACTS) of the leg in children presenting to two large pediatric trauma centers. Methods: 30 consecutive cases (29 children) of ACTS of the leg were collected over a 12-year period. Data collected included cause of injury, associated injuries, character and time course of symptom development, method of diagnosis, compartment pressures, time from injury to diagnosis and fasciotomy, and outcome at last follow-up. Results: 25 boys/4 girls, aged 4 mo-15 years were included. 26 patients were struck by a motor vehicle. 25 sustained tibia fractures, 3 sustained femur fractures, and 1 had no fracture. Average time from injury to diagnosis was 16.56 hours (2.5 – 74 hours). At time of diagnosis, 28 had worsening pain, 9 had paresthesias, 6 had lost motor function, and 3 had diminished pulses (2 associated with femur fractures). Average time from injury to operating room was 19 hours. Follow-up averaged 15 months. At last follow-up, 27 patients had no sequelae. The 2 who lost function had fasciotomy very late (83 and 86 hours) after injury. 10 children underwent fasciotomy 12-41 hours after injury; all had full return of function with no permanent deficits. Discussion: Most children treated had a good outcome, despite time from injury to treatment exceeding 12 hours. This delay may be related to limited communication and need for anesthesia to measure compartment pressures in children. All patients with sequelae at follow-up had a fasciotomy more than 83 hours after injury.

PAPER NO. 030

Subtrochanteric Osteotomy with External Fixation as a Salvage Procdure for Grade III SCFE

Fotios P Tjoumakaris, MD, *Philadelphia, PA (n)*
Richard S Davidson, MD, Philadelphia, PA (e – EBI)

Introduction: Residual deformity, pain, decreased range of motion and the radiographic appearance of avascular necrosis often follow in situ pinning for severe, stable (grade III) slipped capital femoral epiphysis (SCFE). This may be due to the posterior position of the femoral head and anterior position of the femoral neck with impingement against the lateral acetabulum. We sought to determine if a transverse percutaneous subtrochanteric osteotomy using external fixation can decrease pain, restore function and motion, and eliminate the appearance of AVN by restoring the anatomic relationship of the femoral head and neck to the acetabulum. Methods: We performed a transverse subtrochanteric osteotomy with external fixation in eight patients who had undergone prior in situ pinning for severe (Gr III) SCFE. All patients had decreased function, limited range of motion, pain with ambulation, and a limp after in situ pinning. The osteotomy was placed in 20 degrees of valgus, 40 degrees of internal rotation, and 40 degrees of flexion using the external fixation pins as guides. The fixation device was removed at 12 weeks. Progressive physical therapy regimens were instituted throughout treatment and the patients were evaluated using Southwick's classification. The patients' ages ranged from 11-16 years and there were 3 males and 5 females. The average length of follow up was 31 months (range 12-78). Results: Considering pain as a criterion, there were 2 excellent, 4 good and 2 fair results.

Considering function, there were 1 excellent, 6 good and 1 fair results. Considering limp, there were 6 good results and 2 fair results. Considering motion, there were 2 excellent, 5 good results and 1 fair result. Radiographic parameters demonstrated 4 good results and 4 fair results. The average increase in flexion, extension, abduction, internal rotation, and external rotation was: 38 degrees, -3 degrees, 11 degrees, 28 degrees, and –23 degrees respectively (negative values indicate a loss of this motion). The appearance of AVN resolved after osteotomy in three cases. There were three complications: 2 pin tract infections (one requiring hospitalization and intravenous antibiotics), and 1 femur fracture through a drill hole after removal of the fixator (treated with a spica cast). All complications resolved after appropriate treatment. Discussion/Conclusion: Subtrochanteric three dimensional correction using percutaneous transverse osteotomy and external fixation is an effective way to salvage the symptoms and deformity of Gr.III SCFE. This surgery offers an excellent alternative to arthodesis or hip arthroplasty and affords patients an opportunity at an active lifestyle, which is particularly important in the pediatric population.

PAPER NO. 131

Decreased Bracing Effectiveness in Overweight Patients with Adolescent Idiopathic Scoliosis

Patrick J O'Neill, MD, *Baltimore, MD (n)*
Lori A Karol, MD, Dallas, TX (*)
Michael K Shindle, BA, Baltimore, MD (n)
Emily Elerson, MD, Dallas, TX (*)
Karlynn Brintzenhofeszoc, Baltimore, MD (*)
Donald E Katz, CO, Dallas, TX (*)
Kevin W Farmer, MD, Baltimore, MD (*)
Paul D Sponseller, MD, Baltimore, MD (n)

Purpose: To determine whether overweight patients with adolescent idiopathic scoliosis (AIS) are less successful with bracing than those who are not overweight. METHODS: We reviewed all patients with AIS at our institutions for the past ten years who met the inclusion criteria: no prior treatment, Custom TLSO or Boston brace use, curves 25-40 degrees with Risser sign 0-2 at brace initiation, and follow-up to skeletal maturity. Overweight was defined as a body mass index >85th percentile.Success with bracing was defined as curve progression <5 degrees.Statistical analysis included independent t-test, multiple regression analysis, and calculation of the odds ratio. RESULTS: There were 276 patients who met the inclusion criteria and had sufficient data for analysis, with 12% (34) overweight. Average age at bracing was 12.8 years.The mean time in the brace was 14.3 hours per day (S.D. 5.5) and the mean initial curve magnitude was 32.5 degrees (S.D. 4.3).Curve progression ranged from –20 to 47 degrees with a mean progression of 4 degrees and a standard deviation of 9 degrees for the whole sample.For those overweight versus not overweight the curve progressions means were 8.8 degrees (S.D. = 7.9) and 3.6 degrees (S.D. = 9.3), respectively.The range of curve progression was –10 to 25 degrees for those who were overweight and –20 to 47 degrees for those not overweight. There is a statistically significant difference between the mean curve progression of the overweight patients versus those not overweight (t = -3.108, df -=274, p < .01). Regression analysis showed that 31% of the variance in curve progression is explained by average hours in brace per day, being overweight, % correction, gender, and age when brace started (p < .001).Those patients who were overweight were 2.5 times as likely to be unsuccessful than those who were not overweight. CONCLUSION: The results suggest that overweight AIS patients will have greater curve progression and less success with bracing than those not overweight.The ability of a brace to transmit corrective forces to the spine through the ribs and soft tissue may be compromised in overweight patients.SIGNIFICANCE: The effect of being overweight on the outcome of bracing children with AIS has not been reported.This factor should be taken into account when making treatment decisions.Further study is warranted to determine a threshold effect.

PAPER NO. 132

Congenital Scoliosis: Intraspinal Anomalies and Progression

Brett Edward Casey, MD, *Temple, TX (*)*
Elroy Sullivan, PhD, Houston, TX (n)
Richard Justis Haynes, MD, Houston, TX (n)
Robert Huang, MD, Houston, TX (n)

Purpose: The purpose of this study was to identify the incidence of intraspinal pathology associated with congenital scoliosis and to identify the risk of curve progression with or without intraspinal pathology. Methods: A retrospective review of 37 consecutive patients with congenital vertebral anomalies evaluated by MRI from 1999 to 2002 was performed. Patients with spina bifida, cerebral palsy, and arthrogryposis were excluded. Medical records, plain radiographs, and MRI studies were reviewed specifically for intraspinal anomalies. Results: Intraspinal anomalies were identified in 15 of the 37 patients (41%). Anomalies included eight tethered cords, five syringomyelia, four Chiari malformation, four diastematomyelia, two filum lipoma, one filum fibrolipoma, and one basilar invagination. Despite the high rate of intraspinal pathology, 34 patients (92%) had no clinical evidence of neurologic deficit. Twenty seven patients had multiple pre-fusion spine films available for an analysis of progression, 12 with intraspinal anomalies and 15 without. The mean progression of for these 27 patients was 4.2° per year (p<.001). There was no significant difference in curve progression between patients with intraspinal anomalies (5.6° per year) as compared to patients without (6.5° per year) (p=.569). Conclusions: This study confirms the efficacy of MRI identification of patients with intraspinal pathology associated with congenital vertebral anomalies. Given the high rate of intraspinal anomalies discovered on MRI, plain radiographs and clinical neurologic exam are inadequate for the proper evaluation of intraspinal pathology. The data on curve progression suggests that intraspinal pathology does not contribute significantly to curve progression.

PAPER NO. 133

Scoliosis Surgery in California: Surgical Volume at Pediatric vs. Spine Fellowship Training Programs

Michael Vitale, MD, *New York, NY (n)*
David Lee Skaggs, MD, Los Angeles, CA (n)
Mark A Vitale, New York, NY (n)
Benton E. Heyworth, BA, New York, NY (n)

Introduction: A certificate of added qualifications (CAQ) is being considered for spinal deformity surgery. The purpose of this study was to investigate the hypothesis that high-volume scoliosis surgeons may show differences in surgical volume based on fellowship training. Methods: The Office of Statewide Planning and Development (OSHPD) California inpatient database was used to identify all spinal arthrodeses procedures performed in licensed hospitals between 1995-1999 for patients 25 years old or younger with scoliosis. Fellowship programs in California were identified from the North American Spine Society and Pediatric Orthopaedic Society of North America websites and via

phone calls to program directors. Hospitals where fellows performed surgery were identified. Time-trend analyses were used to compare changes in surgical volume over time. Results: Five pediatric orthopedic programs and 12 spine surgery programs were identified. Overall, 1712 spinal fusions for scoliosis were performed at hospitals affiliated with either programs -- 32 percent of cases were performed at hospitals with a pediatric fellowship, 41 percent at hospitals with a spine fellowship, and 27 percent at hospitals with both. The average annual volume of scoliosis surgery was 41 cases per year at pediatric programs, and 19 cases per year at spine programs. Over the study period, there was not a significant increase in the average number of cases per year at spine programs (17 cases per year in 1995 to 20 cases per year in 1999), but there was a significant increase in the number of cases per year at pediatric programs (33 cases per year in 1995 to 48 cases per year in 1999). Discussion and Conclusions: Data from the California OSHPD indicate that pediatric orthopaedic fellowship programs have nearly twice the surgical volume of scoliosis surgery in young adults and children than spine surgery programs. These findings should be considered when establishing criteria for a spinal deformity CAQ.

PAPER NO. 134

Scoliosis Surgery in NY State: Volume Among Surgeons with Pediatric vs. Spine Fellowship Training

Michael Vitale, MD, *New York, NY (n)*
Benton E. Heyworth, BA, New York, NY (n)
Carter B Lipton, MD, New York, NY (n)
David Lee Skaggs, MD, Los Angeles, CA (n)
David Price Roye Jr, MD, New York, NY (n)

Introduction: Controversy exists regarding the appropriate type of fellowship training for optimal exposure to operative correction of scoliosis. The purpose of this study was to investigate the hypothesis that high-volume scoliosis surgeons may show differences in surgical volume based on fellowship training. Methods: The Statewide Planning and Research Cooperative System (SPARCS) inpatient database was used to identify all spinal arthrodeses procedures performed in state licensed hospitals in New York State between 1992-2001 with a primary diagnosis of scoliosis. Physician identifiers were used to analyze operative volume among surgeons. Fellowship training of surgeons was identified using American Board of Medical Examiners physician directories, online curricula vitae, and phone calls to surgeons. Various statistical analyses were conducted using independent samples T-tests and chi-squared tests. Results: From 1992-2001, 6910 spinal fusions for scoliosis were performed in New York State. Among the 284 surgeons who performed one or more of these cases, only 39 surgeons (14 percent) performed over 50 cases in this time period (avg. 5 cases per year). However, these 39 surgeons accounted for 77 percent of all cases, with those who had completed a pediatric orthopaedic fellowship averaging 145 cases per year, a spine fellowship, 131 cases per year, and neither type of fellowship, 137 cases per year. For patients 18 years old or younger, 49 percent of cases were performed by members of the 'pediatric' group, compared to 33 percent by the 'spine' group and 19 percent by the 'neither' group. Discussion and Conclusions: These data indicate that there are a large number of surgeons who are performing less than 5 cases per year. This finding merits further study given the strong evidence of volume-outcome relationships across health care. Among high-volume surgeons, those with pediatric orthopaedic fellowship training perform more scoliosis surgeries than those with orthopaedic spine training, particularly in young adults and children.

PAPER NO. 135

Ambulatory Potential After Spinal Fusion in Cerebral Palsy Patients

Suken A Shah, MD, *Wilmington, DE (n)*
Athanasios I Tsirikos, MD, Wilmington, DE (*)
Wei Ning Chang, MD, Saratoga, CA (*)
Kirk W Dabney, MD, Wilmington, DE (*)
Freeman Miller, MD, Wilmington, DE (*)

INTRODUCTION: Twenty-six ambulatory pediatric patients with spastic cerebral palsy (CP) and neuromuscular scoliosis underwent spinal fusion (PSF) from T1 or T2 to the sacrum with pelvic fixation using unit rod instrumentation. HYPOTHESIS: A child with cerebral palsy can ambulate after spinal fusion to the pelvis. RESULTS: The study group is comprised of 18 female and 8 male patients, 20 of whom have quadriplegic CP, 6 who have diplegic CP. 22 patients had a single thoracolumbar or lumbar scoliotic curve, and 4 patients demonstrated a double curve pattern. Mean age at surgery was 15.4 years. Mean preoperative Cobb angle was 63 degrees and corrected by 68% to 20 degrees. The patients were all evaluated clinically preoperatively, postoperatively, and at follow-up with no alteration in their ambulatory status, except one patient who developed bilateral hip heterotopic ossification and gradually lost her ability to ambulate. Clinical follow-up assessment for ambulatory function occurred at a mean of 3.86 years after surgery (2 yrs.-9 yrs.). In 14 patients who underwent full preop and postop gait analysis, the evaluation of the postoperative gait analysis documented a gait pattern similar to or better than the preoperative pattern by six months after PSF. The caretakers of all 26 patients completed an outcome survey which demonstrated significant improvement in the child's appearance, amount of back pain, head and trunk balance, sitting tolerance, respiratory function, and no compromise in ambulatory capacity. All caretakers reported that they would recommend surgery to ambulatory patients with CP who develop significant scoliosis. CONCLUSIONS: This study demonstrates that in ambulatory patients with spastic CP and neuromuscular scoliosis, PSF with unit rod instrumentation provides stable fixation to the pelvis, achieves satisfactory correction of the deformity, and restores trunk balance in the both the coronal and sagittal planes, without compromising the patient's ability to ambulate.

PAPER NO. 136

Legg-Perthes Disease and Thrombophilia

Charles T Mehlman, DO, *Cincinnati, OH (n)*
Vinod Balasa, Cincinnati, OH (*)
Ralph Gruppo, MD, Cincinnati, OH (*)
Ann Pillow, MD, Cincinnati, OH (*)
Ann Becker, Cincinnati, OH (*)
Davis Stroop, Cincinnati, OH (*)
Ping Hui Wang, MD, Cleveland, OH (*)
Eric Wall, MD, Cincinnati, OH (*)
Alvin Howell Crawford, MD, Cincinnati, OH (*)

Purpose: We examined value of thrombophilia in LPD by assessing associations between LPD and coagulation abnormalities in 81 cases compared to 197 healthy controls. Methods: A series of pts ages 2 to 17 yrs were compared to healthy controls. Assays were done for the V Leiden factor, prothrombin and plasminogen activator gene mutations. Results: The mutation was more common in white cases than in white controls X2 = 4.4, p

= 036. By stepwise logistic regression w/ cases and controls as a binary dependent variable, and sex, race, and the factor V Leiden, prothrombin, platelet and PAI-1 4G/4G mutations as explanatory variables, the ratio for LPD for the V Leiden mutation was 3.1, 95 percent CI 1.07-8.69. 20 of 81 cases had high anticardiolipin antibodies vs 19/197 controls, X2 =10.8, p =. 001. Thromboembolic events was found in probands' 1st or 2nd degree relatives in 21 of 79 of cases. Conclusions: 2 thrombophilic risk factors, the mutation and anticardiolipin antibodies, are associated w/ LPD. We speculate that this association reflects causality w/ thrombosis of the main efferent vein of the head of the femur leading to increased intraosseous pressure and ischemic thrombosis.

PAPER NO. 137

A Prospective, Long-term, Multicenter Study of Legg Perthes Disease

John Anthony Herring, MD, *Dallas, TX*
(a – Texas Scottish Rite Hospital for Children)
Hui Taek Kim, MD, San Diego, CA
(a – Texas Scottish Rite Hospital for Children)

Introduction: The purpose of this study was to determine what factors influence the outcome in Legg Perthes disease. Methods: A long term prospective study was performed between 1984 and 2000 with 34 investigators each using only one of 5 treatment programs. Of 345 hips 129 were treated in a brace, 77 with range of motion, 67 with Salter osteotomy, 52 with femoral osteotomy, and 20 had no treatment. Results: Modified Lateral Pillar Classification was the strongest correlate with outcome, p=.001. Lateral Pillar B hips had 67% Stulberg I,II results and only 6% Stulberg IV,V results while group C hips had only 13% Stulberg I,II results and 35% Stulberg IV,V. B/C border hips were intermediate in their outcome. Age at onset also strongly correlated with outcome, p=.001 and girls did worse than boys if older than 8 at onset. In patients over 8.0 years at onset, those treated surgically did better than those treated non-operatively in lateral pillar groups B, p=.02 and B/C border, p=.04. Lateral pillar C hips were not improved by surgery. Discussion and conclusion: Lateral pillar classification and age at onset are significant predictors of outcome in Legg Perthes disease. In lateral pillar groups B and B/C border, those over 8.0 at onset treated surgically did significantly better than non-operatively treated hips.

PAPER NO. 138

Are We Measuring the Acetabular Index Accurately with X-Rays?

Khodam-Rad Payman, MD, *Los Angeles, CA (n)*
Norman Yoshinobu Otsuka, MD, Los Angeles, CA (n)

Introduction: Developmental dysplasia of the hip is one of the most important orthopaedic conditions of childhood. The value of early recognition and treatment has been documented. The Acetabular Index (AI) is commonly used to assess the dysplastic hip. The purpose of this study was to assess the accuracy of the AI obtained from plain x-ray studies by comparison with MRI and to determine whether there exists a statistically significant association between these two measurements. Methods: Fourteen hips in seven patients were examined. Patient records, x-rays, and MRI's were reviewed and appropriate measurements were obtained. These measurements included cartilaginous and bony AI measurements. Standard linear regression analysis was used to compare the parameters. Results: There was a statistically significant difference between the AI measured on x-ray and MRI, p<0.5. Additionally, there was a statistically significant difference between cartilaginous and bony AI measurements, p<0.5. Discussion: MRI clarified the relationship between the bony and cartilaginous acetabulum. Our data demonstrated a statistically significant correlation between these two entities, showing that x-ray AI accurately reflects true acetabular inclination. There was a statistically significant difference between the AI measurements. This may indicate that AI obtained from x-ray may not be a true measure of acetabular coverage. Conclusions: MRI has a contribution to make in pediatric hip disease. This study does not suport the routine use of MRI in the evaluation of congenital hip dysplasia, but where hip coverage is a concern, one may consider obtaining an MRI to determine coverage by bony and cartilaginous structures.

PAPER NO. 139

Residual Hip Dysplasia Following Medial Open Reduction in the Child < 24 Months of Age

John Anderson, MD, *Saint Louis, MO (n)*
Deborah Szymanski, Saint Louis, MO (*)
J Eric Gordon, MD, Saint Louis, MO (*)
Scott J Luhmann, MD, Saint Louis, MO (*)
Matthew Barrett Dobbs, MD, Saint Louis, MO (*)
Perry L Schoenecker, MD, Saint Louis, MO (*)

Introduction: Children with developmentally dislocated hips were examined under anesthesia and the quality of reduction determined. Hips that were reducible (docked) but remained relatively unstable (narrow safe zone) were treated by protocol by a limited open medial approach(Ludlov, Ferguson) as an adjunct to reduction. Methods: 24 hips (22 patients, 16 girls and 6 boys) were so treated at an average age of 15.6 months (range 3mos-24mos); patients have been followed for average of 7 and one half years post reduction. Results: 6 of 7 hips in children < 12 months stabilized and remodeled with one requiring additional surgery for persistent dysplasia. 6 or 8 hips in children 13-17 months required additional surgical treatment for redislocation (2) or presistent dysplasia (4). 8 or 9 hips > 18 months required additional surgical treatment for redislocation (2) or persistent dysplasia (6) or both (1). To date, outcome as radiographically assessed has been very satisfactory for this group. Type II-IV (Ogden &Buchholtz) AVN was seen in 4 hips. Discussion and Conclusion: A capsulorraphy cannot be performed in an open medial hip approach and consequently hips are relatively unstable immediately post reduction. In younger patients (<12 months of age) predictably the hip stabilizes and rapidly remodels with a resulting normal radiographic appearance. In contrast, in older patients (>12 months) a predictable lack of remodeling will occur following reduction by this method. Most older patients (>12 months) will predictably require a secondary procedure(s) to correct persistent hip dysplasia.

PAPER NO. 140

Hip Stability During Limb Lengthening for Congenital Femoral Deficiency

John E Herzenberg, MD, *Baltimore, MD (*)*
Dror Paley, MD, Baltimore, MD (a – Smith & Nephew)
Mark Eidelman, MD, Baltimore, MD (*)

Introduction: What are the factors contributing to hip instability during femoral lengthening for congenital femoral deficiency (CFD)? Methods: A retrospective review of 91 femoral lengthenings in 69 children with congenital femoral deficiency was conducted. Optimal hip coverage, hip subluxation incidence, age at surgery, fixation type, and level of femoral osteotomy were

examined. Results: Thirty-three pelvic osteotomies were performed before lengthening. Fourteen patients (15.2 percent) had subluxation or dislocation during lengthening. For most patients with acetabular dysplasia and CE angle less than 20 degrees, pelvic osteotomy was performed before femoral lengthening. Coxa vara less than 110 degrees was corrected before lengthening or by valgus osteotomy at the time of lengthening. Lengthening was performed using an Ilizarov circular fixator or a monolateral external fixator (Orthofix or Heidelberg). In some older children with a medullary canal greater than 7 mm, lengthening over a nail was performed. Femoral osteotomies were performed at different levels (distal, mid-diaphyseal and proximal). Discussion: We found that important risk factors for hip instability during femoral lengthening are severity of CFD, hip dysplasia and proximal femoral lengthening. Our results show that age less than 6 years was not associated with increased hip dislocation. We believe that coxa vara neither contributes nor prevents hip subluxation. Dega osteotomy gave the best solution for posterior coverage for all pediatric pelvic osteotomies, and does not require internal fixation.

PAPER NO. 261

Arthroscopic Release of Shoulder Internal Rotation Contractures Secondary to Birth Palsy

***Michael L. Pearl, MD**, Los Angeles, CA (n)*
Bradford Edgerton, MD, Los Angeles, CA (n)
Paul Kazimiroff, MD, Los Angeles, CA (n)
Raoul Burchette, MD, Los Angeles, CA (n)
Karyn Wong, PT, Encino, CA (n)

Introduction: Internal rotation contractures secondary to birth palsy frequently lead to glenohumeral deformity. Treatment recommendations range from open release to primary latissimus dorsi transfer. This is a report of 26 arthroscopic contracture releases with a minimum follow-up of two years. Methods: Arthroscopic contracture releases were performed on 26 children, aged 0.8 to 12 years. Older children (mean age 7.3 years) also received a latissimus dorsi transfer; younger children (mean age 1.6 years) only a release. Pre-operative passive external rotation averaged –33° and 0° for the two groups, respectively. Eleven children received a latissimus transfer in addition to a release, 15 a release only. Pre-operative arthrograms were done in all cases, MRIs in 24. Results: Arthroscopic release was successful in achieving passive external rotation and a centered position of the glenohumeral joint at the time of surgery in all but one case, the oldest child with severe deformity. At F/U, the average increase in external rotation was 86°for the latissimus transfer group and 55° for the release group. The average gain in elevation was 7°. Internal rotation averaged between L4 and L5. Four of the children who had an isolated release developed a recurrent contracture requiring further treatment. None of the children that had a latissimus transfer developed a recurrent contracture. MRI at 2-year's F/U available in 12 children showed reversal of pre-operative deformity in all but one child, again the oldest child. Conclusions: Arthroscopic release is effective in achieving passive external rotation. Most young children have sufficient external rotation strength at early follow-up to maintain a centered glenohumeral joint and normalize glenoid development. Improvements in elevation are modest and loss of internal rotation is common.

PAPER NO. 262

Multiplier Method Validation for Predicting Limb Length Discrepancy and Epiphysiodesis Accuracy

***Julyn Aguilar, MD**, Quezon City, Philippines (*)*
Dror Paley, MD, Baltimore, MD (n)
Sagheih Santpure, Baltimore, MD (*)
Anil Bhave, PT, Baltimore, MD (n)
Jonathan J Paley, MD, Dayton, OH (*)
Minoo Keki Patel, MD, Malvern East VIC, Australia (*)
John E Herzenberg, MD, Baltimore, MD (n)

Introduction: Validation of multiplier method (MM) accuracy predicting limb length discrepancy and epiphysiodesis accuracy and comparison to other methods performed. Methods: Limb lengths and discrepancies measured from 60 patients' serial radiographs with epiphysiodesis for LLD. Using chronologic (CA) and skeletal age (SA) MM predicted skeletal maturity lengths of normal, short, epiphysiodesed limbs, LLD and LLD after epiphysiodesis. MM, Anderson, and Moseley method predictions were compared to actual measurements. Results: MM mean error for mature length prediction, 1.1 cm (CA), 1.5 cm (SA). r2 equals 0.93 (CA), 0.90 (SA) for MM predictions vs. actual measurements. Ninety-eight percent CA and 100 percent SA predictions within 2 cm of actual LLD. In 116 paired predictions of normal and short bones, 81 percent MM errors were same direction. Mean error predicting mature length short limbs 2.5 cm for MM and Moseley. Predicted vs. actual measurements; r2 equals 0.93 (MM, SA), 0.91 (MM, CA), 0.90 (Moseley). Mean error predicting residual discrepancies between MM and Moseley significant. Error predicting mature lengths of paired epiphysiodesed, short limbs was same direction in 93 (MM) and 82 (Moseley) percent predictions. Conclusion: Difference between actual and predicted discrepancies insignificant (p equals 0.09). MM more accurate than Anderson method, as accurate as Moseley method predicting mature limb lengths. MM more accurate than Moseley in predicting LLD and epiphysiodesis accuracy.

PAPER NO. 263

Comparison of PODCI Scores and Technical Measures of Gait in Ambulatory Children with Cerebral Palsy

***Brian Johnson, BS**, Houston, TX (*)*
Richard Justis Haynes, MD, Houston, TX (n)
Janine Calmes, Houston, TX (n)
Nancy Scarborough, PT, Houston, TX (n)
Elroy Sullivan, PhD, Houston, TX (n)

PURPOSE: Gait of children with cerebral palsy (CP) is evaluated with physiologic parameters such as stride length, walking velocity, cadence, and oxygen cost. These are objective but surrogate measures of function during ambulation. The Pediatric Outcomes Data Collection Instrument (PODCI) measures function and quality of life. This investigation compares the relationship of PODCI to technical measurements of gait. METHODS: 53 ambulatory children with CP bilateral lower extremity involvement completed PODCI questionnaires, gait analyses, and energy consumption studies. Mean age was 12.9 years (6.4 to 18.6), 31 males and 22 females. PODCI questionnaires were completed by patients between 11 and 18 years of age, and by parents for patients between 6 and 18 years. PODCI measures function for upper extremity, transfers, sports, comfort/pain, and happiness. 50 patients had completed parental PODCI response scores, 25 had self-completed scores, and 22 with both. PODCI scores were correlated to O2 cost, stride length, walking speed,

and cadence during ambulation. Lower O2 cost indicates higher efficiency. RESULTS: Significant correlations were: O2 cost versus parental transfer scores r= -.47, p<0.001; O2 cost versus child PODCI sports scores r= -.54, p<0.01; stride length versus parental PODCI transfer scores r=.30, p<0.04; cadence versus child PODCI sports scores r=.42, p<0.04; and velocity versus child PODCI sports scores r=.42, p<0.04. CONCLUSIONS: Technical measurements of gait function were found to significantly correlate in expected directions with PODCI scores related to lower extremity function. O2 cost was more strongly correlated with PODCI scores than other gait parameters.

PAPER NO. 264

Distal Femoral Deformity in Children with Tibia Vara

David J King, MD, *Saint Louis, MO (n)*
J Eric Gordon, MD, Saint Louis, MO (*)
Scott J Luhmann, MD, Saint Louis, MO (*)
Matthew Barrett Dobbs, MD, Saint Louis, MO (*)
Margaret Mary Rich, MD, Saint Louis, MO (n)
Perry L Schoenecker, MD, Saint Louis, MO (n)

INTRODUCTION: Distal femoral valgus in children with tibia vara has been noted by a number of authors. Some have described this as compensatory for the observed proximal tibial varus. Distal femoral deformity has not been measured in a large series of patients with different forms of tibia vara. METHODS: A retrospective study of patients without prior operative treatment diagnosed with tibia vara was performed. The lateral distal femoral angle (LDFA) was measured to assess the direction and magnitude of the distal femoral deformity in these patients. Eighty-five patients with 131 involved extremities were identified. Thirty-six patients with 54 involved extremities were noted to have adolescent tibia vara. Forty-nine patients with 68 involved extremities were identified with infantile tibia vara. RESULTS: The mean LDFA (normal range 85 degrees-89 degrees) in extremities with infantile tibia vara was 98 degrees (range 82 degrees-129 degrees). Only 5 extremities were noted to have distal femoral valgus (LDFA less than 85 degrees). No patient was noted to have more than 3 degrees of valgus. The mean LDFA of patients with adolescent tibia vara was 94 degrees (range 82 degrees-110 degrees). Only 1 extremity was noted to have distal femoral valgus and this represented a difference of only 2 degrees from the contralateral normal side. DISCUSSION AND CONCLUSION: Distal femoral valgus deformity is rarely found in patients with tibia vara and in our experience is never great enough to justify treatment. Distal femoral valgus deformity is most often observed as an apparent deformity secondary to abduction of the hip as the child brings the foot to the midline of weight-bearing.

PAPER NO. 265

Reversal of Methotrexate-Induced Suppression of Linear Skeletal Growth in Mice with Folinic Acid

Massod Umer, *Karachi, Pakistan (*)*
Naseema Mehboob Ali, Karachi, Pakistan (*)
Perwiaz Iqbal, PhD, Karachi, Pakistan (*)
Mahmood Ahmed, MD, PhD, Stockholm, Sweden (*)

Introduction:Methotrexate (MTX) may cause suppression of linear growth. Methods: Young male mice were used with the first group recieveing MTX on every 2nd day; another received folinic acid (FA) every 2nd day.Third group recieved MTX on every 2nd day and FA 8 hours post MTX injection & the fourth group (control) recieved saline.The tibia and femur were measured along with the height of growth plate. Results: Comparison of the mean lengths of both tibia and femur and growth plate height in all groups revealed a significant decrease(P=0.001)in the group receiving MTX alone.This effect of MTX was reversed by folinic acid to the level of the control. Conclusions: Children with rheumatoid arthritis, osteosarcoma or leukaemia and receiving MTX might experience suppression of linear skeletal growth.They may benefit from supplementation with folinic acid.

PAPER NO. 266

◆Botulinum Toxin Management of Upper Extremity Spasticity in Cerebral Palsy Patients

L Andrew Koman, MD, *Winston-Salem, NC (a, b – Allergan, a - Medtronic, Elan)*
Beth P Smith, PhD, Winston-Salem, NC (a – Allergan)
Peter J Evans, MD, Cleveland, OH (*)
Rafael M M Williams, MD, Panama City, FL (*)
Rachel Richardson, Annapolis, MD (n)
Michelle Nauhgton, PhD, Winston-Salem, NC (*)

Introduction: Currently accepted treatments of upper extremity spasticity are designed to modify dynamic deformities and delay and/or prevent the development of fixed contractures. The specific aims of this study were to document the efficacy of botulinum A toxin (BTX) compared to placebo injections in the management of upper extremity spasticity in pediatric cerebral palsy patients with regards to function and health-related quality of life. Methods: Patients randomly received either 3 injections of BTX or placebo. Patients were evaluated at baseline and at 4 weeks, 8 weeks, 14 weeks, 20 weeks, and 26 weeks. The physician, occupational therapist, patient, and caregiver did not know the child's treatment until the 26 week visit. Upper extremity outcome measures collected by the physician and occupational therapist included active and passive upper extremity range of motion and function. The patients' caregivers completed questionnaires to document the impact of their child's cerebral palsy on their caregivers and family and their child's function. Results: A total of 115 patients were screened; 73 patients consented to participate in the study (47 males and 26 females; mean age 9.7 years). Improvements following toxin injections were noted in patients of all severity levels. Moderately-involved patients experienced functional improvements with improved wrist and hand range of motion. Diminished discomfort and facilitated caregiving were noted in the severely-involved patients. Discussion and Conclusion: Intramuscular injections of botulinum A toxin administered in the upper extremity of appropriately selected pediatric cerebral palsy patients reduce spasticity allowing increased range of motion and decreased caregiver burden.

PAPER NO. 267

The Role of Intramedullary Decompression in the Treatment of Unicameral Bone Cysts in Children

John P Dormans, MD, *Philadelphia, PA (n)*
Bulent Erol, MD, Philadelphia, PA (*)
Wudbhav N Sankar, MD, Philadelphia, PA (n)
Julia E Lou, MD, Philadelphia, PA (n)

Introduction: This studied aimed to demonstrate the effectiveness of percutaneous intramedullary (IM) decompression in the treatment of unicameral bone cysts (UBCs) in children. Methods: Twenty-six children with UBCs were surgically treated using minimally invasive percutaneous technique that included IM decompression at the authors' institution since 1999. Four patients with less than 12-month followup were excluded. Four

patients had a followup of 14-22 months (average, 18 months) and 18 patients had an average followup of 28 months (range 25-40 months). The average age of patients at the time of surgery was 11 years 6 months (range, 5-17 years), and 20 were skeletally immature. The affected bones were proximal femur, 7; femoral diaphysis, 4; calcaneus, 5; proximal humerus, 5; and proximal fibula, 1. The patients underwent aspiration, cystogram, and biopsy under fluoroscopic guidance to confirm UBC, and then percutaneous IM decompression, curettage and grafting with calcium sulfate pellets. Cyst healing was determined radiographically and defined as opacification of >80% and cortical thickening. Results: The histologic diagnosis for each patient was consistent with UBC. All patients subsequently returned to full daily activities, with complete symptomatic relief. Radiographically, 17 patients (77%) demonstrated complete healing, and 5 (23%) showed significant partial healing (>80% obliteration with cortical thickening) of the cyst. None of the patients required additional treatment. There were no recurrences or complications. Conclusion: This minimally invasive percutaneous technique utilizing IM decompression and grafting with osteoconductive calcium sulfate pellets is potentially an effective treatment for UBCs in children with low complication and reoperation rates.

PAPER NO. 268

Results of the Ponseti Method in Patients with Clubfoot Associated with Arthrogryposis

Jose A Morcuende, MD, *Iowa City, IA (n)*
Matthew Barrett Dobbs, MD, Saint Louis, MO (n)
Steven L Frick, MD, Charlotte, NC (n)
Ignacio V Ponseti, MD, Iowa City, IA (n)

Introduction: Clubfoot associated with arthrogryposis has been traditionally considered very resistant to manipulation and casting, therefore requiring surgical correction. The purpose of this study was to examine the results of the Ponseti Method in this group of patients. Methods We reviewed the records of patients with clubfoot associated with arthrogryposis consecutively treated at our institutions. All patients were treated by serial manipulation and casting as described by Ponseti. Main outcome measures included correction of the deformity and the need for extensive corrective surgery. Age at presentation ranged from newborn to 1 year of age. The average age at last follow up was 28 months. Results: There were 16 patients, all with bilateral deformities (32 clubfeet). There were 11 males and 5 females. Nine patients had both upper and lower extremity involvement. Seven patients had previous treatment elsewhere (average: 7 casts). Initial correction was obtained in all but 1 patient. Thirteen patients required <7 casts. Percutaneous Achilles tenotomy was performed in all but 1 patient. Average ankle dorsiflexion after tenotomy was 10 degrees. One patient required a PMR for insufficient initial correction. Four cases required subsequent surgery (3 posterior releases and 1 PMR). There were no complications after the surgeries. Conclusions: This study demonstrates that the Ponseti method is very effective for the correction of patients with clubfoot associated to arthrogryposis. Although these clubfeet are rigid, most cases can be corrected with <7 casts. In addition, the correction is very stable and only a few cases required subsequent surgery.

PAPER NO. 269

The Use of the Foot Abduction Orthosis Following Ponseti Casts: Is It Really Essential?

David M Scher, MD, *New York, NY (n)*
Mihir Thacker, New York, NY (*)
Debra Anne Sala, PT, New York, NY (n)
Harold J P Van Bosse, MD, New York, NY (n)
David S Feldman, MD, New York, NY (n)
Wallace B Lehman, MD, New York, NY (*)

INTRODUCTION: The purpose of this study was to evaluate the need for the use of the foot abduction orthosis (FAO) in the treatment of idiopathic clubfeet using the Ponseti technique. METHODS: Forty-four idiopathic clubfeet, in children less than 6 months, were treated with serial casting, using the Ponseti method, between January 2000 and August 2001. Following final cast removal, patients were placed into an FAO. Compliance with the FAO was defined as full-time use(23 hours/day) for three months and part-time use(minimum 8 hours/day while sleeping) subsequently. Non-compliance was defined as failure to fulfill above criteria during the first 9 months following casting. Feet were scored according to systems described by Dimeglio et al., Pirani et al., and the authors' Functional Rating system, at time of FAO application and at 6-9 months following its application. RESULTS: At the time of application of the FAO, no significant differences in any of the scoring systems were found between compliant and non-compliant groups using the Mann-Whitney U test. At 6-9 months follow-up, scores in the compliant group were significantly better than the non-compliant group (p less than 0.003). From time of application of FAO to follow-up, for the compliant group, Pirani and Functional Rating scores remained the same; Dimeglio scores showed significant improvement (p equals 0.005), using the Wilcoxon signed rank test. For the non-compliant group, there was statistically significant deterioration in the Dimeglio (p equals 0.001) and Functional Rating scores(p equals 0.007). DISCUSSION AND CONCLUSION: Feet of the patients compliant with the FAO remained better corrected than feet of those who were non-compliant. Proper use of the FAO is essential for successful application of the Ponseti technique.

PAPER NO. 270

Patient Characteristics Predictive of Outcome Using the Ponseti Method for the Treatment of Clubfoot

Matthew Barrett Dobbs, MD, *Saint Louis, MO (n)*
Perry L Schoenecker, MD, Saint Louis, MO (*)
J Eric Gordon, MD, Saint Louis, MO (n)
Christina Ann Gurnett, MD, Webster Groves, MO (*)

Introduction: Idiopathic congenital talipes equinovarus is a complex deformity that can be corrected using serial manipulations described by Ponseti but requires lengthy bracing to maintain correction. The purpose of this study is to examine patient characteristics and family demographics that are predictive of recurrent foot deformities in patients treated with the Ponseti method. Methods: Fifty-one consecutive patients with 86 clubfeet treated in a large metropolitan community by a single surgeon were examined. Patient characteristics at presentation, such as severity of initial clubfoot deformity, age at initiation of treatment, and previous treatment, were examined by univariate logistic analysis modeling recurrence. Family demographic data, including annual income, highest level of parental education, marital status, as well as parental report of compliance with foot abduction bracing, were also studied in relation to risk of recurrence. Results: Twenty-one patients were noncompliant with

abduction bracing. Noncompliance with bracing was the factor most related to risk of recurrence with an odds ratio (OR) of 183 (95% confidence interval [CI]:9.5-3519; p<0.00001). Parental educational level (high school education or less) also was a statistically significant risk factor for recurrence (OR: 10.7; 95% CI:1.2-92.2; p<0.03). There was no statistically significant relationship between gender, race, parental marital status, source of medical insurance, or parental income and risk of clubfoot relapse. Patient's severity classification, age at initiation of treatment, and previous treatment did not have a statistically significant effect on recurrence risk. Conclusion: Noncompliance and parental education level (high school education or less) are significant risk factors for recurrence of clubfoot deformity after correction with the Ponseti technique. Identification of select patients at risk for recurrence after clubfoot correction with the Ponseti method may allow intervention to improve compliance with foot abduction bracing, and, as a result, improve outcome.

POSTERS

POSTER NO. P369

Calcaneal Lengthening for Neurological Planovalgus Foot Deformity in Children

Miguel Puigdevall, MD, *Buenos Aires, Argentina (n)*
Mario Lampropulos, MD, Buenos Aires, Argentina (n)
Ruben Maenza, MD, Buenos Aires, Argentina (n)
Jorge Hokama, MD, Buenos Aires, Argentina (n)
Hector R Malvarez, MD, Buenos Aires, Argentina (n)

Objectives: The purpose of this study was to report the clinical and radiographic results of calcaneal lengthening for the treatment of flexible, planovalgus foot deformity in children with spastic cerebral palsy and myelomeningocele. Materials and Methods: We performed a calcaneal lengthening osteotomy in 16 patients (26 feet) with symptomatic planovalgus deformities of the foot that had failed nonoperative treatment. Eight patients had spastic cerebral palsy and eight myelomeningocele. The average age of these children was 11 years. The operation consists of an opening-wedge calcaneal osteotomy that was made approximately 1.5 cm proximal to the calcaneocuboid joint, perpendicular to the plantar aspect of the foot and directed toward the interval between the anterior and middle facets. The osteotomy was stabilized with a trapezoid-shaped tricortical bone autograft taken from the iliac crest. No internal fixation was used. The Achilles tendon was lengthened when the ankle lacks at least 10 degrees of dorsiflexion. If the peroneal tendons resist distraction of the site of the osteotomy a Z-lengthening of these tendons was also performed. The average follow-up of this study was 41 months. Results: A satisfactory clinical result was obtained when: the deformity of the hindfoot had been corrected, a longitudinal arch had been created, pain and callusing under the head of the plantar flexed talus had been eradicated and tolerance of the braces and shoes had improved. Preoperative radiographs and radiographs on follow-up were taken in the weight-bearing position. The talo-first metatarsal angle, the talohorizontal angle and the calcaneal pitch were measured in the lateral view. At final follow-up, satisfactory clinical results were obtained in 83% of the evaluated feet. Also, the three radiographic measurements had improved in 71% of these feet. All bone grafts united within two months. There was preservation of motion of the subtalar joint in all twenty-six feet. The poor results were due to recurrence of the deformity in children with cerebral palsy and severe spasticity. Conclusions: Calcaneal osteotomy with lateral column lengthening is an effective procedure for the correction of flexible, mild to moderate planovalgus foot deformity in neurologic children. The unsatisfactory results obtained in severe spastic deformities suggest that more aggressive surgical techniques must be used in patients with severe spasticity. We also found a lack of correlation between the clinical results and the radiologic measurements at follow-up. Therefore, we believe that the evaluation of the treatment in neurologic patients must rest with the assessment of the clinical outcome.

POSTER NO. P370

Is Valgus Osteotomy More Effective than Traction for Femoral Head Resection in CP?

Arabella I Leet, MD, *Baltimore, MD (e – NIH)*

INTRODUCTION: We compared femoral head resection (FHR) and traction with femoral head resection and valgus osteotomy (the McHale procedure), in order to determine the effectiveness of these two procedures in the treatment of painful hip subluxation in severely involved individuals with cerebral palsy. METHODS: A retrospective chart and x ray review was combined with a telephone questionnaire regarding post-operative changes in pain, sitting tolerance, and hygiene as well as overall satisfaction with surgical intervention. RESULTS: 27 patients, 36 hips comprise the study cohort; 26 patients have quadriplegia, one has diplegia and is the only patient who is ambulatory. 16 patients underwent FHR, 11 patients underwent McHale procedures. The average age of surgery was 19 years, range from 8 to 42 years. Average follow-up was 3.4 years from time of surgery. Post-operative complications were numerous and included skin breakdown, wound dehiscense, hardware infection or failure, heterotopic ossification, and death. The complication rate was significantly higher in patients who had undergone FHR and traction (13/16) compared with the patients who had a McHale procedure (3/11). The average length of hospitalization was almost twice as long for the FHR group (7 days) as for the McHale group (4 days). Telephone surveys of caregivers often demonstrated equivalent overall satisfaction with surgery in both groups with average scores of 8/10 for the FHR and 7.6/10 for the McHale group (on a scale from 1 to 10, 10 being the most satisfied). Only two of the respondents (one from the FHR group, one McHale) we contacted regretted having had surgery. Caregivers felt that post-operatively pain relief was achieved in almost all patients. The average time to achieve a more pain-free state was three months. Sitting tolerance improved variably between individual patients, while few caregivers felt that hygiene improved after surgery, although they also felt that hygiene had not been a significant problem pre-operatively. CONCLUSIONS: Both FHR and McHale procedures were equally successful in improving hip pain; however the McHale patients had many fewer surgical complications and spent fewer days in the hospital.

POSTER NO. P371

The Role of the AO External Fixator in Supracondylar Femoral Osteotomies in Children

John Ellis Handelsman, MD, *Scarsdale, NY (n)*
Samara Friedman, MD, New Hyde Park, NY (n)
Jacob Weinberg, MD, Bayside, NY (n)

Introduction: Femoral torsion is traditionally treated by a proximal osteotomy. At this level, a significant exposure is required. Furthermore, internal fixation is typically removed by additional surgery at twelve months. We elected to perform femoral corrective osteotomies distally where angular deformities could also be addressed. We propose to demonstrate the efficacy of the AO

external fixator to maintain osteotomies at this site. Methods: Between September 1994 and April 2001, supracondylar osteotomies were performed on 38 femora in 21 children with torsional and angular deformities. The average age at presentation was 10 years. All children had severe femoral torsional problems affecting their gait. Twenty-three femora had excessive anteversion and 15, retroversion. Genu valgum was addressed in eighteen osteotomies. Five extension osteotomies were performed for fixed knee flexion deformities. The technique required the lateral placement of three 4.0 mm end-threaded Schanz pins parallel to the distal growth plate. Three similar pins were inserted more proximally in line with the femoral shaft. A transverse osteotomy was performed through a limited lateral approach, close to the distal pins. After correction of the deformities, each pin was linked to all others by clamps and carbon fiber rods. Results: Lower extremity alignment was restored in all patients. The external fixators were removed at an average of ten weeks. One child had a superficial pin tract infection requiring intravenous antibiotics. All osteotomies united without complications. No postoperative femur fractures occurred. Discussion and Conclusion: Osteotomy at the distal femur has the advantage of correcting both torsional and angular deformities. The exposure required is limited. The AO external fixator provides precise control of the osteotomy and allows for subsequent adjustability. This method effectively controls supracondylar osteotomies and avoids a second procedure for hardware removal.

POSTER NO. P372

Randomized, Prospective Study of Harrington vs. Segmental Instrumentation for Treatment of AIS

Gary Ghiselli, MD, *Cleveland, OH (n)*
Hugh Godfrey Watts, MD, Glendale, CA (n)
Robert Bernstein, MD, West Hollywood, CA (n)

Introduction: Our hypothesis was that the correction with Harrington instrumentation versus segemental instrumentation was equivalent clinically and that the complications and cost were more with the latter technique. This randomized, prospective study compares Harrington instrumentation with segmental instrumentation in the treatment of adolescent idiopathic scoliosis. There is sparse data supporting advantages of segmental systems over Harrington instrumentation. Methods: Twenty-two patients with adolescent idiopathic scoliosis were operated on by the same experienced orthopaedic surgeon. Minimum follow-up was two years. Each patient was randomized into the Harrington group or the segmental group. Sublaminar and/or Wisconsin wires were used routinely with the Harrington system. No pedicle screws were utilized with the segmental system. All radiographs were measured for proximal thoracic, distal thoracic and lumbar curves. Results: Average age of the patients was 15 years. There were 3 males and 19 females. The mean preoperative upper thoracic, lower thoracic and lumbar curves in the Harrington group measured 29„a, 61„a and 35„a. The mean preoperative upper thoracic, lower thoracic and lumbar Cobb angles in the TSRH group were 36„a, 68„a and 40„a. Postoperatively, these means were corrected to 25„a, 42„a and 23„a in the Harrington group, and 27„a, 35„a and 16„a in the TSRH group. The differences were statistically significant for correction of the lower thoracic curve ($p = 0.003$) and the lumbar curve ($p=0.001$). Surgical time was significantly shorter in the Harrington group ($p=0.019$) as was blood loss ($p=0.008$). Cost was significantly different between the two groups as well ($p<0.0001$). Discussion: Harrington instrumentation offers benefits with regards to cost, surgical time and blood loss. Although the segmental system provides greater radiographic correction, the difference is not clinically significant. Evidence to support the use of Harrington instrumentation may proove beneficial in cases where cost, blood loss and surgical time are important factors in the decision making process.

POSTER NO. P373

Peripheral Circulation in Patients with Myelodysplasia

Yi-Meng Yen, MD, *Venice, CA (n)*
Edward C Sun, MD, Minneapolis, MN (*)
Tze C Ip, MD, Torrance, CA (*)
Norman Yoshinobu Otsuka, MD, Los Angeles, CA (n)

Introduction: Patients with myelodysplasia have increased wound dehiscence and ulcer formation. While neurologic deficits and resultant muscle imbalance are the presumed etiologies for these complications, no study has investigated the role of peripheral circulation in myelodysplasia. Methods: Eighty-two patients were prospectively recruited for this study, consisting of 41 patients with myelodysplasia and 41 age-matched controls. Peripheral circulation was quantified using systolic blood pressures in arms and legs (ankle-brachial index, ABI) and transcutaneous pO2 measurements (TcO2) in standardized location in the forefoot. Both groups had similar mean age (11.0 vs. 10.7). Results: Patients with myelodysplasia had lower ABI (1.01 vs. 1.12, $p<0.001$) but similar TcO2 (68.3mmHg vs. 72.1mmHg, $p>0.05$) compared to the control group. Among the patients with myelodysplasia, the ABI and TcO2 did not vary according to the level of neurologic deficit or patient age. However, those with prior surgical procedures had higher ABI and TcO2 compared to those without prior surgery ($p<0.003$). Conclusion: This study suggests that patients with myelodysplasia may have decreased peripheral circulation compared to normal controls. Vascular insufficiency may therefore contribute to increased wound healing complications and ulcer formation in these patients.

POSTER NO. P374

Hinged Hip Distraction for Severe Adolescent AVN or Chondrolysis

David S Feldman, MD, *New York, NY*
(a – EBI – Biomet Co)
Mihir Thacker, Bombay, India (*)
Sanjeev Madan, Southhampton, United Kingdom (n)
David M Scher, MD, New York, NY (n)
Wallace B Lehman, MD, New York, NY (n)

INTRODUCTION: To determine effectiveness of hinged hip distraction in alleviating symptoms of secondary arthritis from avascular necrosis (AVN) or chondrolysis in adolescence. METHODS: From 1996-2000, 11 patients were treated with articulated hip distraction using a custom made EBI external fixator(EBI, Inc., Parsippany, NJ). Clinical follow-up and chart review were performed. Pain, range of motion and walking distance were used to assess clinical results. A good clinical result was defined as no or minimal pain, at least 90 degrees of flexion and independent ambulation for 30 inutes. RESULTS: Mean age was 14.2 years (range:10-18 years). Two patients had AVN due to sickle cell anemia, one due to Lupus and one with Multiple Epiphyseal Dysplasia. Four had idiopathic AVN with secondary collapse. Three had severe idiopathic chondrolysis with secondary OA. Mean length of follow-up was 4.8 years (range:2-6.1 years). Average length of fixator use was 4.4 months (range:3-7 months). All patients had good clinical results. Mean joint space was 2.6mm (range:2-3mm) pre-operatively and 5.8mm (range:5-7mm) postoperatively. Four patients (36.4 percent) had

complications including one pin-tract infection, one painful knee effusion, and two had to return to OR for manipulation and postoperative epidural analgesia. DISCUSSION AND CONCLUSION: Even with a high complication rate, hinged hip distraction was an effective treatment in eliminating pain, restoring joint space and improving function in adolescents with degenerative arthritis secondary to AVN and chondrolysis. Hinged hip distraction should be thought of as a salvage procedure and an alternative to hip fusion in this difficult group of patients.

POSTER NO. P375

Musculo-Skeletal Surgical Outcomes in Ambulatory Children with Cerebral Palsy

Douglas A Barnes, MD, *Houston, TX (n)*
Nancy Scarborough, PT, Houston, TX (n)
Barry Goode, MS, Houston, TX (n)
Allison C Scott, MD, Houston, TX (n)
Janine Calmes, Houston, TX (n)
Elroy Sullivan, PhD, Houston, TX (n)

Purpose: Using Goldberg's model of cerebral palsy outcome assessment, technical, functional, and satisfaction components for ambulatory children were analyzed. Methods: 313 consecutive ambulatory spastic cerebral palsy patients with orthopaedic intervention between 1994-2000 were selected for retrospective review. Mean age at surgery was 11.4 years (4.1 to 19.2). Each served as his/her own control for pre/post (~1 year) comparison. Procedure specific technical goals based upon clinical examination and kinematic data were established for each patient. Functional assessments by mobility, velocity, O2 cost, and PODCI questionnaire of function were examined. Satisfaction was post-operatively assessed per in-house questionnaire. Results: Technical Component: Higher percentages of goals were achieved for diplegic and hemiplegic diagnoses as compared to quadriplegic (p<.001); for comprehensive surgical approach (p<.001); for patients without previous surgery (p<.001); and with intervention at age <11 years (p=.001). Functional Component: There were overall advances in mobility (p<.001). No difference was found in pre/post velocity (p=.08). For those with O2 data (n= 113), post-operative O2 cost was significantly lower (p<.001). For those with PODCI scores, upper extremity, comfort level, and happiness scores (n= 33) improved post-operatively (all p<.05). Satisfaction Component: When parents were surveyed, 68% were very satisfied, 28% satisfied, and 4% neutral or dissatisfied. Conclusion: Best technical outcomes occurred in least involved (independent diplegic and hemiplegic) children. Prior surgery negatively impacted both technical and functional outcomes. Comprehensive surgery consistently yielded better outcomes than selective. 96% were either satisfied or very satisfied with results.

POSTER NO. P376

The Multiplier Method for Adult Height Prediction

Jonathan Paley, *Baltimore, MD (n)*
Jonathan Talor, Baltimore, MD (*)
Anna Levin, Baltimore, MD (*)
Anil Bhave, PT, Baltimore, MD (n)
John E Herzenberg, MD, Baltimore, MD (n)

Introduction: We propose a new, simple, and universal method to predict adult height, termed the Height Multiplier method. The purpose of this study was to calculate Height Multipliers, validate their use for height prediction, and evaluate the method's universality. Methods: Standard growth charts, based on a diverse population, were published by the CDC in 2000. Height Multipliers (M) for boys and girls were calculated by dividing the height at skeletal maturity (Htm) by present height (Ht) (M equals Htm/Ht) for each age, gender and height percentile using CDC data. These multipliers were compared to multipliers derived from 28 boys' and 24 girls' height databases. Accuracy of multipliers was tested on individual longitudinal data from 52 normal children. Results: The average CDC-derived multipliers were significantly different at each age for boys and girls, but within gender, different percentiles at each age were very similar. These multipliers were very similar to multipliers derived from each of the girls' and boys' databases. For predictions based on the individual data from 52 children; median, 90 percent and standard deviation of absolute error prediction (AEP) were calculated. Boys' median AEP ranged from 1.4- 4.3 cm; 90 percent ranged from 1.8- 8.3 cm. Girls' median AEP ranged from 0.68- 4.38 cm; 90 percent AEP ranged from 1.5-10.6 cm. Discussion: Height Multiplier method of stature prediction is as accurate as CDC growth charts when based on single height measurements and is similar in accuracy to other methods. The Height Multiplier method has the advantage of percentile, race, nationality, and generation independence.

POSTER NO. P377

Biomechanical Study of Peroneal Nerve Tension and Surgical Decompression in Cadavers

Monica P Nogueira, MD, *Sao Paulo, Brazil (*)*
Cesar Antonio de Quadros Martins, MD, Passo Fundo Rs, Brazil (*)
Arnaldo Jose Hernandez, MD, Sao Paulo, Brazil (*)
Dror Paley, MD, Baltimore, MD (n)
John E Herzenberg, MD, Baltimore, MD (n)
Anil Bhave, PT, Baltimore, MD (n)

Introduction: The peroneal nerve is commonly stretched during limb lengthening and deformity correction. If the nerve becomes entrapped under the peroneal muscle fascia and/or anterior intermuscular septum, decompression is indicated to treat nerve compromise. We measured the amount of nerve tension after lengthening or varus osteotomy of the proximal tibia and after surgical decompression. Methods: With this cadaver study, we quantified the amount of tension in the peroneal nerve after varus osteotomy of the proximal tibia and quantified the reduction of nerve tension after decompression in 14 lower limbs. A dispositive, consisting of a stength transducer connected perpendicularly by a hook to the nerve and integrated to a PC, was able to indirectly measure nerve tension before varus osteotomy, after osteotomy, and after nerve decompression. Results: Tension of the peroneal nerve increased significantly after varus osteotomy ($p = 0.0002$) and was reduced significantly after decompression ($p = 0.0003$). No significant difference was noted between the pre-osteotomy and post-osteotomy plus nerve decompression measurements ($p = 0.3666$). Discussion: Varus osteotomy of the proximal tibia significantly increases tension of the peroneal nerve. Tension in the peroneal nerve after decompression was not significantly different from initial nerve tension before osteotomy. This study provides biomechanical evidence of the efficiency of nerve decompression in relieving the increase in peroneal nerve tension after procedures that stretch the nerve.

POSTER NO. P378

Body Mass Index in Patients with Slipped Capital Femoral Epipysis: A Predictive Tool?

Nitin Bhatia, MD, *Miami, FL (n)*
Norman Yoshinobu Otsuka, MD, Los Angeles, CA (n)

INTRODUCTION: Approximately 20 percent of children with idiopathic slipped capital femoral epiphysis have bilateral disease. Predicting which patients will develop problems with both hips, however, remains difficult. This study is the first to evaluate the body mass index (BMI) as a tool to predict bilateral hip involvement in children with SCFE. METHODS: All patients treated at the senior author's institution with a final diagnosis of SCFE from 1992 to 2000 were included in the study. Height and weight measurements were obtained at presentation and used to calculate the BMI. A retrospective chart and x-ray review was performed. RESULTS: Fifty-four patients, consisting of 37 males (69%) and 17 females (31%), were enrolled in the study. Sixteen patients (30%) had bilateral disease. The average BMI was 26.8 for the unilateral group, and 31.2 for the bilateral group. Five patients had BMI's greater than 35, and all had bilateral involvement. The average age was 12.6 years old for both the unilateral and bilateral groups, and the average follow-up was greater than 2 years. DISCUSSION AND CONCLUSIONS: In this study, the patients with bilateral disease had a higher average BMI than those with unilateral disease. Furthermore, all patients with BMI's greater than 35 had bilateral involvement. The body mass index may provide an easily obtainable method for predicting which SCFE patients have a higher likelihood of developing bilateral disease.

COMSS POSTER NO. P489

Pediatric Orthopaedic Society of North America

Assuming the Burden of Pediatric Fracture Care in a Children's Medical Center...Efficiently! A Model for a Pediatric Fracture Clinic

John Taylor Smith, MD, *Salt Lake City, UT (n)*
Sohrab Gollogly, MD, Salt Lake City, UT (n)
Nicole Clark, Salt Lake City, UT (n)

Introduction: Sub specialist pediatric orthopedic surgeons are faced with a growing demand that they provide the majority of routine fracture care for children. This demand is based upon changing patterns of referral and "comfort level" among community orthopedic surgeons. Many sub specialists are dismayed at the way in which this burden dilutes their ability to devote time and resources to the needs of children with complex problems within their subspecialty area of interest. However, one solution is to develop a system that manages these patients efficiently utilizing the proper mix of personnel, information technology, and clinical and institutional resources. Purpose: To demonstrate that a focused pediatric fracture clinic can efficiently handle large numbers of children with routine fractures while minimizing the negative effects on the primary focus of a subspecialty-specific clinical practice. Methods: The records of the pediatric fracture clinic at Primary Children's Medical Center were reviewed for the twelve months of 2001. Data were collected on number of patients seen, type of insurance, type of fracture, referral source, number of visits per injury, % of clinical volume, and % of clinical time consumed in fracture care. Results: From January to December 2001, we saw 1047 new patients in our fracture clinic. All patients were seen in a single half-day clinic, with all requests for evaluation accepted without question. An average of 87 new fractures were seen per month. The payer mix was Indemnity Insurance 68%, Medicaid 20%, and Self-Pay 12%. Over half of the patients were initially evaluated at outside institutions and referred to our center for evaluation. Collection rates for billed charges were 58%. A mini c-arm was used for radiographic evaluation of routine fractures, significantly improving the efficiency of patient evaluation and treatment. All patient encounters were documented using established fracture encounter templates using laptop computers and a scribe for completion without the need for dictation or transcription for each encounter. All patients were entered into an electronic billing program at the completion of clinic and the templates completed. The senior attending orthopedic surgeon supervised application of all casts applied by medical assistants or residents. Resident evaluation of this experience is highly favorable in an environment where precise cast technique has become a lost art. Conclusions: This is a viable model for providing efficient fracture care for large numbers of fracture patients in a subspecialty pediatric orthopedic clinic. Furthermore, this type of a clinic can become a community, institutional, and educational resource.

SCIENTIFIC EXHIBITS

SCIENTIFIC EXHIBIT NO. SE066

Spinal Fusion in Ambulatory Cerebral Palsy Patients: Can a Child Walk After Instrumentation to the Pelvis?

Suken A. Shah, MD, *Wilmington, DE (n)*
Anasthasios Tsirikos, MD, Wilmington, DE (*)
Wei-Ning Chang, MD, Wilmington, DE (n)
Kiwk W. Dabney, MD, Wilmington, DE (n)
Freeman Miller, MD, Wilmington, DE (n)

INTRODUCTION: Twenty-six ambulatory pediatric patients with spastic cerebral palsy (CP) and neuromuscular scoliosis underwent spinal fusion (PSF) from T1 or T2 to the sacrum with pelvic fixation using unit rod instrumentation. PURPOSE: To evaluate the effect of this surgery on the ambulatory potential of CP patients. RESULTS: The study group is comprised of 18 female and 8 male patients, 20 of whom have quadriplegic CP, 6 who have diplegic CP. There was no difference in the curve type between the two groups. Twenty-two patients had a single thoracolumbar or lumbar scoliotic curve, and 4 patients demonstrated a double curve pattern. Mean age at surgery was 15.4 years. Mean preoperative Cobb angle was 63 degrees and corrected by 68% to 20 degrees. Preoperative pelvic obliquity was corrected from 11.7 degrees to 3.3 degrees. The patients were all evaluated clinically preoperatively, postoperatively, and at follow-up with no alteration in their ambulatory status. Clinical follow-up assessment for ambulatory function occurred at a mean of 3.9 years after surgery (2 yrs.-9 yrs.). Fourteen patients underwent both preoperative and postoperative full gait analysis. In all 14 patients, the evaluation of the postoperative gait analysis documented a gait pattern similar to or better than the preoperative pattern by six months after PSF. The caretakers of all 26 patients completed an outcome survey which demonstrated significant improvement in the child's appearance, amount of back pain, head and trunk balance, sitting tolerance, respiratory function, and no compromise in ambulatory capacity. All caretakers reported that they would recommend surgery to ambulatory patients with CP who develop severe scoliosis. CONCLUSIONS: This study demonstrates that in ambulatory patients with spastic CP and neuromuscular scoliosis, PSF with unit rod instrumentation provides stable fixation to the pelvis, achieves satisfactory

correction of the deformity, and restores trunk balance in the coronal and sagittal planes, without compromising a patient's ability to ambulate.

SCIENTIFIC EXHIBIT NO. SE067

Decreased Bracing Effectiveness in Overweight Patients With Adolescent Idiopathic Scoliosis

Patrick O'Neill, MD, *Baltimore, MD (n)*
Paul Sponseller, MD, Baltimore, MD (n)

PURPOSE: To determine whether overweight patients with adolescent idiopathic scoliosis (AIS) are less successful with bracing than those who are not overweight. METHODS: We reviewed all AIS cases at our institutions for the past 10 years who met the inclusion criteria: no prior treatment, Custom TLSO or Boston brace use, curves 25-40 degrees with Risser sign 0-2 at brace initiation, and follow-up to skeletal maturity. Overweight was defined as a body mass index >85th percentile. Success with bracing was defined as curve progression <5 degrees. Statistical analysis included independent t-test, multiple regression analysis, and calculation of the odds ratio. RESULTS: There were 276 patients who met the inclusion criteria and had sufficient data for analysis, with 12% (34) overweight. Average age at bracing was 12.8 years. The mean time in the brace was 14.3 hours per day (S.D. 5.5) and the mean initial curve magnitude was 32.5 degrees (S.D. 4.35). Curve progression ranged from –20 to 47 degrees with a mean progression of 4 degrees and a standard deviation of 9 degrees for the whole sample. For those overweight versus not overweight the curve progressions means were 8.8 degrees (S.D. = 7.9) and 3.6 degrees (S.D. = 9.3), respectively. The range of curve progression was –10 to 25 degrees for those who were overweight and –20 to 47 degrees for those not overweight. There is a statistically significant difference between the mean curve progression of the overweight patients versus those not overweight ($t = -3.108$, $df -=274$, $p<.01$). Regression analysis showed that 30.7% of the variance in curve progression is explained by average hours in brace per day, being overweight, % correction, gender, and age when brace started ($p<.001$). Those patients who were overweight were 2.6 times as likely to be unsuccessful than those who were not overweight. CONCLUSION: The results suggest that overweight AIS patients will have greater curve progression and be less successful with bracing than those not overweight. The ability of a brace to transmit corrective forces to the spine through the ribs and soft tissue may be compromised in overweight patients. SIGNIFICANCE: The effect of being overweight on the outcome of bracing children with AIS has not been reported. This factor should be taken into account when making treatment decisions. Further study is warranted to determine a threshold effect.

PAPERS

PAPER NO. 151

Prospective Study of Teleconsultation in Hand Surgery

Joseph Albert Abboud, MD, *Broomall, PA (n)*
David J Bozentka, MD, Wallingford, PA (n)
Pedro K Beredjiklian, MD, Philadelphia, PA (n)

Introduction: Telemedicine is a valuable but underused resource for the delivery of health care to patients in areas that are underserved. The purpose of this study was to determine whether Hand Surgery teleconsultation for upper extremity injuries can be used to accurately diagnose and formulate treatment plans. Methods: 100 patients with acute upper extremity injuries were prospectively evaluated by one orthopaedic resident. The evaluations involved a history and physical examination, digital images of the patient, and digital radiographs. This patient information was presented electronically to two hand surgeons six weeks after these surgeons directly evaluated the patients in the outpatient clinic. The physicians formulated a diagnosis and treatment plan for the patients based on the blinded electronic information, and these findings were then compared to the treatment plans made by the physicians directly at the earlier time point. Kappa coefficients (kappa) of intraobserver and interobserver reliability for diagnosis and treatment were generated. Results: Telemedicine consultation did not alter proposed treatment plans within observers (intraobserver agreement: kappa =. 89, high) or between observers (kappa =. 86, high). The actual number of diagnoses and treatments which changed within observers was four and five, respectively. Discussion and Conclusion: Telemedicine consultation resulted in no significant change in the proposed management of upper extremity injuries, and appears to provide an accurate and powerful method for delivery of orthopaedic care.

PAPER NO. 152

Time to Orthopedic Treatment Between California Medicaid and Private Patients

Donald Saroff, MD, *Alexandria, VA (n)*
Richard M Dell, MD, Bellflower, CA (*)

Introduction : Actual Medicaid patients' ability to access orthopaedic care remains unstudied. This study of actual patients compares time to definitive orthopaedic treatment - after Emergency Department (ED) presentation, between Medicaid and privately insured children in California. Methods: Retrospective analysis of chart and claims encounter data of California children aged 0-16 enrolled in Medicaid (Medi-Cal) or with private insurance. The children had isolated acute supracondylar humeral fractures (requiring operation) or forearm fractures (requiring reduction). The study period was July – December 1999. N= 147 for California Medi-Cal patients and N=176 for privately insured patients. Results: Of 147 Medi-Cal patients, 25% with forearm reductions and 18% with supracondylar operations waited three or more days, after initial ED presentation, for definitive treatment. Of 176 privately insured patients, 2% with forearm reductions and 3% with supracondylar operations waited three or more days, after initial ED presentation, for treatment. Also, in the Medi-Cal group, forearm reductions initially performed by non-orthopaedic personnel resulted in a 50% re-reduction rate. Conclusion: This study reveals striking delay in the actual orthopaedic treatment of Medicaid children compared to privately insured children. Also, forearm fracture reduction competency among non-orthopaedists is questionable.

PAPER NO. 153

How Good are Hip Replacement, Spinal Surgery and Menisci Surgery for Improving Quality of Life?

Olof Johnell, MD, *Malmo, Sweden (n)*
Sofia Lofvendahl, Stockholm, Sweden (n)
Bengt Malmqvist, Gavle, Sweden (n)
Sylvia Resch, MD, Karlshamn, Sweden (n)

Question: How large are the benefits in health-related quality of life after total hip replacement, spinal surgery (herniated disc and spinal stenosis) and arthroscopic surgery for meniscus lesions? Method: The Swedish County Council sent out an inquiry to 1336 consecutive patients in 10 Swedish hospitals operated on 3 months earlier with the three procedures. 79% answered the inquiry. The number of answered inquiries for the different procedures was for total hip replacement 452 (87% response), spinal surgery 258 (80%), menisci 350 (70%). For defining patient satisfaction, standardized questions were asked. For quality of life a modified quality of life instrument (EQ-5D) was used. The patients answered questions about their status just before the operation and 3 months after the procedure.The patients´ judgments of the operation result 3 months after the operation was for hip replacement very good 60%, good 33%, either good or bad 5%, bad 2% and very bad 0%. The corresponding figures for spinal surgery were 34, 36, 20, 8% and 3%. For menisci surgery the figures were 25, 35, 26, 10 and 5%. These results were fairly independent of the time the patients had been on the waiting list.For quality of life modified EQ-5D utilities (in the range from 0-1, where 1 is perfect health and 0 is dead) were used. The preoperative status was for hip replacement 0.09 and was after 3 months increased to 0.73, for spinal surgery 0-0.69, for meniscal surgery 0.29-0.73. Another way of expressing it is the proportion of patients with average or severe problems measured through EQ-5D for the different domains of EQ-5D. These were for hip fractures for mobility 97-68% (preoperatively vs 3 months after surgery), for own hygiene 36-17%, for activity 76-42%, for pain 100-60% and for anxiety 58-25%. The length on the waiting list had only a small effect on the results. Discussion: It is important to measure quality of life in patients since this is the problem that causes the visit to the doctor. It is also the only way of comparing different diseases and different procedures as in this study. It is important to notice that all 3 procedures improve patient satisfaction and quality of life substantially. Total hip replacement had the best effect on these variables and also affected all domains on the quality of life scale, not only pain and mobility. Surgery for herniated disc did better than surgery for spinal stenosis. It is also important to notice that prior to the operation all patient groups had a substantially reduced quality of life, which indicates that they should be prioritized also compared with diseases in other specialities. Indeed, this substantial increase in quality of life after operation justifies this statement.

PAPER NO. 154

RCT of Home Based vs Inpatient Rehab Following TJA: Functional Outcomes and Patient Satisfaction

Nizar Mahomed, MD, *Toronto, ON Canada (n)*
James G Wright, MD, Toronto, ON Canada (a – Canadian Institute for Health Research)
Gillian Hawker, MD, Toronto, ON Canada (n)
Aileen M Davis, PhD, Toronto, ON Canada (n)
Elizabeth Badley, MD, Toronto, ON Canada (n)

Introduction: Home based rehab is increasingly utilized to save costs but concerns have been raised about early hospital discharge and adverse clinical outcomes. This study compares the efficacy and patient satisfaction of home based verses inpatient rehabilitation following total joint arthroplasty (TJA). Methods: 234 patients were randomized to either home based or inpatient rehabilitation following TJA, using block randomization techniques. Standardized care pathways were followed for both procedures. All patients were evaluated at baseline (2 weeks prior to surgery), 6 weeks, 12 weeks and 1 year post surgery using standardized questionnaires. Primary outcomes were the self-reported WOMAC pain and function score and satisfaction in terms of improvement in pain and function. Results: The groups were similar at baseline for patient demographics and WOMAC scores. At the 6 weeks, 12 weeks and 1 year follow-up post TJA there was no statistically significant difference in WOMAC pain, physical function, stiffness and overall WOMAC scores. Both groups showed a trend of decrease in pain, stiffness, restriction in physical function over the follow-up period. Similarly, patient satisfaction scores at 6, 12 weeks and 1 year did not show a statistically significant difference between the home versus inpatient group (P>0.05). Discussion and Conclusions: Despite concerns about early hospital discharge there was no difference in functional outcomes and in patient satisfaction with procedure at the primary endpoints, between the groups receiving home based verses inpatient rehabilitation. Given that home based rehab is less expensive, we would recommend the use of home based rehab protocols following elective primary TJA.

PAPER NO. 155

A Cost-Effectiveness Analysis of Total Ankle Arthroplasty

Nelson Fong SooHoo, MD, *Los Angeles, CA (n)*
Gerald Kominski, PhD, Los Angeles, CA (*)

Introduction: Total ankle arthroplasty is in the early stages of dissemination for use among clinicians in the community. The purpose of this cost-effectiveness analysis is to assist clinicians in judging whether currently available data justify the widespread implementation of total ankle arthroplasty at this time. Methods: A decision model was created for the treatment of ankle arthritis. Literature review was used to identify possible outcomes and their probabilities following ankle fusion and ankle arthroplasty. Each outcome was weighted for quality of life using a utility factor and effectiveness was expressed in units of quality-adjusted life years. Gross costs were estimated from Medicare reimbursement data for the relevant CPT and DRG codes. Results: In the reference case of our model, the cost-effectiveness ratio for ankle arthroplasty was $9,281 per life-year gained. This reflects a gain of 1.1 quality-adjusted life years at a cost of $10,302 when ankle arthroplasty is chosen over fusion. This ratio compares favorably to the cost-effectiveness of other medical and surgical interventions. The reference case assumes a high level of prosthetic function for 15 years following ankle replacement. These findings are also dependent on the assumption that ankle replacement results in improved function when compared to ankle fusion. Conclusions: This study supports ankle arthroplasty as a potentially cost-effective choice over ankle fusion. This conclusion assumes prosthestic survival for fifteen years with a functional result superior to ankle fusion. Currently available data have not yet demonstrated that ankle replacement predictably generates these levels of durability and function. Widespread dissemination of ankle replacement would be better justified when these thresholds are met.

POSTERS

POSTER NO. P356

Can Faculty Review Capture Quantitative Differences in Orthopaedic Residency Applications?

Susan Scherl, MD, *Omaha, NE (n)*
Nicole Wilson, BA, Lombard, IL (n)
Stephanie Smith, BA, Omaha, NE (n)

INTRODUCTION: Recruiting new residents is one of the most important tasks undertaken by orthopaedic faculties. However, comparing candidates is difficult, since little objective data is contained in the Electronic Residency Application Service (ERAS) charts. The purpose of this study is to determine if there are quantifiable differences in the credentials of candidates subjectively graded by faculty reviewers. METHODS: The ERAS applications of 186 candidates to a university orthopaedic residency were graded subjectively by 3 independent reviewers and given an average score between 1.000 and 3.000, with 1.000 being the best. The candidates were divided into 7 cohorts based on the average grade. The charts were then analyzed as to whether quantifiable differences existed between the grading cohorts in USMLE Step I score, medical school grades, AOA standing, and numbers of publications and positive catchphrases in letters of recommendation. RESULTS: There were 186 candidates (18 female, 168 male). The grade cohorts were divided as follows: Cohort: Subjective Grade, Number of Candidates.A : 1, 21; B: 1.08-1.5, 37; C: 1.58-1.75, 54; D: 1.83-1.917, 14; E: 2, 24; F: 2.083-2.667, 15; G:3, 21. Mean USMLE score, percent of candidates who were AOA, mean percentages of basic science and clinical medical school honors, mean number of publications, and mean number of positive catch phrases from recommendation letters (such as "best this year"), were found to correlate directly to subjective cohort rank. DISCUSSION AND CONCLUSION: There is a linear correlation (R2=0.8335) between subjective grade and cohort rank and USMLE score. Similar correlations exist for each of the other data categories analyzed. Thus there are quantifiable differences between each cohort, as subjectively determined by faculty evaluation.

POSTER NO. P357

Hospital-Based Allogenic Bone Bank: Ten-Year Experience

Chun-han Hou, *Taipei, Taiwan (n)*
Sheng-Mou Hou, MD, Taipei, Taiwan (*)
Rong-Sen Yang, MD, Taipei, Taiwan (*)

[Introduction] One of the most pernicious and potentially disabling complications of musculoskeletal allograft use is the transmission of disease, especially infection, from donor to recipient. [Materials and Methods] We have reviewed 1365 allografts used on 1353 recipients from the bone bank of the Orthopedic Department of National Taiwan University Hospital

from July 1991 to June 2001. Serum HBsAg, STS (VDRL) test, bacterial swab culture, serum anti-HCV, and anti-HIV test were screened consequently. A second swab culture was done after defreezing before implantation. All allografts were washed by gentamycin solution before it was implanted into recipient¡_s body.[Results] In this series, there were 309 allografts discarded due to failure in passing the screening tests. The discard rate was 18.46% (309/1674). The leading cause was HBsAg positive in donor serum (67%), followed by VDRL positive (15%), and Anti-HCV positive (12%). The overall allograft-related infection rate was 1.26% (17/1365). [Discussion and Conclusion] The astonishing high HCV positive rate in monitoring survey for the past two years indicated that further screening of unknown pathogens should always be seriously considered if new techniques of detecting pathogens are available. Our bone bank had been functioning well under strict monitoring system in terms of low infection rate to international standards. The allograft we implanted currently might have unknown pathogens, further close monitoring of these patients are mandatory. The sterilization during the operation was more critical than the diseased allograft itself.

POSTER NO. P358

Inadequate Documentation in Compartment Syndromes: A Review of 30 Cases

Brett Cascio, MD, *Baltimore, MD (n)*
Michael Craig Ain, MD, Owings Mills, MD (a – Synthes Spine)
Frank J Frassica, MD, Baltimore, MD (*)

Introduction: Chart documentation is often found to be inadequate following the initiation of legal action for compartment syndromes. This study examines the adequacy of chart documentation of a series of compartment syndromes. Methods: Thirty consecutive cases of fasciotomy for compartment syndrome from 1992-2002 were reviewed at an academic health center. Notes and consent forms were evaluated for legibility, notation of date and time, and the presence of core physical exam and history findings: 1.pain, 2.paresthesias, 3.tense compartments, 4.pain on passive stretching, 5.sensory deficit, 6.motor deficit, 7.pulses, 8.compartment pressures, and 9.diastolic blood pressure. Results: Seventy percent of cases did not have full documentation. Twenty-nine percent of the notes were not timed, a single note was not dated, and two notes were not dated or timed. Twenty-seven percent of consent forms were not timed and one was not dated or timed. Presence of pain was not recorded in 17 percent of cases, paresthesias in 37 percent, tenseness of compartments in 10 percent, presence of pain on passive stretch in 33 percent, the sensory exam in 30 percent, the motor exam in 27 percent, and pulses in 23 percent. Compartment pressure measurements were incompletely recorded in 21 percent of measurements. The diastolic blood pressure was not documented in 52 percent of cases. Fifty-three percent of the notes were at least partially illegible. Discussion/conclusion Documentation of the core history and physical exam findings in a series of compartment syndromes was inadequate. More intensive education is needed in the documentation of the core physical examination findings in compartment syndrome.

POSTER NO. P359

Medical and Surgical Costs of Care in Patients with Osteoarthritis of the Knee

Gurkirtal Singh, MD, *Palo Alto, CA (a – Wyeth Labs)*
Bonnie Bruce, Palo Alto, CA (n)
Miho Bennett, Palo Alto, CA (*)
Reiko Sato, PhD, Saint Davids, PA (n)
David D Waddell, MD, Shreveport, LA (a – Genzyme)

Introduction: To describe long term direct medical and surgical costs and predictors of cost in patients with knee osteoarthritis (OA) in a prospective observational cohort study. Methods: We studied 1576 patients with 4946 patient-years of observation who were enrolled in the Arthritis, Rheumatism and Aging Medical Information System (ARAMIS) program. Semi-annual data were collected on self-reported health care resource utilization and level of disability using a validated Health Assessment Questionnaire (HAQ disability index (HAQ-DI) 0-3 scale; 3=complete immobility). Costs were computed as units of service multiplied by uniform costs in inflation-adjusted 2001 dollars. Medicare reimbursement rates were used to approximate costs for physician services; wholesale prices for medications. Results: At baseline, patients averaged 66 years old, with 14 education years, a mean body mass index of 28.9 and a disease duration of 15.5 years. Patients were moderately disabled with a mean HAQ DI of 0.91. Average annual direct costs were $2318, with hospitalization costs predominating at $1155. Surgical hospitalizations accounted for 38% of overall costs. Remaining proportions of costs were comprised of physician visits (15.8%), laboratory (12.2%), radiographs (8.9%), and medications (13.2%). After adjusting for confounding variables, a strong, significant relationship remained between increase in HAQ-DI and costs ($p<0.0001$) with costs increasing 53% for every unit increase in HAQ-DI. Conclusions: Patients with knee OA incur significant medical costs of care, which are closely tied to functional status. Therapies that have a significant effect in improving functional status are likely to be more cost-effective over the long-term compared to symptomatic treatments.

POSTER NO. P360

In-Hospital Outcome and Resource Use in Hip Arthroplasty: Influence of Body-Mass Index

Ilksen N Gurkan, *Towson, MD (n)*
Stefan R Jibodh, MD, Boston, MA (n)
James F Wenz Sr, MD, Baltimore, MD (*)

Introduction: To determine the influence of body-mass index (BMI) on perioperative morbidity, functional recovery from surgery, and their effects on hospital utilization, the current authors reviewed patients undergoing primary total hip arthroplasty (THA) at their institution over a 5-year period. Materials & Methods: Patients were grouped into BMI categories according to the consensus guidelines established by the International Obesity Task Force. This study analyzed 207 primary THAs for transfusion requirements, operative complications, functional recovery, and assistance needed for transfers from supine to sit, sit to stand, and bed to chair positions at the first physical therapy. Charges were categorized as: operating and recovery room fees; anesthesiology and blood bank services; inpatient room charges; pharmacy dispensing and drug fees; imaging studies; laboratory and other diagnostic tests or pathology; physical therapy, respiratory therapy, and other rehabilitation services; and supplies and ancillary charges. Results: Compared with others, morbidly obese patients had significantly longer mean operative time and higher mean intraoperative blood loss, a

trend toward more complications, but no significant difference in functional recovery and hospital utilization. No significant differences in charges were noted among the different BMI groups in any of the eight billing categories. Conclusion: In-hospital outcomes for patients with primary THA were comparable across a wide range of BMIs. Although there were significant differences (such as longer operative times and greater blood losses) between morbidly obese and other patients, adjusted total transfusion requirements, length of stay, and resource utilization were comparable among the four BMI groups.

POSTER NO. P361

Analysis of Conflict of Interest at the Annual Meetings of the OTA

Erik Kubiak, MD, *Brooklyn, NY (n)*
Kenneth A Egol, MD, Jamaica, NY (*)
Kenneth J Koval, MD, New York, NY (n)
Joseph D Zuckerman, MD, New York, NY (*)

Introduction: Our purpose is to evaluate the extent and changes in industry sponsorship over the past decade presented at the annual meetings of the Orthopaedic Trauma Association. Methods: All conflicts of interest and type were recorded for each year and frequencies were calculated since the adoption of reporting policies 1993-2002. ANOVA and Students t-test were performed on the data. Results: There was an increase in the percentage of papers accepted and presented at the OTA between 1993 and 2002 with conflicts of interest. The number of papers reporting conflict of interest rose from 7.6% in 1993 to 12.6% in 2002; p=0.0129. There was no significant increase in posters with conflict of interest over that same time period. Between 1999 and 2002 research distributions were: 0.84 research, 0.17 consultant fees, 0.12 misc funding, 0.03 royalties, and 0.02 stocks/royalties. Discussion: The degree to which industrial support compromises the ethical pursuit of knowledge to further the improvement of patient care remains in large part hidden. The increasing industrial support of scientific research in the public sector is to be applauded as long as it does not lead to the sequestering and suppression of information that may be disadvantageous to the industrial sponsor.

POSTER NO. P362

How Presenting the Risk of Fracture Surgery to Patients Influences Decision-Making

Mohit Bhandari, MD, *Hamilton, ON Canada (n)*
Paul Tornetta III, MD, Boston, MA (n)

INTRODUCTION: Risk information is understood differently when it is presented in absolute or relative terms; the latter tends to overemphasize the magnitude of risk. We evaluated whether presenting the risks and benefits of surgery in absolute and relative terms affected patients' decisions to accept or reject surgical alternatives. METHODS:We administered a face-to-face survey to 50 patients attending the fracture clinic at a University hospital. We asked patients to consider a scenario (hip fracture) and to decide which treatment alternative they preferred based upon risk presentation. We presented risk in 5 ways: 1) absolute risk difference , 2) relative risk reduction (RRR) , 3) relative risk, 4) number needed to treat (NNT) , and 5) odds ratio. RESULTS: Patients were 21 to 88 years-old, 66 percent male and 52percent had previous fractures. Seventy-six percent of patients favored internal fixation when the mortality results comparing internal fixation versus arthroplasty were presented as a RRR (ie: internal fixation may reduce the risk of mortality by 33percent when compared with arthroplasty). NNT and Odds ratios resulted in the lowest degree of endorsement for internal fixation (36 and 34 percent, repectively). Patients continued to favor internal fixation despite being presented with a significantly increased risk of revision surgery. CONCLUSION/DISCUSSION: Patients concerns about mortality, even if non-significant differences are presented by using the term "may", outweigh concerns about significant "definite" increases in revision surgery with internal fixation.

POSTER NO. P363

Decision-Making for Submitted Abstracts to an Annual Trauma Meeting

Mohit Bhandari, MD, *Hamilton, ON Canada (n)*
Paul Tornetta III, MD, Boston, MA (n)
David C Templeman, MD, Minneapolis, MN (c – Zimmer)

INTRODUCTION: No previous studies have evaluated the abstract selection process at an orthopaedic subspecialty meeting. We examined the consistency of reviewers in grading abstracts submitted for podium presentations at the 2001 and 2002 Annual Meetings of the Orthopaedic Trauma Association (OTA). METHODS: Reviewers (2001, N=8; 2002, N=9) independently graded all abstracts submitted to the OTA for presentation in a blinded manner. Prior to final decision-making, all reviewers met to discuss the abstracts submitted for oral presentation. Discussions varied depending upon the variability of the scores until consensus regarding the pre-meeting ranking of papers was achieved. During the meeting, unblinded reviewers independently re-graded the podium presentations. RESULTS: Among the 440 papers reviewed in 2001 and 420 papers in 2002, the inter-reviewer reliability for abstract grade was 0.23 (95% C.I.= 0.19-0.27) and 0.27 (95%C.I= 0.22- 0.32), respectively. Agreement on the abstracts selected for presentation was no better than for those that were not. Despite disagreements in the quality of the abstracts, reviewers achieved consensus by discussions in a face to face meeting to determine the program. Agreement among unblinded reviewers of the podium presentations during the meetings did not improve agreement: ICC=0.22 (95%C.I=0.12-0.36). Of the 2002 papers that ranked in the top 20 after the full presentation, 15 had originally been ranked below 20 in the initial grading. CONCLUSION/DISCUSSION: Program committees should consider adding a "consensus meeting" to rank all articles in light of our findings that reviewers independently achieve poor agreement.

POSTER NO. P364

Bone Regeneration Using Cryopreserved Arterial Allografts as Osteopromotive Membranes

Miguel Angel Suarez, MD, *Aviles, Spain (n)*
Maria Jesus Arriaga-Florez, Oviedo, Spain (*)
Primitiva Menendez-Rodriguez, MD, Oviedo, Spain (*)
Pedro Riera-Rovira, MD, Oviedo, Spain (n)
Maria Angeles DelBrio-Leon, MD, Oviedo, Spain (n)
Juan Carlos DeVicente-Rodriguez, MD, Oviedo, Spain (n)
Antonio Murcia-Mazon, MD, Gijon, Spain (n)
Eduardo Luis Fuente-Martin, MD, Gijon, Spain (*)

Introduction: The objective of the study was to evaluate the use of an allograft of cryopreserved abdominal aorta as a membrane for guided bone regeneration in long-bone defects. Methods: Prospective, randomized, blinded study in 10 New Zeland rabbits. 10 mm mid-diaphyseal defects were created in both radii. In one side the defect was covered with a cryopreserved aortic allograft as a tube. The contralateral side, with no barrier

membrane, served as control. In vivo X-rays were obtained monthly for morphometric and densitometric analysis. Animals were sacrificed at 6, 12, 24 and 30 months for computed tomography study and to obtain images with electronic and optical microscopy. Results: None of the control defects were healed. Nine of the ten experimental defects were completely reconstituted, with a nearly normal cortical-medullar pattern, in continuity with the bone in the extremes of the defect. Densitometric and morphometric analysis of the regenerated bone showed progressive increasing in the density and thickness of the medullar and the cortical, and also in the cortical-medullar index, to values very similar to that of the normal long bone. Morphological and ultrastructural studies showed images suggesting osteoinductive properties of cryopreserved arterial allografts in guided bone regeneration (not only as barrier membranes) due to the differentiation of viable endothelial or smooth muscle vascular cells towards osteoblastic cells, and calcification/ossification due to changes in proteins of the arterial extracellular matrix. Discussion and Conclusions: Cryopreserved aortic allografts can be used as a membrane barrier for guided bone regeneration, being an alternative to synthetic membranes.

POSTER NO. P365

Face Mask Pollution of the Operating Room Air

Eugene Sherry, MD, *Penrith, NSW Australia (n)*
Max Reynolds, MSc, Penrith, Australia (a – Nicrosol Technology Pty. Ltd: Privately Owned Company)
Patrick H Warnke, MD, Kiel, Germany (*)

INTRODUCTION: A clean Operating Room (OR) is essential for successful surgical outcomes.To date little is known about the biological load of the OR air. We decided to investigate the biological load in the air of the OR during a knee replacement operation. METHOD: Air samples were taken, using a vacuum pump drawing air sample through sterile 0.42 micron filters, at the beginning of the operation, and for every 30 minutes until the patient was taken to the recovery area. Two sets of samples were taken. All micron filters were transferred onto Tryptic Soy Agar and Malt Agar plates immediately. At completion of surgery (3.5 hours) all plates were incubated for 24 hours and the results tabulated.All surfaces in the OR were cultured. Also, all facemasks used were collected and checked, both back and front. Identification and the classifiaction of these microorganisms were undertaken. RESULTS: The biological profile showed increased bacteria and mold in the air of the OR from 10x1 to 10x4. All OR surfaces remained sterile.However, all masks were found to be contaminated both back and front, with the same high levels of throat and nasal flora after 15 mins.We redesigned these masks. DISCUSSION AND CONCLUSIONS: It is postulated that this increased bio load was introduced into the OR by the masks of the surgeons and nurses present. Clearly there is a need to Improve facemask design and function to prevent pollution of the OR air. Our redesigned mask now lasts 3.5 hours.

POSTER NO. P366

Cultural and Practical Determinants of Satisfaction with Medical Malpractice Law

Samir Mehta, MD, *Collingswood, NJ (n)*
Hyams S Elias, BA, Philadelphia, PA (*)
Joseph Bernstein, MD, Bala Cynwyd, PA (*)

There have been reports of dissatisfaction among surgeons regarding the administration of malpractice law to the point where the AMA has declared a malpractice crisis. Dissatisfaction may stem from economic factors but also may reflect deeper sentiments. To assess this, the attitudes of American orthopedic surgeons and neurosurgeons were compared to those of their Japanese counterparts. A 31-question survey was administered to 58 Japanese and 79 American orthopedic and neurosurgeons. Respondents were asked to grade agreement with statements regarding medical error, error reporting, malpractice suits, and quality of care, among other issues. A linear scale (0-100) was used, and a difference of 20 points was defined a priori to be clinically significant. There was no significant difference between the two cohorts with respect to clinical practice experience. Strikingly, the average American surgeon had been sued 4.30 times while the Japanese surgeons had been sued 0.03 times. Of the 31 statements, there was clinically and statistically significant disagreement in 24 of them. Notable areas of disagreement include whether the malpractice environment affects the quality of care, stifles reporting of errors, or promotes defensive medicine. Japanese and American surgeons differ with regard to their attitudes regarding medical error and medical malpractice litigation. American surgeons also report greater professional dissatisfaction. Although cultural difference may explain some of these findings, the simplest explanation is that American surgeons have been sued more frequently. The non-economic costs of prevalent lawsuits must be considered in any reform effort.

POSTER NO. P367

The Impact of New York State 405 Workforce Regulations at One Institution

Amar D Rajadhyaksha, MD, *Valhalla, NY (n)*
Avinash Mohan, MD, Valhalla, NY (*)
Jonathan R Mallen, MD, Chestnut Hill, MA (*)
David E Asprinio, MD, Valhalla, NY (n)

INTRODUCTION:New York State (NYS) was the first governing body to restrict resident work hours (NYS Public Health Law Section 405.4 "commonly referred to as 405 regulations"). The ACGME has announced similar restrictions effective July 2003. Impact on patient care and resident education at one orthopaedic surgery residency program was examined. METHODS:Changes required in resident rotation schedules, on-call schedules, institutional cost, conference schedules, attendance at educational conferences and resident work hours at one institution from 1998-2002 were reviewed. Compliance was assessed by internal monitoring and New York State audits. RESULTS:The involved residency program is accredited for 3 residents yearly. Prior to initiation of the 405 regulations, eight of fifteen residents were located at the primary institution. Ten of fifteen residents are now located at the primary institution. A "night float" on call system has been utilized. Five physician extenders (nurse practitioners and physician assistants) have been added at an additional cost of 516,537 dollars including salary and benefits for the year 2002. This calculation does not include additional expenses associated with monitoring compliance practices. Though the educational conference schedule has been maintained, resident attendance has decreased. CONCLUSION: The ACGME regulations will significantly impact all Orthopaedic residency programs (n=152). The compliance efforts at one institution increased hospital costs and decreased time available for formal resident education. This program's experience can help others plan changes which will be most cost effective while maintaining resident education.

POSTER NO. P368

Metallic Implants used in Orthopaedic Surgery. Can They Interfere with Airport Security Devises?

Piers Yates, MD, *Southhampton, United Kingdom (n)*
Robert Gordon Middleton, Poole, United Kingdom (a,b,c – Zimmer)
Christos Plakogiannis, Poole, United Kingdom (*)

A frequently asked question at our institution when discussing metallic prosthetic implantation with patients is whether airport security scanners will detect the metal, and what will happen if this occurs. To date there is a relative paucity of research in this area and that which has been done shows the probability of implant detection to be negligible. However, with recent changes to airport detector settings and tighter security practices following September 11th, anecdotal evidence from patients suggests that metallic joint replacements are now being more frequently detected by airport security systems. this, coupled with an increasing governmental drive towards improving patient information and education, provides the underpinning for this study. We reviewed 100 patients with known prosthetic implants to determine whether the rate of prosthesis detection was significant, what variables were involved and whether this should mark a shift in the post operative information that patients receive We correlated episodes to the quantity of metal in the implant and the date of detection at airport security.We report the outcomes on these patients and make recemmendations.

SCIENTIFIC EXHIBITS

SCIENTIFIC EXHIBIT NO. SE064

Increasing Your Patient Safety and Orthopedic Device Quality Via Adverse Event Reporting Mechanisms

Michael Tanner, MS, *Royal Oak, MI (n)*
Gloria Bradley, BSN, Royal Oak, MI (n)

Introduction: Patient safety and orthopedic device quality are negatively impacted by low provider compliance to adverse event reporting requirements. Implant recalls, for example, may have been issued earlier, saving patients from an unnecessary major procedure. While physicians generally agree with the importance of adverse event reporting activities, many are unaware of the reporting tools available to them. This scientific exhibit will communicate identification and usage of adverse event reporting tools readily available to the provider help enhance patient safety and medical device quality. Methods: The authors will briefly review national and state adverse event reporting requirements. Orthopedic case reports will be discussed to enhance the importance of such requirements. The authors will present paper-based, electronic, and web-based solutions in a hands-on fashion, all freely available to the provider to facilitate compliance to adverse event reporting requirements. Results: The viewer of this scientific exhibit will: 1) Gain an understanding of adverse event reporting requirements, both on a national and state level 2) Understand how adverse event reporting impacts their patients' safety 3) Recognize low and no cost solutions available in the hospital and clinic 4) Learn how to obtain and use information from existing national adverse event resources Discussion and Conclusion: Orthopedic surgeons, their clinics, as well as the hospitals in which they practice, can positively impact patient safety and orthopedic device quality via increased compliance with adverse event reporting mechanisms. This exhibit will help remove perceived obstacles to increasing reporting compliance.

SCIENTIFIC EXHIBIT NO. SE065

Reengineering Private Practice Business Strategies to Deal With Declining Reimbursement and Increasing Costs

David Wold, BS, *Des Plaines, IL (n)*
Wayne M. Goldstein, MD, Des Plaines, IL (n)
Thomas Gleason, MD, Des Plaines, IL (n)
Matthew Jimenez, MD, Des Plaines, IL (n)
Neal T. Goldstein, JD, Chicago, IL (n)
Jay Sanders, CPA, Des Plaines, IL (n)
Maureen Zizzo, Des Plaines, IL (n)

Our costs between 1985-2001 were analyzed and new cost reduction strategies were implemented. We created an orthopedic network to improve malpractice and health insurance rates. Multiple mergers with neighboring groups created a single group, yet allowed some local management. Equal revenue sharing of our MRI and Physical Therapy services and central integration was implemented within Stark II laws. A new common practice management system kept billing costs less than 5%. All rental offices moved from professional buildings to less expensive sites with improved parking and more exam rooms. We utilized paramedical professionals (PA's, Nurses, and X-ray Technicians) for a larger percentage of face to face care. Single signature contracting was done to avoid a lower fee schedule by a hospital IPA's and some were dropped due to low reimbursement and delay in collection time. An internet-based appointment system was implemented and contained call center rules, thus decreasing voice mails. We outsourced transcription and moved medical records to a low cost warehouse site. In 16 years, the following expenses increased: operating 391%, staffing 135%, fringe benefits (health insurance and retirement benefits) 126%, clerical and clinical supplies 169%, rent and occupancy 136%, administrative 161%, malpractice and business insurance 210%. Overhead remained an average of 45% for the entire group. Despite requirements to implement OSHA, compliance, CLIA and HIPAA plans, overhead remained under 50%. The most important first step to implement such a plan is to secure billing and collections, then to use ancillary income to fund future improvements such as electronic medical records and digital x-rays.

PAPERS

PAPER NO. 156

Role of Rehabilitation After Knee Immobilization in Octogenarians with Patellar Fractures

Shay Shabat, MD, *Dallas, TX (n)*
Gideon Mann, MD, Jerusalem, Israel (n)
Benjamin Kish, MD, Kfar-Saba, Israel (*)
Avinoam Stern, MD, Atula, Israel (*)
Meir Nyska, MD, Nitzan, Israel (*)

Introduction: Patellar fractures are not common in the very old age. Any efforts should be done to maintain the activities of daily living (ADL), thus preventing the sequela of recumbency. Methods: Between 1/1990 and 12/1999 17 octogenarians (9 females, 8 males, age range 80-88, mean 83 years) were treated due to a patellar fracture. Follow-up time ranged from 1-8 years (mean: 3.5). Ten out of 17 patients were totally independent, while 7 patients used a cane for mobilization. 14 patients had background diseases. Results: 14 patients underwent operative treatment with tension band wires followed by cast immobilization (knee in extension) for 6 weeks. The remaining 3 patients were treated conservatively by cast alone for 6 weeks. Immediate full-weight bearing was initiated in all patients, and intense rehabilitation program to increase range of motion was performed after cast removal. Complete union was noted for all fractures and none of the wires had broken. 13 patients had extension lag of 0-15 degrees and 4 patients had 20-50 after end of physiotherapy. All patients had flexion of more than 100 degrees. 14 out of the 17 patients returned eventually to their pre-fall functional level, and in 3 a slight deterioration was noted. Discussion and Conclusion: Although knee immobilization has the potential to cause severe limitation in range of motion, its use in the elderly with patellar fractures followed by intense rehabilitation is advocated and showed good results.

PAPER NO. 157

Simultaneous Distal Radius and Hip Fractures in Elderly Patients - Implication to Rehabilitation

Shay Shabat, MD, *Dallas, TX (n)*
Gideon Mann, MD, Jerusalem, Israel (n)
Benjamin Kish, MD, Kfar-Saba, Israel (*)
Avinoam Stern, MD, Atula, Israel (*)
Meir Nyska, MD, Nitzan, Israel (*)

Introduction: The reasons for fractures in elderly patients are multifactorial. The most common sites at which these fractures occur are the hip, vertebra and distal radius. A combination of these is uncommon. Methods: 46 patients older than 65 years who were treated between 1/1990 and 12/2000 with a combination of distal radius and hip fractures were retrospectively evaluated for the following parameters: age; sex; pre fall function; use of drugs; chronic and acute comorbidity; circumstance of the fall; hospitalization length of stay; treatment procedure; complications and post-hospitalization rehabilitation. Results: Group I consisted of 16 patients between 65-80 years, and group II consisted of the remaining 30 patients older than 80. All patients suffered low energy trauma. Ten out of the 16 patients in group I, and 8 out of the 30 patients in group II were totally independent, while the remaining patients needed some help with activity of daily living (ADL). In all patients the simultaneous fractures were ipsilaterally. 28 patients were transferred to a geriatric rehabilitation center. 26 out of them returned eventually to their previous ADL. Among the 18 remaining patients, 11 gained full recovery and 7 patients (5 from group II) had a slight reduction in ADL. Discussion and Conclusions: A combination of these fractures occurs in the higher-age group. It is always located in the ipsilateral side. The double trauma represents a better pre-morbid condition relative to patients in the same age group, and it may serve as a prognostic indicator for success in rehabilitation.

PAPER NO. 158

Treatment Satisfaction in Patients Treated with Hylan G-F 20 Vs. Intra-articular Steroids at 6 months

Gurkirtal Singh, MD, *Palo Alto, CA (a – Wyeth)*
Bonnie Bruce, Palo Alto, CA (n)
Reiko Sato, PhD, Saint Davids, PA (e – Wyeth)
David D Waddell, MD, Shreveport, LA
(a – Genzyme Biosurgery, e – Wyeth)

Introduction: Patient satisfaction is an important goal of medical treatment for knee osteoarthritis (OA), but there are few studies that have systematically studied this outcome. We evaluated patient satisfaction of treatment with Hylan G-F 20 (Synvisc") versus intra-articular steroids in routine orthopedic practice. Methods: The Measurement of Outcomes from Viscosupplementation Effectiveness Study (MOVE) is a large naturalistic longitudinal observational cohort study of patients recruited primarily from practicing orthopedic surgeons that is designed to measure clinical, economic and humanistic outcomes of 1301 Hylan G-F 20 patients and 559 controls who received standard of care over 4 years. Patients reported treatment satisfaction of their knee OA on a 0 to 10 scale (0=totally dissatisfied, 10=extremely satisfied). Results: Six-month patient satisfaction data were available from 305 Hylan G-F 20 treated and 107 intra-articular steroid treated patients. Patients treated with Hylan G-F 20 were more likely to be male (37% vs. 27%), but were similar in age (67 vs. 66 years) and disease duration (8.1 vs. 8.5 years) than those treated with intra-articular steroids, although these differences were not statistically significant. The average (standard error) treatment satisfaction was better in the Hylan G-F 20 treated group (6.0[0.16]) on the 0-10 scale compared to patients treated with intra-articular steroids (5.3 [0.28]) (p=0.02). Discussion and Conclusion: Previous knee OA studies have shown that Hylan G-F 20 may provide a more durable response with no differences in tolerability than intra-articular corticosteroids. This may explain the greater patient satisfaction with Hylan G-F 20 treatment in our cohort.

PAPER NO. 159

Hylan G-F 20 Significantly Improves Pain, Function and Patient Global after 6 months in Knee OA

Bonnie Bruce, *Palo Alto, CA (n)*
Gurkirtal Singh, MD, Palo Alto, CA (a – Wyeth)
Reiko Sato, PhD, Saint Davids, PA (e – Wyeth)
David D Waddell, MD, Shreveport, LA
(a – Genzyme Biosurgery, e – Wyeth)

Introduction. Clinical trials have established the efficacy of Hylan G-F 20 (Synvisc,) in the treatment of knee osteoarthritis, but there is little data on its effectiveness in routine orthopedic surgical practice. We studied longitudinal changes in patient outcomes from a large controlled prospective clinical study. Methods. The Measurement of Outcomes from Viscosupplementation Effectiveness Study (MOVE) is a 4-year observational cohort study of patients recruited primarily from offices of practicing orthopedic surgeons, and is designed to measure clinical, economic and humanistic outcomes of 1301 patients treated with Hylan G-F 20 and 559 control patients in routine practice. Patient outcomes were evaluated by the WOMAC physical function, stiffness, and pain scales and patient assessment of pain and global health. Results. 769 patients assessed at 6 months post treatment showed that Hylan G-F 20 treated (n=497) and control patients (n=272) were similar in mean age (65 vs. 66 years), mean disease duration (8.1 vs 7.6 years) and gender proportion (33 vs. 32 % males). Patients treated with Hylan G-F20 had significantly better improvement in all outcomes (except stiffness) compared to the control population. Pain scores improved by 26% in the Hylan G-F20 group vs 12% in the controls, physical function scores improved by 15% vs 7%, patient assessment of pain and global health scores improved by 25% vs 15%, and 12% vs 3%, respectively (all $p<0.05$). Discussion and Conclusion. Patients treated with Hylan G-F 20 in routine orthopedic surgical practice had significantly greater improvement in pain and function vs controls at 6 months post-treatment.

PAPER NO. 160

Proximal Tibial Segmental Prosthetic Replacement Without the Use of Muscle Flaps

Rajesh Vitthal Patel, MD, *Philadelphia, PA (n)*
Joseph Albert Abboud, MD, Broomall, PA (n)
Rakesh Donthineni-Rao, MD, Sacramento, CA (*)
Richard D Lackman, MD, Philadelphia, PA
(a, e – Stryker HowMedica Osteonics)

Introduction. When performing a proximal tibial prosthetic reconstruction, many surgeons have felt that the subcutaneous location of the proximal tibia necessitates employment of a gastrocnemius muscle flap for closure and function. Methods In this retrospective review, 22 patients with high-grade malignancies underwent proximal tibial segmental prosthetic replacement utilizing direct reattachment of the patellar tendon to the prosthesis without the use of a muscle flap. Mean follow-up was 47 months (range 13-99 months). The patients ranged in age from 15-74 yrs (mean age 39 yrs). Results. Two out of 19 patients required re-operation in the postoperative period for hematomas. Both are free of infection or other complications at 24-month mean follow up. No other wound complications occurred despite the initiation of chemotherapy four weeks post surgery in patients with high-grade malignant tumors (15 of 19).The range of motion achieved postoperatively showed a mean of 97 degrees (+/-16.3). All patients had full passive extension with a mean extensor lag of 7.5 degrees. The mean. Musculoskeletal Tumor Society (MSTS) score was 27.6 (+/- 2.0). Conclusion. These results of patients without muscle flaps compare favorably with published results advocating gastrocnemius flaps for the attachment of the patellar tendon to the prosthesis.

POSTERS

POSTER NO. P195

The Trajectory of Center of Mass in Negotiating Obstacles with Different Heights in The Elderly

Horng-Chaung Hsu, MD, *Taichung, Taiwan (n)*
Shu-Ya Chen, MS, Taichung, Taiwan (n)
Hsiu-Chen Lin, MS, Taichung, Taiwan (n)
Hong-Wen Wu, Tainan, Taiwan (n)
Hui-Fen Pan, BS, Taichung, Taiwan (n)

Introduction: The most common falling occurs while crossing over obstacles among the elderly. The trajectory of center of mass (COM) has been used to identify human¡_s static/dynamic motions. Therefore, the aims of this study were to investigate the effects of the obstacle height on the motion of COM and to compare the trajectory of COM between the high-risk and low-risk falling groups. Methods: Twelve elders aged over 65 were recruited and performed stepping over the obstacles (height adjusted to 0, 10, 20, 30 percent of leg length) at a self-selected pace. The VICON system and a 15-linked human model were used to collect kinemetic data and to compute the trajectory of whole body¡_s COM. Range, velocity, and acceleration of the COM trajectory were analysed with significance level of 0.05. Results: Higher obstacle resulted in increasing range and velocity of the COM trajectory in the vertical direction. The high-risk falling group showed greater range of the COM displacement in the vertical plane, smaller peak velocity in the vertical direction, and smaller peak acceleration in the medial-lateral and vertical directions. Discussion and Conclusion: The elders with high-risk of fall demonstrated less controlled COM and wider range of COM displacement, which could cause higher possibility of loss of balance. These results can be a reference in screening falling risk in the elderly and in assessing the effectiveness of intervention for the elderly.

POSTER NO. P196

◆Effects of a Heat-Retaining Sleeve on Pain, Stiffness and Function in Knee Osteoarthritis (OA)

Russell D Meldrum, MD, *Indianapolis, IN (n)*
Mark C Page, MD, Indianapolis, IN (*)
Steven A Mazzuca, PhD, Indianapolis, IN (n)
Kenneth D Brandt, MD, Indianapolis, IN
(a – Spine-Issimus, Ltd)
Satham Petty-Saphon, PhD, Saffron Walden, United Kingdom
(d,e – Spine-Issimus, Ltd)

INTRODUCTION: This placebo-controlled study examined changes in pain, stiffness and function resulting from use of a novel heat-retaining knee sleeve in patients with knee OA. METHODS: Fifty-two subjects (mean age, 63 years; 77% female; 92% Kellgren-Lawrence grade 2-3) were randomly assigned to wear either an experimental (E) or placebo (P) cotton-elastane sleeve for a minimum of 12 hours/day for 4 weeks. In contrast to P, the E sleeve had a polyester film substrate liner with an entangled fiber matrix sub-microscopically coated with aluminum to retain body heat. All subjects continued their NSAIDs/analgesics.

Pain, stiffness and function (WOMAC) were administered at baseline, after 2 and 4 weeks of sleeve use, and 2 and 4 weeks after cessation of use. RESULTS: Both groups reported decreased pain at 4 weeks (16% and 10% in E and P, respectively, p=.001) but did not differ with respect to improvement in stiffness or function. Four weeks after cessation of sleeve use, pain scores in E and P had risen to baseline levels. Subjects who believed correctly that they received an E sleeve had greater improvement in pain (28%) than E subjects who thought they wore P sleeve (13%) and greater than subjects who wore P sleeve (9%). DISCUSSION/CONCLUSION: The heat-retaining sleeve produced marked improvement in knee pain beyond that achieved with NSAID/analgesics alone. Replication of this pilot study with a larger cohort is needed to determine the extent of the placebo effect versus that of the sleeve itself in amelioration of knee OA pain.

POSTER NO. P197

Factors Associated with Disability & Activity in Patients Seeking Care for Osteoarthritis

Karen K Briggs, *Vail, CO (n)*
J Richard Steadman, MD, Vail, CO (*)
David W Wing, BA, Vail, CO (n)
Timothy O'Brien, MD, Bozeman, MT (n)

The purpose of this study was to identify determinants of patient disability and activity level in patients diagnosed with osteoarthritis(OA) of the knee. Methods: A cohort 242 of patients(average age = 56(range 29 to 82); 101 females, 141 males) diagnosed with knee OA, had complete demographic, subjective and objective data. The dependent variables were patient disability, as assessed by Lysholm score(0-100), and Tegner Activity level(1-10). Level of signifcance was $p<0.05$. Results: In 299 knees(57 bilaterals), prior surgeries were reported in 58%, and 80% had joint space narrowing on radiographic examination. Tegner was significantly associated with age, gender, and prior surgery. There was a significant decrease in Lysholm with the presence of joint space narrowing, extension and flexion deficits. Tegner level was not associated with joint space narrowing; however, it was significantly lower with extension and flexion deficits. Patients reporting knee stiffness at initial visit had significantly lower Lysholm scores. Patients reporting severe stiffness had an average Lysholm score of 24 points less than those with no stiffness. Multivariate analysis identified joint space narrowing and patient-reported stiffness as independent predictors of Lysholm. Independent predictors of Tegner activity level were age, gender, patient-reported stiffness, flexion deficit, and Lysholm score. Conclusions: Determinants of patient disability and activity level in patients with OA of the knee were established. Patient-reported stiffness and range of motion deficit were found to be associated with both decreased Lysholm score and decreased activity level. These factors may be important in prevention of disability caused by OA of the knee.

POSTER NO. P198

The Determinants of Length of Stay Following Primary Total Knee Replacement

Tom C Carlson, BS, *Sacramento, CA (n)*
William Lamont Bargar, MD, Sacramento, CA (n)
Carol Parise, Sacramento, CA (n)
Pat Blair, Sacramento, CA (*)
Debbie Zakerski, RN, Elk Grove, CA (n)

Hospital length of stay (LOS) following total knee replacement (TKR) surgery is often an outcome of significant clinical and economic interest. The purpose of this study was to assess the peri-operative factors that impact LOS. Retrospective chart reviews were conducted on 150 patients who underwent uncomplicated unilateral primary TKR. The primary endpoint was total LOS. Correlation coefficients were used to determine the selected demographic, pre-operative, intra-operative, and postoperative factors hypothesized to be independently associated with LOS (p.05). Multiple regression analysis was used to construct a model for LOS. Factors were retained in the model if they contributed a statistically significant (p.10) percent of the variance of the endpoint.Age, gender, total medical comorbidities, hours on PCA, knee flexion, and percent of physical therapy (PT) components missed in acute care were independently correlated with LOS and contributed the approximately 34 percent of the variance of LOS: Age (4.6, p.012), gender (7.7, p.001), comorbids (3, p.033), hours on PCA (6.3, p.001), knee flexion (8.2, p.000), and percent of PT components missed (6.8, p .000).These factors warrant consideration when establishing patient specific peri-operative interdisciplinary plan of care. Healthcare provider education and training should include patient care alternatives appropriate for demographic variations, consideration of clinical variable associations in pain management decisions, and PT delivery of care programs for increased participation.

PAPERS

PAPER NO. 071

Immobilization in External Rotation after Shoulder Dislocation: An Interim Report of an Ongoing Trial

Eiji Itoi, MD, *Akita, Japan (n)*
Yuji Hatakeyama, Tazawako, Japan (n)
Takeshi Sato, MD, Akita, Japan (n)
Tadato Kido, MD, Akita, Japan (n)
Hiroshi Minagawa, MD, Akita, Japan (n)
Ikuko Wakabayashi, Akita, Japan (n)
Moto Kobayashi, MD, Akita, Japan (n)
Hidetomo Saito, Akita, Japan (*)
Koji Nozaka, MD, Akita, Japan (*)

Introduction: Recurrent dislocations have been reported in 66 percent to 94 percent of young patients after immobilization of the shoulder in internal rotation. Based on the previous studies that illustrated the benefits of external rotation both in cadavers and on MRI, we began a prospective study. Our early findings demonstrated that patients immobilized in external rotation avoided recurrent dislocations. The present study reports further results of this ongoing prospective multicenter study. Methods: Since January 2000, 96 patients with anterior dislocation of the shoulder were randomly assigned to immobilization in either internal rotation (IR group) or external rotation (ER group) for 3 weeks. After excluding patients with humeral fractures, and those whose shoulders were not immobilized within 3 days after injury, 80 patients were left for analyses. Sixty-four shoulders were initial dislocations and 16 were recurrent dislocations. There were 40 patients in each group (average age 37 yrs). The average follow-up period was 12.4 months. Results: The average immobilization period was 15.9 _} 8.1 days in the IR group and 16.9 _} 7.1 days in the ER group. Recurrence rate was 12/40 (30 percent) in the IR group and 4/40 (10 percent) in the ER group (p=0.0255). Among those who were younger than 29 years of age, recurrence rate was 9/24 (37.5 percent) in the IR group and 3/26 (11.5 percent) in the ER group (p=0.0319). Discussion and Conclusion: Immobilization in external rotation after shoulder dislocation is better than the conventional immobilization in internal rotation in terms of reducing recurrent dislocations.

PAPER NO. 072

Kim Procedure for Multidirectional Instability of the Shoulder

Seung-Ho Kim, MD, *Seoul, Korea, Republic of (d – Linvatec)*
Jong-Il Sun, Seoul, Korea, Republic of (n)
Jun-Sic Park, MD, Seoul, Korea, Republic of (n)
Irvin Oh, MD, Seoul, Korea, Republic of (n)

Introduction: To evaluate pathologic lesions of posteroinferior multidirectional instability of the shoulder and the results of arthroscopic capsulolabroplasty. Methods: Thirty-one patients (27 male and 4 female, mean age, 23 years) with posteroinferior multidirectional instability were treated with arthroscopic capsulolabroplasty and prospectively evaluated for the outcomes (mean follow-up, 51 months) using 3 objective scales (Rowe, ASES, and UCLA scores) and 2 subjective scales (pain and function VAS). Results: All had a labral lesion and variable capsular stretching in the posteroinferior aspect. There were 11 type I labral lesions (Incomplete detachment), 12 type II (Kim's lesion: Incomplete and concealed avulsion), 6 type III (Chondrolabral erosion), and 2 type IV lesions (Flap tear). All patients had retroversion of the posteroinferior labrum. Shoulder scores, function and pain scores improved.Rowe scores were excellent in 21 patients, 9 good, and 1 fair. One patient had recurrent instability. Twenty-eight patients returned to more than 90 percent of previous activity. There was 2 degree loss of external rotation and 1 vertebral level loss of internal rotation. Discussion and Conclusion: Symptomatic patients with multidirectional instability had posteroinferior labral lesion including retroversion of the posteroinferior labrum, which was previously unrecognized. Restoration of the labral buttress and capsular tension by arthroscopic capsulolabroplasty successfully stabilized the shoulder with posteroinferior multidirectional instability.

PAPER NO. 073

Glenoid Reconstruction for Recurrent Traumatic Anterior Shoulder Instability

Thomas James Gill, MD, *Boston, MA (n)*
Peter J Millett, MD, Boston, MA (n)
James O'Holleran, MD, Jamaica Plain, MA (*)
Neil Pathare, BA, Boston, MA (*)
Jon J P Warner, MD, Boston, MA (n)

Introduction: Little is written regarding management of recurrent traumatic anterior shoulder instability in the setting of large osseous glenoid defects. While Bristow or Laterjet procedures are proposed to manage such situations complications are associated with these non-anatomical salvage reconstructions. The purpose of this study is to present an experience treating recurrent anterior instability in such a setting with anatomical reconstruction of glenoid deficiency using tri-cortical iliac crest bone graft combined with capsular shift. Methods: From 1999-2001 the senior author performed 262 instability surgeries. Of these, twelve patients were identified who had significant glenoid bone loss, which precluded either arthroscopic or open capsulorrhaphy. This was based on preoperative CT-examination demonstrating loss of glenoid depth. There were 10 males and 2 females with an average age of 35 years (range 20-80 yo). 8 of these patients had an average of 1.7 previous surgeries (range 0-2) which had failed. Surgical reconstruction consisted of intra-articular placement of a tricortical iliac crest autograft placed in a manner to reestablish the normal glenoid concavity and held in place with 2-3 cannulated 4.0mm AO screws. In all cases the capsule was repaired directly to the edge of the graft. Postoperative assessment was performed using the ASES rating system as well as plain radiographs, and postoperative CT scans taken after 6 months. Results: At a minimum follow-up of 24 months (range 24-61) the mean ASES score was 78 (range 45-100) and no patient complained of recurrent instability. Only 2 patients had mild pain with overhead activity and two professional hockey players returned to full competition. Average motion loss compared to the contralateral side was 7˚ flexion (range 0-30˚), 14˚ external rotation in abduction (range 0-45˚) and one intervertebral level (range 0-2) internal rotation. Plain radiographs and CT scans showed no evidence of arthritis and union of all bone grafts. All patients stated they would do the procedure again based on their experience. Conclusion: Anatomical reconstruction of glenoid insufficiency in the setting of recurrent instability is an effective method of treatment with a high level of patient satisfaction. It offers an alternative to the Bristow or Laterjet procedures.

PAPER NO. 074

Open Posterior Stabilization for Recurrent Posterior Glenohumeral Instability

Brian R Wolf, MD, *Iowa City, IA (n)*
Riley Joseph Williams, MD, New York, NY (*)
Answorth Anthony Allen, MD, New York, NY (n)
Sabrina Strickland, MD, New York, NY (n)
David W Altchek, MD, New York, NY (n)
Russell F Warren, MD, New York, NY (n)

Background: Open posterior capsular shift is used for posterior glenohumeral instability that has failed non-operative treatment. The purpose of the present series was to evaluate the clinical and radiographic outcome following open posterior stabilization of the shoulder. Materials and Methods: Forty-eight consecutive shoulders were identified that had undergone primary open shoulder stabilization using open posterior capsular shift. Four shoulders were lost to follow-up resulting in a study group of forty-four shoulders in forty-one patients. Eleven shoulders were classified as multidirectional instability (MDI) and 33 as posterior-inferior instability (PI) at the examination under anesthesia. Shoulders were evaluated at a mean of 7.6 yrs (range of 1.8 to 22.5 years) using the L'Insalata shoulder form, SF-36, and a subjective shoulder rating following. All patients underwent a primary open posterior capsular shift and eighteen shoulders underwent concomitant posterior capsulolabral repair. Thirty-nine shoulders were evaluated using physical examination and thirty-seven shoulders underwent radiographic examination at 7.6 and 7.7 years respecfully. Results: A recurrence of posterior instability occurred in eight (19%) shoulders. This included 40% of MDI shoulders and 13% of PI shoulders. Patients were satisfied with the current status of their shoulder in 84%. This included 90% satisfaction in MDI shoulders and 82% in PI shoulders. 74% of patients were able to fully return to their previous level of recreation or sports. The mean L'Insalata score was 81.25 ± 17.8 points, the mean SF-36 physical component score was 50.81 ± 7.87, and the mean mental component score was 53.82 ± 7.55. The average radiographic score was 3.7 ± 1.1 on a 5-point scale. Radiographic findings did not correlate with time from surgery and did not correlate with patient outcome measures. Significantly poorer outcomes were seen in shoulders found to have a chondral defect at the time of stabilization and in patients greater than 37 years of age at the time of surgery. Discussion: Open posterior stabilization is a reliable procedure for refractory posterior shoulder instability. No evidence of progressive radiographic arthritis was found. Patients found to have chondral damage within the shoulder and older patients were found to have less success following stabilization.

PAPER NO. 075

Pain Scores in the Management of Post Operative Pain in Shoulder Surgery

Stephen C Weber, MD, *Sacramento, CA (n)*
Ritu Jain, MD, Sacramento, CA (n)

In response to recent public opinion regarding postoperative pain control, JCAHO has attempted to address this by mandating pain scores. No studies exist to validate these scores in orthopedics. 99 patients for arthroscopic rotator cuff repair were followed and multivariate analysis assessed in regard to pain scores, objective physiologic correlates, complications, patient satisfaction, and MMPI scores. No correlation existed between the number of portals, anchors, and pain scores. Wide variability existed in pain scores. No correlation existed between pain scores and any physiological correlate of pain. Higher pain scores resulted in an increase in complications, specifically postoperative nausea ($p<0.01$) and increased recovery room stay ($p<0.05$). Pain scores correlated strongly with MMPI results. While pain scores have been mandated as a measure of adequacy of post-operative care, they correlated poorly with physiologic manifestations of pain. Excessive treatment of those patients whose pain scores fall outside the 25th percentile increases complications postoperatively. Pain scores correlate better with MMPI indices involving depression and self-esteem. Considerations of treatment of post-operative pain based solely on pain scores must be tempered by the lack of physiologic correlates and increased complications.

PAPER NO. 076

Long Term Results of Manipulation Under Anesthesia for Frozen Shoulder

John William Sperling, MD, *Rochester, MN (n)*
Christopher Michael Farrell, MD, Rochester, MN (n)
Robert H Cofield, MD, Rochester, MN (n)

Introduction: Currently, there are no long-term results of manipulation under anesthesia (MUA) for the treatment of frozen shoulder. Therefore, we reviewed the results of MUA for idiopathic frozen shoulder to determine the results, complications, and rate of failure. Methods: Between 1981 and 1993, 25 patients (26 shoulders) who had failed nonoperative treatment for idiopathic frozen shoulder underwent MUA. No patients had prior shoulder trauma or surgery, all had negative shoulder x-rays, and all but one had either an MRI or arthrogram demonstrating an intact rotator cuff. All had had physical therapy for an average of 6.2 months. Follow-up was by examination until the end of active treatment. Longer term follow-up was obtained in 19 shoulders by questionnaire and averaged 15 years (range, 8.1 to 20.6 years). Five patients had died; one patient declined to participate. Results: There were significant improvements in forward elevation from a mean of 103° pre-manipulation to 168° and in external rotation from 24° to 67°. There were 13 shoulders with no pain, 3 with slight pain, 2 with occasional moderate pain, and 1 with severe pain. There were no fractures, dislocations or other complications. Eighteen of the 19 shoulders required no further surgery. The one shoulder with severe pain developed a rotator cuff tear, which was repaired. At long-term follow-up, the mean Simple Shoulder Test was 9.5 of 12 and the mean American Shoulder and Elbow Surgeons' score was 77 or 100. Discussion: Treatment of idiopathic frozen shoulder by MUA leads to sustained improvement in shoulder motion and function an average of 15 years after the procedure. It is unlikely that other shoulder problems will develop.

PAPER NO. 077

Mobilization of a Congenital Radioulnar Synostosis with a Vascularized Fat Graft and Radius Osteotomy

Fuminori Kanaya, MD, *Okinawa-ken, Japan (n)*
Hideki Asato, Okinawa, Japan (*)
Akira Omine, MD, Okinawa, Japan (*)

INTRODUCTION: Congenital proximal radio-ulnar synostosis is characterized by a fixed forearm rotation and the high rate of re-ankylosis after separation of the synostosis. We reported that separation of a synostosis with use of a vascularized fat graft successfully prevented re-ankylosis (1998). Currently we have used a mobilization procedure consisted of separation of the synostosis, shortening osteotomy of the radius and a free vascularized fascio-fat graft. We reported the results of consecutive 20 patients receiving this procedure. METHODS: We performed this

procedure on 18 boys and 2 girls without other congenital anomalies. The average age at the surgery was 8.3 year-old (range, 5.3 to 13.4 year-old). Unilateral ankylosis was seen in 17 patients and bilateral in 3. Preoperatively, the forearm showed ankylosis between neutral and 90 degrees of pronation in 19 patients and in 30 degrees of supination after a failed previous mobilization in 1 patient. The radius head was dislocated in all but 1 patient (posterior in 12, anterior in 6 and radial in 1). The average follow-up duration was 44 months (range, 24 to 111 months). RESULTS: Neither re-ankylosis nor neurological complications occurred except the transient radial nerve palsy in 1 patient. The radius head was dislocated posteriorly in 9 patients (preoperatively, 7 patients showed posterior dislocation and 2 showed anterior dislocation). The mean range of active forearm rotation after surgery was 89 degrees (supination 25 degrees and pronation 64 degrees). All patients reported improvements in throwing or catching a ball, performing gymnastics, holding a bowl of soup and accepting objects, such as coins, into the palm. CONCLUSION: This mobilization procedure prevented re-ankylosis after separation of the synostosis, provided the ability to rotate the forearm and improved a child's daily activities.

PAPER NO. 078

Use of Osteochondral Bone Graft in Elbow Instability Following Fracture of the Coronoid Process

Roger P van Riet, MD, *Wilrijk, Belgium (n)*
Bernard F Morrey, MD, Rochester, MN (n)
Shawn W O'Driscoll, MD, PhD, Rochester, MN (n)

Background: Rigid fixation may be difficult to achieve for comminuted coronoid fractures. The authors have used osteochondral bone graft for the reconstruction of a deficient coronoid process in chronic elbow subluxation. The purpose of this study was to analyze the results of this reconstructive method. Methods: Osteochondral bone graft was used to reconstruct the coronoid process of 10 patients. Average age was 43 years (27-58). Nine injuries were from falls and one from a motor-vehicle-accident. All patients were initially treated elsewhere, and eight had at least one surgery done before. All injuries were of the so-called terrible triad. Coronoid fractures consisted of seven Regan-Morrey type II and three type III. All had persistent posterior subluxation prior to reconstruction. Average period from injury to reconstruction was 8 months (1-13). Charts, surgical records and radiographs were reviewed and patients were contacted to determine the Mayo Elbow Performance Score. Mean follow-up was 42 months (18-104). Results: Four patients had no or mild pain. Two failed due to severe contractures, one of which had severe pain. Mayo Elbow Performance Scores included, one excellent, four good, two fair and three poor. Radiographs showed graft resorption in four patients with post-traumatic arthritis. Three of these had complete erosion of the graft, with hardware erosion into the trochlea. Conclusions: Considering the severity of these cases, osteochondral bone grafting may be a useful salvage option for the reconstruction of an irreparably fractured coronoid process in a chronically unstable elbow. However, results are unpredictable and sometimes disappointing.

PAPER NO. 079

Triceps Insufficiency Following Total Elbow Arthroplasty

Andrea Celli, MD, *Carpi Modena, Italy (n)*
Arash Araghi, DO, East Northport, NY (*)
Robert A Adams, PA, Rochester, MN (*)
Bernard F Morrey, MD, Rochester, MN (n)

INTRODUCTION: Over the past decade, the indications for total elbow arthroplasty (TEA) have increased. One complication is insufficiency of the extensor mechanism, involving complete or partial rupture, or avulsion of the triceps tendon. We therefore reviewed the records of patients who underwent surgery for triceps insufficiency following TEA to determine the outcome of intervention for this problem. METHODS: The records of 887 procedures were assessed to determine those that subsequently underwent surgery for extensor mechanism reconstruction after TEA between 1982 and 2001. Patients who developed the deficiency after debridement for infection were excluded.The data was used to calculate the postoperative Mayo Elbow Performance Score (MEPS). RESULTS: 18 of 887 (2%) patients were identified as having undergone triceps reconstruction after TEA. After exclusion of the infected elbows, there were 7 males and 7 females remaining (16 elbows). The mean age was 54.7. The mean follow-up after the triceps reconstruction was 66 months.Several techniques were performed to reconstruct the extensor mechanism. The reconstructive procedure was successful in 14 of 16 elbows (88%). Eleven elbows had an excellent outcome based on the MEPS. 3 elbows had a good outcome and the last two elbows were considered a clinical failures. CONCLUSION: The incidence of triceps insufficiency following TEA ranges from 1-29%. At our institution, the incidence requiring surgery between 1982 and 2001 was 2%. The results of our study reveal that it is possible to effectively reconstruct the triceps mechanism in 88%, using the appropriate procedure based upon tissue quality, tendon retraction, and status of the olecranon.

PAPER NO. 080

Distal Humeral Nonunion: Reconstruction with Semiconstrained Total Elbow Arthroplasty

Dawn LaPorte, MD, *Baltimore, MD (n)*
Michael S Murphy, MD, Lutherville, MD (*)
J Russell Moore, MD, Lutherville, MD (n)

Introduction: Over an eight year period, twelve distal humeral nonunions were successfully reconstructed with a semiconstrained total elbow arthroplasty. Methods: Twelve patients, with an average age of 61 years (range 36-81), form the study group. In all cases, the nonunion was painful and long-standing: average 28 months, range 14-96. Pain at rest was present in all cases. Patients averaged two previous operations prior to arthroplasty (range 1-5). All patients had an initial attempt at rigid internal fixation. Six patients had followup bone grafting. Three patients were morbidly obese and three additional patients were heavy smokers. Patients were assessed for pain relief and functional gains. Postoperative range of motion was quantitated. Radiographic review was performed in all cases. Results: Followup averaged 63 months (range 36-94). Seven patients reported no pain, four had occasional pain with activity, and one patient had a painful, infected arthroplasty. With the exception of the infected arthroplasty, all patients felt the procedure had provided excellent pain relief and substantial functional gains. Flexion/extension arc was 134 degrees (range 120-150) to 18 degrees (range 0-40). Pronation/supination was 74 degrees (range 60-80) to 69 degrees (range 55-80). There were nine post-

operative complications. These included triceps weakness (2), ulnar neuropathy (3), triceps avulsion (1), olecranon fracture (1), superficial infection (1), deep infection (1). All extensor mechanism complications occurred in patients with previous olecranon osteotomies. Two patients required additional surgery, one triceps repair and one ulnar nerve transposition. The patient with deep infection elected suppressive antibiotics. There was evidence of radiographic lucency around 3 humeral implants at 36 months. Discussion and Conclusion: Osteoporosis, devascularized fracture fragments, and periarticular fibrosis limit potential reconstructive options for long-standing distal humeral nonunions. Semiconstrained total elbow arthroplasty provided good pain relief and significant functional gains. Complications were common, particularly in the extensor mechanism following olecranon osteotomy. Our findings would support the use of a triceps sparing exposure during initial osteosynthesis.

PAPER NO. 141

Repair of Tears of the Subscapularis: Minimum Two Year Follow-up Results of 84 Cases

Thomas Bradley Edwards, MD, *Houston, TX (n)*
Gilles Walch, MD, Lyon, France (n)
Daniel Mole, MD, Nancy Cedex, France (*)
Laurent Nove-Josserand, MD, 69001 Lyon, France (n)
Aziz Boulahia, MD, Lyon, France (*)
Lionel Neyton, MD, Lyon, France (n)
Bruce Lindgren, Minneapolis, MN (e – Minneapolis Sports Medicine Center)
Istvan Szabo, MD, Lyon, France (n)

INTRODUCTION: The purpose of this study is test the hypothesis that results of repair of isolated tears of the subscapularis are acceptable in most patients. METHODS: Eighty-four shoulders that had undergone open repair of the subscapularis tendon were reviewed. The mean age at surgery was 53 years. The mean interval from onset of symptoms to surgery was 13 months. Fifty-seven tears were traumatic, and 27 were degenerative in etiology. Twenty-three of the tears involved the superior third of the subscapularis tendon, 41 involved the superior two thirds, and 20 were complete tears. Fifty-four shoulders had a dislocation or subluxation of the long head of the biceps tendon, while 10 shoulders had a rupture of the long head of the biceps tendon. Forty-eight shoulders underwent concomitant biceps tenodesis; 13 shoulders underwent concomitant biceps tenotomy; and four shoulders underwent concomitant recentering of the biceps. Patients were evaluated clinically and radiographically at a mean 45 month follow-up (range 24 to 132 months). RESULTS: The mean Constant score increased from 55 points preoperatively to 80 points postoperatively ($p<0.0001$). Seventy-five patients were satisfied or very satisfied with the result. Preoperatively, four patients had mild glenohumeral arthritis. Postoperatively, twenty-five patients had mild glenohumeral arthritis and two patients had moderate glenohumeral arthritis. Tenodesis or tenotomy of the biceps tendon at the time of subscapularis repair was associated with improved subjective and objective results independent of the preoperative condition of the biceps tendon. DISCUSSION AND CONCLUSIONS: Repair of isolated subscapularis tears yields acceptable improvement in shoulder function in properly selected patients. Additionally, results from this study seem to advocate routine tenodesis or tenotomy of the long head of the biceps tendon at the time of subscapularis repair.

PAPER NO. 142

Teres Major Transfer using for Irreparable Rotator Cuff Tears (Long Term Follow-up)

Andrea Celli, MD, *Carpi Modena, Italy (n)*
Maria Carmen Marongiu, MD, Modena, Italy (n)
Claudio Rovesta, MD, Modena, Italy (*)
Luigi Celli, MD, Modena, Italy (n)

INTRODUCTION: There is little data in the literatures regarding long term outcome of Teres Major transfer for irreparable cuff tears. The aim of our study is to review the patients with irreparable cuff tear who were treated using the Teres Major transfer, for restoring the shoulder function and relieve the pain, during five years of our experience to obtain long term follow-up. METHODS: The clinical evaluations, as the pain, range of motion, strength and personal satisfactory were analyzed. The Teres Major transfer was studied using MRI and EMG studies. The Constant score was used to calculate our results. RESULTS: 20 patients were treated with Teres Major transfer for irreparable cuff tears between 1993 to 1998. The main follow-up was 35 months. The Constant score improve from an average of 32 percent preoperative to an average of 67 percent postoperative. Pain relief was satisfactory. In preoperative evaluations, the average values of flexion was 90 degree, the extra rotation in adduction was 7 degree and the strength was 2.8 pounds. In the postoperative evaluations, the average values improved to 147 degree in flexion and 27 degree of the extra rotation in adduction, 6.60 pounds of strength. DISCUSSION AND CONCLUSION: Our study in long term period shows that in patients with irreparable rotator cuff tears, the Teres Major Transfer recovers good active range of motion and relieves the pain. it is a good alternative to others muscular transfers in the treatment of the irreparable cuff tear.

PAPER NO. 143

Glenoid Bone-Grafting With Uncemented Glenoid Fixation in Total Shoulder Arthroplasty

Scott David Martin, MD, *Boston, MA (n)*
Thomas S Thornhill, MD, Boston, MA (n)

Introduction: Glenoid bone deficiency with alteration of glenoid version can adversely affect glenoid fixation during total shoulder arthroplasty. The purpose of this study was evaluate the intermediate-term results associated with the use of uncemented glenoid to fix glenoid bone grafts. Methods: 53 shoulders received autogenous corticocancellous bone grafts buttressed with an uncemented glenoid with no other supplemental fixation of the graft. All glenoids were fixed with two cancellous screws. 51 shoulders were available for follow-up at average of 7.8 years (range 4 to 13.5 years). Diagnoses included osteoarthritis in 37 shoulders and rheumatoid arthritis in 14 shoulders. There were 41 posterior grafts and ten anterior grafts. All bone graft was obtained from the resected humeral head. Results: The average glenoid version after correction was 5 degrees of retroversion with an average correction of 31 degrees. In all cases the grafts incorporated and maintained the original correction. Five glenoids failed including on fractured tray, and four aseptic loosening. Bone grafting, age, diagnosis, broken screws,major cuff tear, preoperative ASES score, and radiolucencies to the keel were not found to be predictive in the final multivariate analysis (p less than 0.01 for each variable). ASES scores improved from 16 to 75 postoperatively. Clinical survivorship according to Kaplan-Meier method was 96 percent at 5 years and 85 percent at 10 years. Discussion: Glenoid bone deficits can adversely affect the outcome of TSA. Corticocancellous bone-grafting is technically demanding and failure with dissolution of the graft can occur when multiple screw fixation is utilized. Press-

fitting and buttressing corticocancellous glenoid bone grafts with an uncemented glenoid component produce reliable results with incorporation of the grafts and no failures in this series.

PAPER NO. 144

Complications of Total Shoulder Arthroplasty: Is it Getting Lower?

Patrick Chin, MD, *Nanaimo, Canada (n)*
John William Sperling, MD, Rochester, MN (n)
Robert H Cofield, MD, Rochester, MN
(c – Mayo, Smith & Nephew)

Introduction: Although there has been significant evolution of total shoulder arthroplasty (TSA) design and improvement in technique over the past twenty-five years, there is no information available whether this has translated into lower complication rates. Therefore, the purpose of this study was to determine whether complication rates have improved by analyzing the complication rate over time. Methods: Between 1990 and 2000, the senior author performed 431 total shoulder arthroplasties using an all polyethylene glenoid component. Complications were categorized into type of complication, acute or delayed, and major or minor complications. Our results were compared with the complication rates of TSAs performed from 1975-1989. Results: Our overall complication rate was 12% (53/431). In comparison to the cohort of patients who underwent shoulder arthroplasty from 1975 to 1990, the rate of complication decreased by 9% (from 21 to 12%). The most common complication was symptomatic rotator cuff tears (4%). Other complications include fractures, symptomatic instability, infection, component loosening and neurologic injury. The majority of complications occurred early (60%) instead of late (40%). Interestingly, factors such as sex, age, previous surgery, humeral head size and pre-operative diagnosis were not found to affect survivorship ($p > 0.05$) of the prosthesis in this group of patients. Discussion/Conclusions: The data from this study suggest that the complication rate of TSA has improved over time and this may be attributed to the evolution of component design for both humeral and glenoid prosthesis.

PAPER NO. 145

Revision Total Shoulder Arthroplasty

Scott David Martin, MD, *Boston, MA (n)*
Thomas S Thornhill, MD, Boston, MA (n)

The purpose of this study was to retrospectively evaluate the clinical and radiographic performance of revision total shoulder arthroplasty. Methods and Materials: The clinical and radiographic results of revision total shoulder replacement were evaluated at an average of 7.8 years (range2.5 to 17 years). At revison surgery 27 patients were noted to have rotator cuff tears. The cause of failure of primary TSR included aseptic loosening in 59 shoulders, polyethlyene wear in 8 shoulders periprostheitc fracture in 2 shoulders and fractured glenoid trays in 2 shoulders. Tweleve shoulders required bone grafting of the glenoid and 5 humeri required bulk allograft. 21 shoulders were revised to hemiarthroplasty, in 4 shoulders only the stem was revised and in 46 both the stem and glenoid were revised. Results: the mean modified ASES scores were 17.7 pre-op and 58.9 postop. Pain was minimal or absent in 37 shoulders, mild in 15 shoulders moderate in 13 shoulders and severe in 6 shoulders. Greater pain relief was noted in patients with glenoid revision vs. hemiarthroplasty ($p<.01$) but no significant difference in fucntion was noted. All bone grafts incorporated. The overall complication rate was 41% including 6 subscapularis ruptures, 1 tuberosity fracture, 4 introperative humerus fractures, 3 chronic anterior instabilities, and 2 deep infections. Four shouldere required re-revsion including 1 periprostheitc fracture and three aseptic loosening. Discussion: The incidence of complications in primary TSR is 14%. The incidence of complications in revision shoulder arthroplasty are not well documented but are significantly higher than primary TSR. Difficult exposure, deficiencies of soft tissue and bone and reliable fixation are all problematic. Conclusion: Revision TSR can be successful, however, pain relief, and functional results are inferior to primary TSR with a significant increase in complication rate (41%).

PAPER NO. 146

The Fate of Revision Shoulder Arthroplasty with Positive Intraoperative Cultures

Mark S Topolski, MD, *Rochester, MN (n)*
Patrick Chin, MD, Nanaimo, BC Canada (*)
John William Sperling, MD, Rochester, MN (n)
Robert H Cofield, MD, Rochester, MN
(c – Mayo, Smith & Nephew)

Introduction: Currently, there are no reported results of patients who had a positive intraoperative culture during revision shoulder arthroplasty. Therefore, we reviewed the intraoperative and preoperative investigations as well as the postoperative course of these patients who had positive intraoperative cultures. Methods: We reviewed the results of patients who underwent revision shoulder arthroplasty at our institution over 28 years who had positive intraoperative cultures. Some of the studies characterized to determine the possibility of positive intraoperative cultures included standard infectious blood laboratory work (WBC, ESR, etc.) and intraoperative histology. The postoperative course included either reoperation, intravenous antibiotics followed by suppressive therapy, suppressive therapy alone, or no treatment. Results: Sixty-five of seventy-two WBC counts (90%) were negative. Thirty-six of forty-two samples of ESR (86%) were negative. Sixty-seven of seventy-three patients (92%) had negative intraoperative histology. The most common pathogen cultured was Propionibacterium acnes (45/75) at 60%. Ten of seventy-five shoulders (13%) had to undergo another operation to decrease pain or improve function. The remaining sixty-five patients were either treated with intravenous antibiotics and then oral therapy, or were treated with oral therapy only or received no treatment at all. Conclusions: The data from this study suggests that there are no good investigations in order to detect a positive intraoperative culture at the time of revision shoulder arthroplasty. Also those patients that do have positive cultures at revision are more likely to be treated with either antibiotics (intravenous and/or oral) or no therapy compared to having another surgery.

PAPER NO. 147

Glenoid Cortico-Cancellous Autograft After Glenoid Component Removal in the Treatment of Glenoid Component Loosening in Total Shoulder Arthroplasty

Lionel Neyton, MD, *Lyon, France (n)*
Thomas Bradley Edwards, MD, Houston, TX (a, b, e - Tornier)
Francois Sirveaux, Nancy, France (n)
Daniel Mole, MD, Nancy Cedex, France (n)
Gilles Walch, MD, Lyon, France (n)
Pascal Boileau, MD, Nice, France (*)

Introduction: Glenoid component failure in shoulder arthroplasty is associated with functional impairment and frequent bone loss. The purpose of this study is test the hypothesis that component removal and cortico-cancellous bone grafting of the

glenoid represents an acceptable option in the treatment of glenoid component failure in total shoulder arthroplasty. Methods: Nine patients underwent removal of a loose glenoid component and cortico-cancellous iliac crest autografting of the bony defect. Patient age averaged 61 years at the time of revision surgery. Five patients were male, and four were female. Glenoid bone loss was categorized at the time of surgery based on location and severity. Eight bony defects were large, central, and cavitary, and one had an additional peripheral component. All patients underwent component removal with autografting of the defect. No revision glenoid components were inserted. Patients were evaluated with a subjective assessment, a Constant score, and radiographs at a mean 30 month follow-up (range 24 to 39 months). Results: Seventy-eight percent of patients rated their result as good or excellent. Functional improvement was modest with the mean Constant score increasing from 45.5 to 49.1 points. Radiographs demonstrated a mean 4.1 mm of medialization of the humeral head within the glenoid (range 1 to 11 mm). Two cases demonstrated wear of the bone graft thought to be induced by eccentric glenoid loading secondary to rotator cuff insufficiency. No other case demonstrated wear or graft resorption. One patient required reoperation for a rotator cuff tear; at the time of surgery excellent glenoid bone continuity was observed. Conclusions: Cortico-cancellous autografting appears to be a reliable procedure for restoration of glenoid bone stock following removal of a loose glenoid component. Although functional gains were modest, restoration of glenoid bone stock allows for later revision glenoid component implantation if deemed necessary.

PAPER NO. 148

Periprosthetic Humeral Fractures After Shoulder Arthroplasty

John William Sperling, MD, *Rochester, MN (n)*
Sanjay Kumar, MD, Rochester, MN (*)
George John Haidukewych, MD, Rochester, MN (n)
Robert H Cofield, MD, Rochester, MN
(c – Mayo, Smith & Nephew)

Introduction: Currently, there is little information concerning periprosthetic humeral fractures after shoulder arthroplasty. Therefore, we reviewed our experience with these fractures to determine results, risk factors for unsatisfactory outcome, and rates of reoperation. Methods: Between 1976 and 2001, 19 postoperative periprosthetic humerus fractures occurred among 3091 patients who underwent shoulder arthroplasty at our institution. Sixteen patients had a complete series of radiographs and are included in this study. The time from the arthroplasty to the fracture averaged forty-nine months (range, 1 to 146 months). Seven patients had severe osteopenia. Twelve fractures were centered at the tip of prosthesis of which six extended proximally and six did not. Three fractures were distal to the implant and extended into the distal humeral metaphysis. One fracture occurred in proximal diaphyseal region due to osteolysis. Results: Six fractures healed with nonoperative treatment at a mean of 180 days (range, 49 to 332 days). Ten fractures required operative intervention. Five of those ten fractures failed to heal at a mean of 123 days (range, 49 to 173 days) before operative treatment was used. All fractures healed. One patient required multiple operations including a free fibula transfer and took 1116 days from the time of first surgery to heal. Except for this case, it took 230 days (range, 133 to 406 days) after the first surgery for the fractures to heal. Discussion: Our experience suggests that fractures distal to the tip of prosthesis can be treated nonoperatively similar to humeral shaft fractures. Fracture at the tip of prosthesis and fractures extending to the humeral shaft overlying the implant stem should be treated operatively. Autogenous bone graft should be used.

PAPER NO. 149

◆Complications Associated with the Delta-III Reverse Ball-and-Socket Shoulder Prosthesis

Michael Gilbart, MD, *Pittsburgh, PA (n)*
Christof Pirkl, MD, Zurich, Switzerland (*)
Christian Gerber, MD, Zurich, Switzerland (n)

Introduction: To document and evaluate the complications associated with a large series of reverse ball-and-socket shoulder prostheses. Methods: 113 Delta III prostheses were performed on 111 patients. Average follow-up was 26 months. All intraoperative and postoperative complications were documented. At follow-up all postoperative radiographs were reviewed. All revision procedures were documented and the etiology of failure was investigated. Results: The mean patient age was 69 years. Seventy three patients (64.6%) had the Delta prosthesis inserted as a revision procedure. There was 1 (0.9%) primary postoperative infection, 4 nerve palsies (3.5%) and two arterial injuries (1.8%). Seventeen patients (15%) had postoperative hematomas, and 7 patients (6.2%) suffered postoperative dislocations. Five patients (4.4%) exhibited signs of impingement. The overall prosthetic loosening rate was 8.8%. Thirteen patients (11.5%) underwent a subsequent revision of a portion of their components. Seven (6.2%) patients suffered secondary fracture of the acromion or scapula. Twenty one patients (18.6%) had notching of the inferior scapular neck on postoperative radiographs, and 19 patients (16.8%) had inferior scapular neck osteophyte formation. Discussion/Conclusions: This is in the largest series of Delta III prostheses reported which evaluates the associated complications. There was a higher percentage of prostheses inserted as revision procedures in this study than existing series, and a resulting higher complication rate. Thirty-nine patients experienced at least one complication or radiological abnormality. The Delta III prosthesis remains a viable treatment option in patients with limited goals, irreparable RTC tears and pseudoparalysis.

PAPER NO. 150

◆The Delta III Reverse Ball-and-Socket Shoulder Prosthesis: Clinical Results

Michael Gilbart, MD, *Pittsburgh, PA (n)*
Patrick Steinmann, Zurich, Switzerland (*)
Christian Gerber, MD, Zurich, Switzerland (n)

Introduction: The purpose of this study was to evaluate the clinical and radiographic results of a series of patients treated for rotator cuff arthropathy and pseudoparalysis with the Delta III shoulder prostheses. Methods: Forty patients had a Delta III prosthesis inserted between July 1999 and March 2001. Clinical and functional assessments were performed pre and postoperatively according to the method of Constant and Murley. Documentation was made of all complications. Postoperative AP, lateral, and axillary radiographs were reviewed for all patients at follow-up. Results: The mean patient age was 68 years. The average patient followup was 31 months (range 24-44 months). Twenty three patients (57.5%) had a Delta prosthesis inserted as a revision procedure. These patients had a higher rate of complication, including nine patients requiring revision of a portion of their components. There was a significant decrease in pain postoperatively (p=0.01). Nine patients (18%) developed postoperative hematomas. There were no postoperative infections. One patient suffered a partial axillary nerve palsy. The absolute constant score increased significantly from 23.2 preopera-

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

tively to 46.0 postoperatively (p=0.02). The activities of daily living score increased significantly from 2.9 to 6.2 (p<0.05). Eleven patients had inferior scapular neck notching and twelve patients had inferior neck bone on postoperative radiographs. Discussion/Conclusions: The reverse ball-and-socket prosthesis is a viable treatment option for patients with pain associated with rotator cuff arthropathy and debilitating pseudoparalysis. The expectations following this operation should be moderate, and can include significant improvement in pain and function.

PAPER NO. 211

Arthroscopic Subacromial Decompression for Advanced Impingement Syndrome: Five Year Follow-Up

Francis van Glabbeek, MD, *Edegem, Belgium (n)*
Roger P van Riet, MD, Wilrijk, Belgium (n)
Olivier Verborgt, MD, Berchem, Belgium (n)
Karl Dom, Baltimore, MD (n)
Dirk Petre, MD, Deerlijk, Belgium (n)
Floris Wuyts, MD, PhD, Edegem, Belgium (*)

INTRODUCTION The objective of this study was to analyze the evolution of the long-term functional outcome after arthroscopic decompression for stage II disease. METHODS A prospective study was performed in 52 patients (average age 52 years (23-73)) with an rthroscopically visualized impingement syndrome. The average duration of symptoms was 18 months (3-84). Acromial shape was noted to be Bigliani type I in 12, type II in 32 and type III in 8. Acromioplasty was performed. Patients were scored preoperatively, at 6 months and 5 years postoperatively, according to the ASES and the Constant–Murley scores. The Wilcoxon matched-pairs signed ranks test was used to evaluate the evolution of these scores in time. RESULTS The average Constant score improved from 76.4 to 84.9 (p< 0.001). The mean values (±Standard Error) of the individual components of the Constant score all increased between 6 months and 5 years postoperatively. Pain: 9.4±0.5 to 12.6±0.7 (p<0.001). ADL: 15.9±0.3 to 17.6±0.5 (p<0.001), ROM: 35.5±0.6 to 37.1±0.8 (p=0.003) and Strength: 12.9±0.6 to 17.4±0.8 (p<0.001). The ASES score improved from 76.3±2.2 to 86.4±2.5. The ASES score for pain improved from 2.8±0.3 to 1.2±0.3 (p<0.001). The score for ADL improved from 23.1 ± 0.7 to 25.9±1.0 (p<0.001). DISCUSSION This study shows that the majority of patients had satisfactory improvement and relief of symptoms 5 years after arthroscopic subacromial decompression for advanced impingementsyndrome. In conclusion, this study suggests that function and comfort after arthroscopic subacromial decompression for advanced impingementsyndrome may still increase from 6 months up to 5 years postoperatively.

PAPER NO. 212

Minimum Twenty-One Year Follow-up of Open Anterior Acromioplasty for Impingement Syndrome

Patrick Chin, MD, *Nanaimo, Canada (n)*
John William Sperling, MD, Rochester, MN (n)
Robert H Cofield, MD, Rochester, MN (n)

Introduction: Currently, there are no long-term follow-up studies of open acromioplasty. Therefore, we performed a study of patients with a mean twenty-four year follow-up who had undergone open acromioplasty at our institution to determine the results and rate of re-operation. Methods: Between 1975 and 1979, anterior acromioplasty was performed in 65 patients with 66 involved shoulders at our institution. At a mean follow-up of twenty-four years, 35 out of 40 patients (36 shoulders) were contacted and agreed to participate; 25 patients were deceased. Minimum follow-up was 21 years. Each patient completed a detailed shoulder questionnaire survey and their clinical records reviewed. Results: At latest follow-up, the mean elevation was 168 degrees versus 171 degrees in the non-operated side (p>0.10). Mean external rotation was 70.3 degrees and 69.3 degrees in the non-operated side (p>0.10). From the patients surveyed, average pre-operative satisfaction was 2.3 and post-operative satisfaction was 7.0 reported from a scale of 1 to 10 (Poor to Excellent). The mean SST score was 8.9 on the operated side and 9.2 on the non-operated side (p>0.10). The mean ASES score was 74.7 on the operated side and 83.3 on the non-operated side (p<0.05). Since the last follow-up, only 3 of 35 (8.6%) shoulders had a re-operation. Conclusions: The data from this study suggest that open acromioplasty is a durable procedure that can provide long lasting pain relief and improved function. Rate of reoperation is relatively low.

PAPER NO. 213

Comorbidities Affect Function and General Health Status Associated With Chronic Rotator Cuff Tears

Robert Tashjian, MD, *North Providence, RI (n)*
R. Frank Henn, MD, Providence, RI (*)
Lana Kang, MD, Riverside, RI (*)
Andrew Green, MD, Providence, RI (*)

Introduction: The results of preoperative assessment of factors that might affect the outcome of orthopaedic surgery have rarely been studied. We evaluated the relationship between the number of medical comorbidities and preoperative performance on outcome assessment tools in patients with chronic rotator cuff tears. Methods: 199 patients (total of 206 shoulders) with chronic rotator cuff tears who were treated with surgery were evaluated with a detailed history (including medical comorbidities) and outcome tools. Baseline outcome information was evaluated with the DASH, the SST, visual analog scales (pain, function and quality of life), and the SF-36. Results: The mean number of comorbidities was 2.07 (range 0 to 7). Utilizing univariate regression analysis, a greater number of comorbidities was associated with worse function (DASH [p=0.0064], SST [p=0.001], VAS [p=0.0003]), worse scores for increased pain (VAS [p=0.05]), and worse general health status (physical function [p<0.001], role physical [p=0.286], general health [p<0.001], vitality [p=0.0014], social function [p=0.0004], role emotional [p=0.0003], and quality of life VAS [p=0.0102]). These results were confirmed with multivaariate regression analysis which included age, sex, workers compensation, number of previous surgeries, smoking and average patient expectations as possible confounding variables. Discussion and Conclusion: Medical comorbidities have a profound negative impact on patient reported baseline pain, function and general health status associated with chronic rotator cuff tears. We postulate that this effect may ultimately influence the results of surgical treatment of rotator cuff tears and should be considered when analyzing postoperative outcomes.

PAPER NO. 214

Rotator Cuff Repair Patients: Their Temporal Pain and Function Outcomes Over Two Years

Judie Walton, PhD, *Sydney, NSW Australia (n)*
Craig Cummins, MD, Barrington, IL (n)
Jeanette Marshall, RN, Sydney, Australia (n)
George A C Murrell, MD, A/Prof, Kogarah Sydney, Australia (a – Mitek Corporation)

Introduction: A prospective study tested the hypothesis that rotator cuff repair benefits shoulder patients. Methods: 150 rotator cuff tear patients were, on their pre-operative visit, clinically assessed with 24 shoulder tests and given a pain/function questionnaire to complete. This protocol was repeated at 2, 6, 13, 26, 52, and 104 weeks after RCR to evaluate the outcome measures over time. At 2 years, the patients were invited to return for imaging tests to determine whether re-tear had occurred. Results: Most improvement took place within 6 months post-surgery. Patient-perceived pain frequency and severity decreased linearly for six months and then fell more gradually over the next 18 months. Forward flexion and abduction took 6 months to improve to pre-operative levels but continued to improve through year 2. Strength was almost as good as may be achievable by 6 months. Only one-third of patients with pre-operative impingement still had impingement at 6 months, with no further decrease thereafter. Of the original cohort, 55% attended for the imaging tests and 81% of those were found to have a rotator cuff re-tear. Regardless, at 2 years, 70% of the entire cohort (excluding workers compensation insurance patients) rated their over-all shoulder condition as "good", the highest possible score of 5 choices. The initial surgery did not appear to be a placebo effect because their Constant scores related inversely to re-tear sizes (p = 0.0018). Conclusion: Given accurate and consistent data collection, it is possible to measure both extent and time-frame of improvement after RCR.

PAPER NO. 215

Arthroscopic Repair of Full-Thickness Tears of the Supraspinatus: Does the Tendon Really Heal?

Pascal Boileau, MD, *Nice, France (n)*
Nicholas Brassart, Nice, France (n)
Armodios Miltiadis Hatzidakis, MD, Denver, CO (n)
Sumant Krishnan, MD, Dallas, TX (n)

Aim : To evaluate the rate of healed tendon after arthoscopic repair of full-thickness supraspinatus tears. Methods : 65 consecutive chronic full-thickness tears of the supraspinatus, repaired arthroscopically in 65 patients, were evaluated. Patients ranged in age from 28 to 79 years (average 59.5 years). A tendon to bone fixation was carried out using bioabsorbable sutures and self-locking anchors, placed lateral to the footprint. The repair was protected with an abduction splint for 6 weeks. All patients were followed prospectively for an average of 19 months (range, 12 to 43 months). Forty-one of the patients (63% of the study population) accepted to have a CT-arthrogram, performed between 6 months and two years after surgery to assess tendon healing. Results : Sixty one of 65 patients (94%) stated they were satisfied with the result. The Constant score improved from an average of 51.6 (_ 10.6) points preoperatively to 80.2 (_ 13.2) points at the last follow-up (p<0.001). CT-arthrography demonstrated that the cuff was completely healed and watertight in 29/40 cases (70%). The supraspinatus tendon did not heal to the tuberosity in 8 cases (25%), and only partially in 2 (5%). The size of the re-tear was smaller than the initial tear in all but one case. Factors affecting tendon healing were: age over 65 years (only 43% of healing, p= 0.02), and large tears. Conclusions: Arthroscopic repair of isolated detachment of the supraspinatus leads to completely healed structural integrity of the tendon in 70% of the cases tested by CT-arthrography. These results are comparable to those historically obtained with open repair. Older patients tend to have larger tears and have significantly lower healing rates.

PAPER NO. 216

Cuff Integrity Following Arthroscopic Versus Open Rotator Cuff Repair: A Prospective Study

Julie Bishop, MD, *Cleveland, OH (n)*
Ian Lo, MD, Calgary, AB Canada (n)
Steve Klepps, MD, Billings, MT (*)
Justin Bird, New York, NY (n)
James N Gladstone, MD, New York, NY (n)
Evan L Flatow, MD, New York, NY (n)

Introduction. Arthroscopic rotator cuff repair (RCR) has been reported to have good clinical results but 70% to 90% retear rates by ultrasound. This study prospectively assesses postoperative cuff integrity and outcome following arthroscopic RCR, and compares these results to open RCR by the same surgeon. MethodFifty-five consecutive patients after arthroscopic RCR by a single surgeon were prospectively enrolled for evaluation preoperatively and at one year follow-up, including a postoperativeRI. A prior prospective study of open RCR by the same surgeon was used for comparison Results There were 32 patients in the open RCR group, and 40 patients have completed the arthroscopic RCR protocol. ASES scores improved from 40 to 85 in the open group and from 46 to 84 in the arthroscopic group, and Constant scores from 53 to 80 in the open group and from 52 to 75 in the arthroscopic group (p<0.0001). 69% of the open and 53% of the arthroscopic group were intact by MRI. Of tears <3cm, 74% in the open and 84% in the arthroscopic group were intact. Of tears >3cm, 62% were intact in the open group and only 24% in the arthroscopic group. This difference was insignificant with p=0.036. There was a trend towards better scores with an intact cuff than with a retear in both groups, however this only reached significance (p<0.03) in the arthroscopic group when evaluating the ASES score, (Constant 79, ASES 89 - when intact and Constant 72, ASES 75 - when retorn). In the arthroscopic group, patients with intact cuffs had significantly greater strength of elevation (p=0.01) and external rotation (p=0.02) ConclusionOpen and arthroscopic RCR had similar outcomes. Cuff integrity was comparable for small tears, but the retear rate for large tears was twice as high after arthroscopic repair.

PAPER NO. 217

Fatty Infiltration & Atrophy of the Rotator Cuff Do Not Improve Following Rotator Cuff Repair

Julie Bishop, MD, *Cleveland, OH (n)*
Ian Lo, MD, Calgary, AB Canada (n)
James N Gladstone, MD, New York, NY (n)
Evan L Flatow, MD, New York, NY (n)

Introduction:There has been controversy as to whether rotator cuff repair (RCR) can improve the fatty infiltration (FI) and muscle atrophy (MA) often seen in large rotator cuff tears. This study compares FI and MA seen on pre- and post-operative MRIs as part of a prospective outcome study of rotator cuff repair. Methods: The clinical outcome of 39 patients (mean 62yo, minimum follow-up 1yr) following RCR was determined with ASES and Constant scores. FI was graded on a 5 point scale and MA on a 4 point scale on pre and post-operative MRIs.

Results:Pain, function, ASES and Constant scores all significantly improved following RCR (p<0.05). FI and MA positively correlated with tear size (p<0.0001, r=0.712).Those with greater degrees of supraspinatus FI were more likely to retear (p<0.001, r=0.745). ASES and Constant scores, and strength measurements, all inversely correlated with FI and MA (p<0.03). Strength in FF and ER was affected more by infraspinatus FI than similar levels of the supraspinatus. Pain relief was independent of the severity of FA/MA. Only one patient improved from moderate to mild MA. In 18 MA/FI were unchanged and in 21 MA and/or FI was actually worse. Conclusion FI and MA significantly affect the functional outcome following RCR even though pain is relieved. Neither FI nor MA appear to reverse following surgery, even with a successful outcome, and in moderate to severe cases may actually worsen. Patients' expectations should not include reversal of muscle degeneration once present.

PAPER NO. 218

The Effect of Repaired Rotator Cuff Tendon on the Process of Fatty Infiltration in a Rabbit Model

Dominic Sprott, MD, *Dayton, OH (a – DePuy)*
Lynn A Crosby, MD, Dayton, OH (a – DePuy)
Harold F Stills, Jr, Dayton, OH (n)
L Joseph Rubino, MD, Dayton, OH (a – DePuy)

Introduction:Our objective was to determine if the process of fatty infiltration that occurs following a rotator cuff tear could be reversed by surgical repair and allowing unrestrained activity of the injured shoulder. Methods: The supraspinatus muscle was unilaterally detached from the greater tuberosity in 15 NZW rabbits. Six weeks post detachment, 5 rabbits were sacrificed to halt the process of fatty infiltration and 10 underwent repair of the rotator cuff tear. Following repair the rabbits were housed in open pens to allow unrestricted activity. Six months post repair, the remaining 10 rabbits were sacrificed and underwent whole body perfusion. The muscle specimens were examined microscopically to determine if the process of fatty infiltration reversed. Results: Fatty infiltration was evident at 6 weeks post detachment of the supraspinatus tendon (p=0.0012), progressing from the musculotendinous junction to the origin. The presence of fat was measured as a percent of total muscle volume. At 6 months post repair, the muscle showed no increase in percent fat compared to that of the unattached muscle at 6 weeks (p=0.3). There was a stabilization of the fatty infiltration process after surgical repair of the rotator cuff. Conclusion:The process of fatty infiltration into a torn rotator cuff muscle can be halted from further progression by surgical repair. The process was not reversed within the 6 month period of this study. No formal rehabilitation program for muscle strengthening post surgical repair was instigated. Whether this would have any effect on reversal of fatty infiltration is not yet known. Introduction: Our objective was to determine if the process of fatty infiltration that occurs following a rotator cuff tear could be reversed by surgical repair and allowing unrestrained activity of the injured shoulder. Methods: The supraspinatus muscle was unilaterally detached from the greater tuberosity in 15 NZW rabbits. Six weeks post detachment, 5 rabbits were sacrificed to halt the process of fatty infiltration and 10 underwent repair of the rotator cuff tear. Following repair the rabbits were housed in open pens to allow unrestricted activity. Six months post repair, the remaining 10 rabbits were sacrificed and underwent whole body perfusion. The muscle specimens were examined microscopically to determine if the process of fatty infiltration reversed. Results:Fatty infiltration was evident at 6 weeks post detachment of the supraspinatus tendon (p=0.0012), progressing from the musculotendinous junction to the origin. The presence of fat was measured as a percent of total muscle volume. At 6 months post repair, the muscle showed no increase in percent fat compared to that of the unattached muscle at 6 weeks (p=0.3). There was a stabilization of the fatty infiltration process after surgical repair of the rotator cuff. Conclusion:The process of fatty infiltration into a torn rotator cuff muscle can be halted from further progression by surgical repair. The process was not reversed within the 6 month period of this study. No formal rehabilitation program for muscle strengthening post surgical repair was instigated. Whether this would have any effect on reversal of fatty infiltration is not yet known.

PAPER NO. 219

A Novel Pathomechanical Concept Explains the Fatty Muscular Changes Following Tendon Tear

Dominik Christoph Meyer, MD, *Zurich, Switzerland (n)*
Hans Hoppeler, MD, Berne, Switzerland (*)
Brigitte Van Rechenberg, PhD, Zurich, Switzerland (n)
Christian Gerber, MD, Zurich, Switzerland (*)

Tendon degeneration and tears are frequent causes of painful disability in man. They are associated with musculotendinous retraction, atrophy and infiltration of the muscle with fat. After few weeks, these changes become irreversible and represent the main cause for persistent disability despite successful tendon healing. These changes are currently considered to represent a non–specified degenerative process involving the muscle fibers. We studied the muscular changes caused by unilateral tendon release, myotendinous retraction and delayed repair in the infraspinatus muscle of eight sheep using computertomography, MRI, histology and electronmicroscopy.At sacrifice (75weeks after tendon release) the muscle had retracted by 2.6cm (13 percent, P<0.0001), the pennation angle had increased from 22 ± 2.5degrees to 50 ± 11degrees (P<0.0001) and the mean muscle fiber length had shortened from 32 ± 3mm to 16 ± 5mm (50 percent, P<0.0001). In electron and light microscopy, we found essentially normal muscle fibers with an unaltered fiber diameter and myofibrillar structure, while interstitial fat and fibrous tissue had increased from 3.7 percent to 46 percent (P<0.0001) of the muscle volume. Geometric modeling showed that the increase of the pennation angle separates the muscle fiber bundles like limbs of a parallelogram.We hypothesize that the fat tissue serves to fill opportunistically the mechanically created spaces between muscle fibers and is not primarily the consequence of a degenerative process. These gaps may quantitatively be predicted with this model. Therefore, to reverse muscle changes caused by tendon retraction we will have to restore pennation angle and muscle fiber length.

PAPER NO. 220

Intraoperative Supraspinatus Strength, Histology and Correlation with the Outcome of Tendon Repair

Dominik Christoph Meyer, MD, *Zurich, Switzerland (n)*
Hans Hoppeler, MD, Berne, Switzerland (*)
Alberto G Schneeberger, MD, Zurich, Switzerland (*)
Christian Gerber, MD, Zurich, Switzerland (*)

Following tendon tear, the myotendinous unit suffers permanent retraction, atrophy and infiltration with fat. Reversal of these changes is known to be rare. To understand the functionality of such altered muscle tissue and the potential for recovery we stimulated the suprascapular nerve intraoperatively in thirteen patients during supraspinatus tendon repair and measured the maximal contractile muscle strength. Before and after repair,

muscle biopsies were taken. The patients were assessed clinically and with MRI before and 3, 6 and 12 month after tendon repair.Maximal contractile strength correlated strongly with the cross-sectional area and the fatty infiltration and ranged from 12 N/cm2 in Goutallier stage 3 to 42 N/cm2 in Goutallier stage 0. Of the five patients with re-tears, four were amongst the strongest six patients and one was the weakest of all. Muscle atrophy and fatty infiltration did not improve after successful tendon repair, but got significantly worse with recurrence of the tear. Histology revealed infiltration of fat and Lipofuszin in the muscles with marked atrophy and sings of disturbed muscle structure, predominantly in the biopsies taken after muscle stimulation.We conclude that both, exceptionally strong or weak muscle conditions represent risk factors for recurrence of a tendon tear and need careful postoperative protection of the tendon repair. Maximal muscle contraction exceeded the strength of a single suture repair (200N), appears to cause further histological damage to already altered muscle tissue and should therefore be avoided. Atrophy and fatty infiltration seem irreversible, despite successful tendon repair.

POSTERS

POSTER NO. P252

The Use of Biceps Compression for the Diagnosis of Distal Biceps Tendon Ruptures in the Military

Robert Thomas Ruland, MD, *Portsmouth, VA (n)*

When the diagnosis of a DBT rupture is unclear most clinicians will resort to MRI. This study is expensive and, in many military settings, inaccessible. Utilizing the old concept that deformation of muscle creates tension at the site of insertion, we offer a simple physical finding to evaluate for rupture of the DBT. Methods- Biceps compression was performed in 65 normal subjects.10 normal individuals underwent EMG testing during the performance of the maneuver.Between July 1999 and Aug 2003, 22 patients with 23 suspected DBT ruptures had both upper extremities evaluated with the biceps squeeze test (BST). Results- The response to biceps compression in all normal individuals was forearm supination . EMG testing during the BST revealed no motor unit action potentials. In 22 of the 23 extremities evaluated, the BST accurately demonstrated the absence or presence of a complete DBT rupture. The BST had a positive predictive value of 95% and sensitivity of 100%. Discussion- The BST is a simple, reproducible maneuver to evaluate for DBT ruptures.

POSTER NO. P253

Coronoid Fracture Patterns

David Ring, MD, *Boston, MA (a – AO Foundation)*
Job Doornberg, MS, Boston, MA (n)

Introduction: Fractures of the coronoid have been classified on the basis of size alone. With greater experience treating coronoid fractures, it has become clear that the overall injury pattern and specific fragment characteristics may also be important. Methods: A single surgeon repaired 41 coronoid fractures in 40 patients with fracture-dislocation of the elbow over a 3-year period. Each coronoid fracture was characterized on the basis of operative exposure. Results: Among 22 patients with olecranon fracture-dislocations 20 involved greater than 50% of the coronoid height and two were smaller fractures involving the anteromedial facet. Among the twenty large coronoid fractures, 9 were large single fragments, 8 had three fragments (anteriomedial facet, central, and lesser sigmoid notch), 1 had a single sagittal split, and 2 had greater than 3 fragments. All sixteen patients with terrible triad injuries had small (less than 50%) coronoid fractures and LCL injury. There was a transverse fracture of the tip in 15 patients (14 simple, one comminuted) and a fracture of the anteromedial facet and the tip in one. The 3 patients with posteromedial varus rotational instability (PVRI) injuries had fracture of the anteromedial facet of the coronoid, fracture of the tip of the coronoid and fracture of the sublime tubercle. All 3 had injury to the LCL. Conclusions: Fractures of the coronoid have distinct patterns according to injury type, recognition of which can help guide treatment. Anteromedial facet fractures may require a medial exposure and comminuted fractures may benefit from hinged external fixation.

POSTER NO. P254

Hinged External Fixation for Elbow Instability After Fracture-Dislocation

David Ring, MD, *Boston, MA (a – AO Foundation)*
Didier Hannouche, MD, Boston, MA(a – AO Foundation)
Jesse B Jupiter, MD, Weston, MA (b – AO Foundation)

Introduction: Reconstruction of persistent instability after fracture-dislocation is one of the most challenging problems in elbow surgery. The results of operative treatment may be improving as concepts of elbow stability evolve and technological advances such as hinged external fixation are introduced. Methods: Thirteen consecutive patients with dislocation (4), subluxation (6), or recurrent dislocation (3) of the ulnohumeral joint two weeks or more after injury and adequate articular surfaces were treated with temporary hinged external fixation, preservation or reconstruction of both the coronoid process and radiocapitellar contact, and repair or reconstruction of the lateral collateral ligament complex. There were nine men and four women, with an average age of forty-five years. Seven patients had a terrible triad pattern injury and six had a posterior olecranon fracture-dislocation. Thirteen patients had radial head fracture and 10 had fracture of the coronoid. Results: At an average follow-up of fifty-seven months, a stable elbow was restored in every patient. The average DASH score was 15 and the average Mayo score was 84 with six excellent, four good, and three fair results. The average arc of ulnohumeral motion was 99 degrees. Six patients had radiographic signs of arthrosis including 5 of 6 patients with olecranon fracture-dislocations. Conclusions: A stable, functional elbow can be restored in most patients with persistent instability after fracture-dislocation of the elbow using a treatment protocol incorporating hinged external fixation. Injuries with greater involvement of the trochlear notch (e.g. posterior olecranon fracture

POSTER NO. P255

Post-Op Loss of Alignment Posterior Monteggia Fractures: Salvage with Dorsal Contoured Plating

David Ring, MD, *Boston, MA (a – AO Foundation)*
Jason D Tavakolian, MD, Brookline, MA (n)
David Leonard Helfet, MD, New York, NY (d – Synthes-Stratec)
Peter Kloen, MD, Amsterdam, Netherlands (n)
Jesse B Jupiter, MD, Weston, MA (b – AO Foundation)

Background: The operative treatment of posterior Monteggia fractures is sometimes complicated by loosening of fixation and loss of alignment, with or without ulnohumeral instability. Methods: Seventeen patients with malalignment after operative

treatment of a posterior Monteggia fracture were treated with realignment of the ulna and fixation with a 3.5-millimeter limited contact dynamic compression plate applied to the dorsal of the ulna and contoured to wrap around the olecranon process. Fifteen had loose fixation and twelve had subluxation or dislocation of the ulnohumeral joint. Sixteen patients had fracture of the radial head and nine had fracture of the coronoid process. Results: At the final evaluation an average of fifty-nine months after the index surgery, the fracture was healed and the ulnohumeral joint concentrically reduced in all seventeen patients. The average arc of elbow flexion was 108 degrees and the average arc of forearm rotation was 134 degrees. The average American Shoulder and Elbow Surgeons Elbow Evaluation Score was 88. According to the system of Broberg and Morrey, the final result was rated excellent for five patients, good for nine, fair for two, and poor for one. Conclusions: Malalignment after operative treatment of posterior Monteggia fractures usually reflects unstable fixation. Dorsal contoured plating of the ulna in combination with other procedures can help salvage a malaligned posterior Monteggia fracture with satisfactory function restored in the majority of patients.

POSTER NO. P256

Latissimus Dorsi Transfer for Massive Irreparable Rotator Cuff Tears - An Anatomic Study

Ruby Grewal, MD, *Vancouver, BC Canada (n)*
Robert H Hawkins, MD, Vancouver, BC Canada (n)

Latissimus dorsi tendon transfer has been recommended in the treatment of massive rotator cuff tears. However direct visualization of the latissimus insertion is often difficult and thus potentially hazardous. Since the anatomic details of structures at risk have not been previously reported we dissected five cadaveric shoulders to investigate the anatomic relationships of vulnerable structures and to develop a new method of surgical exposure. We investigated the safety of the "arm akimbo" position and the use of a narrow Bennett retractor over the humeral shaft, at the insertion of the latissimus dorsi tendon. This provides excellent visualization of the tendon insertion and avoids contact with adjacent neurovascular structures. Our dissections revealed that the radial nerve and profunda brachii artery were found 7mm and 6mm distal to the latissimus dorsi tendon respectively. Proximally, the axillary nerve and posterior humeral circumflex artery were found 12mm and 16mm away. When dissecting the latissimus dorsi tendon from the humeral shaft, the radial nerve and profunda brachii artery are found on its immediate undersurface, 20mm and 18mm from the humeral shaft respectively. When tunneling underneath the deltoid for tendon transfer, the motor branch of the axillary nerve is vulnerable, as it is only 15mm lateral to the greater tuberosity. We conclude that the "arm akimbo" position and retractor placement, as described, provides direct visualization of the latissimus dorsi insertion. Although the neurovascular structures are at a potentially vulnerable location, they are not placed at risk with the surgical approach, retractor and arm positioning described.

POSTER NO. P257

Biomechanical Evaluation of an Arthroscopic Rotator Cuff Stitch - the Massive Cuff (MaC) stitch

C Benjamin Ma, MD, *San Francisco, CA (n)*
John Clabeaux, MD, New York, NY (*)
Samuel Lee, New York, NY (*)
James Otis, PH D, New York, NY (*)
John Dougald MacGillivray, MD, New York, NY
(e – Arthrex)

Introduction: Recent reports have indicated high failure rates of arthroscopic repairs at the suture-tendon interface. The goal of the study was to determine the biomechanical properties of a novel arthroscopic stitch, massive cuff (Mac) stitch, and to compare it with other commonly used rotator cuff stitches. Methods: 8 pairs of sheep infraspinatus tendons were split in half to yield four tendon specimens from each animal. 4 stitch configurations (simple, horizontal, modified Mason-Allen, and Mac stitch) were randomized and biomechanically tested on each set of tendons. The Mac stitch consists of a horizontal loop tied first, followed by a simple vertical loop placed medial to the horizontal loop. Each specimen was cyclically loaded from 5-30N for 20 cycles, followed by load to failure test. Elongation, peak-to-peak displacement, ultimate tensile load and stiffness were measured using an optical motion analysis system and load cell output. Results: There was no difference in peak-to-peak displacement and elongation among the 4 stitches. Elongation of the Mac stitch was 0.7 ± 0.3mm while the other stitches was 0.9 ± 0.3mm. The ultimate tensile load for the Mac stitch (233±40N) and the modified Mason-Allen stitch (246±40N) were significantly higher ($p<0.05$) than both the simple (72±18N) and horizontal stitches (77±15N). There was no difference in stiffness among the 4 stitches. The simple and horizontal stitches all failed by tissue pull-out while the MaC stitch and the modified Mason-Allen stitch failed by a mixture of suture breakage and pull-outs. Conclusions: The ultimate tensile load of the Mac stitch is three times that of the simple and horizontal stitches. The Mac stitch is a technically easy arthroscopic stitch that provides comparable strength to the modified Mason-Allen stitch commonly used in open rotator cuff tendon repair.

POSTER NO. P258

Reimplantation of a Shoulder Arthroplasty after Previous Infected Arthroplasty

John William Sperling, MD, *Rochester, MN (n)*
Joseph Mileti, MD, Powell, OH (*)
Robert H Cofield, MD, Rochester, MN
(c – Mayo, Smith&Nephew)

Introduction: Currently, there is little information on the results of reimplantation of shoulder arthroplasty after previous infected arthroplasty. The purpose of this study was to determine the results, risk factors for an unsatisfactory outcome, and the rates of failure. Methods: Between 1975 and 2000, five patients with an infected shoulder arthroplasty underwent prosthesis resection and subsequent reimplantation of a prosthesis. This group consisted of 3 woman and 2 men with a mean age of 58 years. Each of the shoulders underwent resection arthroplasty, IV antibiotics for 2-8 weeks, and reimplantation of a shoulder arthroplasty. The mean clinical follow-up was 7.5 years (range, 2 to 15 years). Results: There were no patients with recurrent infection. At the most recent follow-up, three patients had no pain, one had slight pain, and one had moderate pain. Mean elevation improved from 76 degrees to 100 degrees and external rotation

improved from 17 degrees to 52 degrees. With regards to patient satisfaction, two patients rated themselves as much better, two better, and one the same. There was one excellent result, two satisfactory results, and two unsatisfactory results. Discussion: Reimplantation of a shoulder arthroplasty can be performed with a low risk of reinfection. However, arthroplasty in this setting is especially challenging due to the potential for significant bone and soft tissue deficits. These challenges can compromise the clinical results in this group of patients.

POSTER NO. P259

Split Anconeus Fascia Transfer for Reconstruction of the Elbow Lateral Collateral Ligament Complex

Anand M Murthi, MD, Baltimore, MD (n)
Caroline M Chebli, MD, Columbia, MD (*)
Joseph Anthony Ciotola, MD, Baltimore, MD (*)

Introduction: Reconstruction of the elbow lateral collateral ligament complex (LCLC) for posterolateral rotatory instability remains a difficult procedure. We propose a novel technique to anatomically reconstruct the LCLC using a local transfer of split anconeus fascia (SAF). Materials/Methods: In 20 fresh frozen cadaver elbows, the LCLC was divided and subsequently reconstructed. All specimens had a positive manual pivot shift and varus instability prior to SAF reconstruction. The local anatomy and distance to the neurovascular structures was defined in all specimens. A strip of anconeus fascia was detached from its origin and split in line with its fibers and dissected down to its' insertion on the ulna. One segment (superior) was passed under the annular ligament to reconstruct the proper radial collateral ligament while the inferior segment was used to reconstruct the lateral ulnar collateral ligament. A docking technique was used to secure the SAF to the isometric point on the lateral epicondyle. Results: The SAF technique was reproducible and safe in every specimen tested. All specimens had full range of motion, stability to manual varus stress, and a negative manual pivot shift after SAF reconstruction. Conclusion: Our novel LCLC reconstruction provides an anatomic restoration of the LCLC, without the morbidity of tendon harvest. Furthermore, it allows for intraoperative local reconstruction when instability develops during surgery. This technique provides a theoretically stronger reconstruction in cases of posterolateral rotatory and varus elbow instability while maintaining motion and stability.

POSTER NO. P260

Improved Clinical Diagnosis of Distal Biceps Tendon Rupture: The Flexion Initiation Test

Glen Ross, MD, Wayland, MA (n)
Michael D Gordon, MD, Milwaukee, WI (*)
Daniel P Bouvier, MD, Nashua, NH (n)
Arnold D Scheller, MD, Brookline, MA (n)
Scott P Steinmann, MD, Rochester, MN (n)

Introduction:Distal biceps tendon rupture (DBTR) of the elbow appears to be increasing in prevalence. The etiology is unclear. Many ruptures are easily diagnosed. Deformity may be present, along with supination weakness. However, a subset of DBTR, with the lacertus fibrosus intact or with high grade partial tears, can be more difficult to diagnose. The purpose of this study is to describe a physical examination test that assists primary care providers, and orthopaedists, in identifying DBTR. Methods: Frequent evaluation of DBTR has lead to the observation that these patients lose the ability to initiate flexion from a fully extended position. This is termed the Flexion Initiation Test (FIT). It is performed by having the patient fully extend the injured elbow with the wrist supinated. The examiner applies a steady ten pound resistive force, as the patient attempts to flex the elbow. The inability to flex from a fully extended position indicates a positive test for DBTR. The FIT was performed on consecutive patients with suspected DBTR. Acute and chronic (>6 weeks) ruptures were included. Correlation of clinical examination with surgical and MRI findings was performed to evaluate the test. Results: 22 consecutive patients with suspected DBTR were referred for care. One patient with a prior dislocation and flexion contracture was excluded. All were male, 35-62 years old. Time from injury to surgical repair ranged from 2-49 days. 3 patients elected nonoperative treatment. MRI was available on all patients, usually ordered by the referring physician. 20 out of 21 patients were noted to have a positive FIT. On the contralateral elbow, the examination was noted to be normal. One patient, a professional bodybuilder with a surgically proven DBTR, retained the ability to perform the FIT. However, his strength was clearly weaker than his contralateral side. During this time period, 25 patients undergoing rountine tennis elbow surgery had the FIT performed as part of a preop exam. 100% of this control group were able to perform the test. Conclusions: Despite an increase in clinical awareness, DBTR can still be misdiagnosed, especially at the primary care level where the injury is often first seen. The FIT is an easy to perform clinical examination, that can increase the accuracy of DBTR diagnosis. This may result in earlier treatment, with potentially less reliance on expensive imaging.

POSTER NO. P261

Arthroscopic Biceps Tenodesis: Experience with the Castagna Technique

***Jeffrey I Kauffman, MD,** Sacramento, CA (n)*
Stephen C Weber, MD, Sacramento, CA (n)
Deanna Higgins, Sacramento, CA (*)

Objective: The long head of the biceps has become recognized as a well-known cause of shoulder pain. While arthroscopic biceps tenodesis seems desirable, currently described arthroscopic techniques are complex and risk the axillary nerve. Tenotomy, while appropriate for many, may result in cosmetic deformity or biceps cramping in a significant number of patients. Castagna et. al. presented a technique of arthroscopic suturing of the tenotomized biceps to the rotator cuff and transverse ligament. This allows relatively simple reattachment of the tendon without hardware or transosseous drilling. We present our results with the Castagna "soft-tissue dynamic tenodesis". Methods: Thirty-Seven patients were treated over an 8-year period. Mean age was 59.9 years, with 27 males and 10 females. Thirty-Four patients had significant rotator cuff pathology; all patients had an arthroscopic acromioplasty. The biceps was arthroscopically tagged, and then tenotomized with electrocautery. It was then sutured to the rotator cuff tendon using permanent #2 sutures. In the 34 patients with rotator cuff tears, the suture used was from an arthroscopically placed suture anchor, and the biceps was incorporated into the repair of the rotator cuff. Results: UCLA scores improved from a mean of 18.8 to a mean of 31.2. Postoperatively, SST scores averaged 9.4 categories. Following tenodesis, no patient developed a cosmetic deformity and no patient complained of upper arm cramping. There were no complications related to the procedure. Discussion: Arthroscopic soft tissue tenodesis appears to be a reliable technique to manage the pathologic biceps tendon. The ease and low morbidity compares favorably with tenotomy, without the risk of cosmetic deformity or cramping. This procedure may allow tenodesis in those patients where open or complex arthroscopic surgery seems undesirable.

POSTER NO. P262

Arthroscopic Bankart Repair Using a Knotless Method: Technique and Results

Jon J P Warner, MD, *Boston, MA*
(a – Fellowship Support, Mitch Johnson & Johnson)
Michael Gilbart, MD, Pittsburgh, PA (n)
Edward Yian, MD, Rancho Cucamonga, CA (n)
Peter J Millett, MD, Boston, MA (n)

Introduction: The purpose of this study is to present a new technique of arthroscopic Bankart repair using knotless suture anchors, and report the outcomes following its use. Methods: Thirty-six patients with traumatic anterior shoulder instability were treated arthroscopically, with a mean patient age of 34 years (range 16-67). All were treated with a repair of the Bankart lesion and capsular tensioning with one standard suture anchor inferiorly at the 5'oclock position and two knotless suture anchors superiorly in the 3 to 4 o'clock position. Outcome measures included ASES scores and patient satisfaction. ASES scores were correlated with demographic and clinical variables. Results: The mean follow-up was 37 months (range 24-46). Mean ASES scores improved from 40_ 18 preoperatively to 83_ 19 postoperatively ($p<0.001$). Mean pain score improved from 6.9_ 2.6 to 1.7_ 1.8 ($p<0.001$), and mean instability score improved from 7.7_ 2.6 to 1.7_ 2.5 ($p<0.001$). Thirty two patients had good/excellent results with improvement in function and return to activities, and 27 returned to their preinjury overhead sporting activities. Two patients required arthroscopic capsular release for stiffness. Four patients had recurrent instability following new traumatic injuries, which required revision in three patients. Two of these were found to have bony deficiency of the glenoid. Conclusions: This study introduces a novel technical approach to arthroscopic Bankart repair with good results in most patients at a minimum 2 year follow-up. Advantages of this approach are faster surgery, avoidance of knot tying, and reliably good outcome.

POSTER NO. P263

Arthroscopic Debridement in the Treatment of Isolated Tears of the Subscapularis

Thomas Bradley Edwards, MD, *Houston, TX (n)*
Gilles Walch, MD, Lyon, France (n)
Laurent Nove Josserand, MD, Lyon, France (n)
Aziz Bouhalia, Lyon, France (n)
Lionel Neyton, MD, Lyon, France (n)
Bruce Lindgren, Minneapolis, MN
(e – Minneapolis Sports Medicine Center)
Istvan Szabo, MD, Lyon, France (*)

INTRODUCTION: Even after failure of nonoperative treatment, certain patients remain poor candidates for conventional subscapularis repair (irreparable tear, unwilling to comply with rehabilitation required following repair). Therefore, the purpose of this study is to test the hypothesis that arthroscopic debridement of isolated subscapularis tears in selected patients yields acceptable postoperative subjective, objective, and radiographic results. METHODS: Eleven shoulders that had undergone arthroscopic glenohumeral debridement in the treatment of subscapularis tears were reviewed. All patients had previously failed appropriate nonoperative management. Patients were selected for arthroscopic debridement if the tear was thought to be irreparable or the patient was older and not willing to participate in the rehabilitation required following repair. The mean age at surgery was 58 years. The mean time interval from onset of symptoms to surgery was 11 months. Seven tears were traumatic, and four were degenerative in etiology. Four of the tears involved the superior third of the subscapularis tendon, two involved the superior two thirds of the subscapularis tendon, and five were complete tears. Nine shoulders had a dislocation or subluxation of the long head of the biceps tendon and underwent a concomitant biceps tenotomy. Patients were evaluated clinically and radiographically at a mean 34 month follow-up (range 24 to 48 months). RESULTS: The mean Constant score increased from 48 points preoperatively to 80 points postoperatively ($p<0.0001$). Nine patients were satisfied or very satisfied with the result. Preoperatively, two patients had mild glenohumeral arthritis. Postoperatively, radiographs demonstrated no progression of arthritis in these two patients and no new onset arthritis. DISCUSSION AND CONCLUSIONS: Arthroscopic debridement in the treatment of subscapularis tears in selected patients yields good objective improvement and a high degree of patient satisfaction.

POSTER NO. P264

Early Results of Rotator Cuff Repair Using a Porcine Small Intestine Submucosa Implant

Hilary Malcarney, MD, *Haddonfield, NJ (n)*
George A C Murrell, MD, A/Prof, Kogarah Sydney, Australia (n)

INTRODUCTION. The RestoreTM Orthobiologic Implant (DePuy, Warsaw, Indiana, USA) is a recent development designed to strengthen the repair of soft tissues such as the rotator cuff. Derived from porcine small intestine submucosa (SIS), the RestoreTM Implant is an acellular, resorbable scaffold which allows for host cell proliferation. Reported results of animal studies using the Implant to repair the gut, dura, bladder, and rotator cuff have been favorable. There are no reports of its use in human rotator cuff repair. METHODS. Twenty-five patients underwent rotator cuff repair using the RestoreTM Implant from August, 2002-February, 2003. RESULTS. Four patients presented with an overt inflammatory reaction at an average of seventeen days after the procedure, characterized by an errythematous surgical wound with subcutaneous fluctuance. All four patients were taken back to the operating room for irrigation and debridement. A large amount of yellow mucinous tissue was noted to communicate between the glenohumeral joint and the subacromial space. The Implant was not identifiable. Histopathological analysis noted inflamed granulation tissue. Blood work and cultures did not indicate infection. DISCUSSION AND CONCLUSION. While the RestoreTM Implant is an exciting development in soft tissue repair, our clinical results suggest that it should be used with caution. Overt inflammation with apparent breakdown of the repair was the result in four patients, at approximately two weeks post-operatively. Our sample size of 25 patients is small, but with a failure rate of 16 percent, further investigation into the cause of this reaction is warranted.

POSTER NO. P265

Evaluation of the Constant Score for Normal Shoulders

Edward Yian, MD, *Rancho Cucamonga, CA (n)*
Arun J Ramappa, MD, Vail, CO (n)
Christian Gerber, MD, Zurich, Switzerland (n)

Introduction: The Constant score is the most commonly used instrument to assess shoulder function. The purpose of this study was to determine normal scores in a separate population using a standardized technique and to verify whether the normal values established in 1986 by Constant remain valid.Materals and

Methods:Constant scores were calculated for 1,620 clinic patients seen between 1996 and 2002. All had subjectively normal shoulders. ROM was determined and abduction strength was measured with a validated electronic dynamometer. Results:1,046 males and 573 females were studied. Age ranged from 11 to 87 years (mean46.3, SD16.0). Average strength was 8.6kg (SD2.8) in males and 4.6 kg (SD1.7) in females. Average ROM (degrees) was: forward flexion - males 162.4 (SD11.1), females 161.4 (SD 13.6); external rotation - males 62.9 (SD16.9), females 65.9 (SD17.0). Males achieved significantly higher abduction strength and Constant scores than females. There was no significant difference between dominant and non-dominant shoulders. There was an age-related decline in abduction strength and Constant score after age 40. Compared with Constant's original study, women over 40 and men over 60 had significantly higher Constant scores. Conclusion:Use of Constant's normal values for the calculation of the relative Constant score can substantially overestimate shoulder function in women over 40 and men over 60. Different population norms may need to be used and absolute Constant scores should be reported.References:Constant CR. Age Related Recovery of Shoulder Function after Injury,thesis. Cork, Ireland, University College,1986.

POSTER NO. P266

Hemiarthroplasty for Proximal Humeral Fracture: A New Method to Obtain Correct Humeral Length

Ariane Gerber, MD, *Berlin, Germany (n)*
Maria Apreleva, PhD, Beverly, MA (*)
Fraser Harrold, BS, Dundee, United Kingdom (n)
Philippe Clavert, MD, Boston, MA (n)
Jon J P Warner, MD, Boston, MA (n)

Introduction: Prosthetic reconstruction of proximal humeral fractures is difficult. We hypothesized that the pectoralis tendon insertion would be a consistent landmark to guide accurate placement of a humeral component for fracture hemiarthroplasty. Methods: In part I a cadaver analysis was performed on 50 proximal humeri in which the pectoralis major tendon (PMT) was dissected and all soft-tissue removed. A 3-dimensional digitizing device and computer recorded anatomy. The pectoralis head height (PHH) was defined as the distance from the edge of the PMT to the top of the humeral head.. A proximal humerus fracture was then created and a prosthesis was placed to reconstruct the fracture using the PHH mean value as the basis for height of the prosthesis. This reconstruction was then compared to the original value for each shoulder.Part II was a clinical analysis in 7 patients of the accuracy of humeral head placement for hemiarthroplasty for fracture. The mean value for PHH guided intraoperative positioning of the humeral prosthesis. Bilateral postoperative long arm radiographs adjusted for magnification were obtained, in order to compare humeral length. Results: In part I the mean PHH distance of the reconstructed cadaveric humeri was 53mm_ 7mm and this did not represent a significant difference from the original PHH distance. In part 2 the mean difference between the length of the reconstructed and contralateral humerus was 4.1mm_ 2.1mm. Conclusion: Our hypothesis was validated by both experimental and clinical study, which showed that the relationship of the pectoralis insertion to the top of the humeral head is a reliable and accurate measurement, which can be used for hemiarthroplasty reconstruction.

POSTER NO. P267

Results of Surgical Treatment of Isolated Axillary Nerve Lesions

Christine B Caltoum, MD, *Rochester, MN (n)*
Scott P Steinmann, MD, Rochester, MN (n)
Robert J Spinner, MD, Rochester, MN (n)
Allen T Bishop, MD, Rochester, MN (n)
Sheri M Merten, RN, Rochester, MN (n)

Introduction: Isolated axillary neuropathy is an uncommon finding after a shoulder girdle injury. From a group of over 200 patients with nerve injuries about the shoulder, 10 patients were identified and surgically treated for an isolated complete axillary nerve lesion. Seven patients with a prior nerve transection or neuroma in continuity underwent sural nerve grafting using two cable grafts. Three patients underwent scar decompression and neurolysis. Methods:Post-operative function was assessed by manual range of motion testing, electromyography and nerve conduction studies and by completion of the ASES Standardized Shoulder Assessment Form. Other factors such as age at the time of injury, concomitant bony or soft tissue injury and time interval from injury to operative treatment were evaluated. Results:The mean time interval from injury to surgery was 6 months. Forward flexion and abduction improved from pre-operative means of 80 and 50 degrees to post-operative means of 120 and 110 degrees respectively. Average ASES score post-operatively was 75 out of 100. Strength of abduction improved from pre-operative average of 0/5 to 3/5. Discussion and Conclusion:Significant improvement in activities of daily living, with satisfactory ASES scoring can be achieved if operative intervention is undertaken within the first three to six months post-injury. If the nerve is transected, primary repair was not possible in this series. Use of two sural nerve cable grafts provided reliable in reanimation of the deltoid.

POSTER NO. P268

Arthroscopic Biceps Tenodesis. A New Technique with Fixation Over the Subscapularis Tendon

Celeste Bertone, MD, *Novara, Italy (n)*
Dario Petriccioli, MD, Parma, Italy (n)
Nicola Ivaldo, Savona, Italy (n)

INTRODUCTION: Surgical treatment of symptomatic pathology of the long head of the biceps tendon (LHB) generally consists of either biceps tenotomy or tenodesis. Biceps tenodesis is generally recommended for younger patients and has been well described using open techniques. With advancements in arthroscopic ability and equipment, new arthroscopic techniques have recently been reported. We present a new personal arthroscopic technique of biceps tenodesis using a fixation over the subscapularis tendon. MATERIALS AND METHODS: 92 patients, average age 65 years, underwent tenodesis of the LHB for a pathologic tendon (tenosynovitis, pre-rupture, subluxation, or dislocation) encountered during arthroscopic treatment of impingement syndrome or rotator cuff repair. These steps were required: 1) three arthroscopic portals (posterior, anteromedial and anterolateral); 2) gleno-humeral joint exploration; 3) intra-articular transfixation of the LHB and subscapularis tendon with a No. 4 suture using a suture grasper (45° angled); 4) intra-articular stitching; 5) tenotomy of the LHB from its glenoid insertion using a radio-frequency probe. RESULTS: Shoulder function was evaluated using the Constant score before surgery and at follow-up. No deficit of flexion or extension of the elbow was observed compared with the contra-lateral side. Spring-balance strength of the tenodesed biceps averaged 90% of the contra-lateral side. DISCUSSION AND

CONCLUSION: Tenodesis of the LHB can give excellent and good long-term results. The different arthroscopic techniques result in few failures, the incidence of which can be minimized by attention to technical details. It should be emphasized, however, that routine tenodesis or tenotomy is not recommended.

POSTER NO. P269 - WITHDRAWN

POSTER NO. P270

An Experimental Study for Repair of the Rotator Cuff -The Effects of Synovial Tisssue-

Kazuhiko Kikugawa, MD, *Matsuyama, Japan (n)*
Yu Mochizuki, Hiroshima, Japan (n)
Mitsuo Ochi, MD, Hiroshima, Japan (n)

(Introduction) The purpose of this study was to clarify the effects of synovial tissue and growth factor on the healing process of the rotator cuff in rat model.(Methods) A 3mm-diameter defect at the supraspinatous tendon was created in 48 rats. They were classified into 2 groups: group-F with only defect, group-S with defect filled with synovium. The shoulders were removed at 1, 2, 4 and 8 weeks postoperatively. The specimens were investigated using H-E staining, immunostaining with antibodies against proliferating cell nuclear antigen (PCNA), TGFƒÀ-1, bFGF and in situ hybridization using the cRNA probe for procollagen types I and III. Each sample was evaluated by the histologic tendon mature scoring system and the percentage of positively stained cells.(Results) At 1 and 2 weeks, the histologic tendon mature score for group-S was significantly higher than that for group-F. The percentage of positively stained cells of PCNA was higher in group-S than in group-F throughout all periods. Signals of procollagen types I and III for group-S were detected in tissues whole around the defect area, whereas those for group-F were localized in tissue adjusted to the bursal side and articular side. Expressions of bFGF were detected in tissues whole around the defect areas in both groups, whereas those of TGFƒÀ-1 were detected marked higher in group-S than in group-F. (Conclusion) The synovium plays an important role in enhancing the tendon healing capacity and expressions of TGFƒÀ-1 may affect the synovial effect of the healing process for the rotator cuff.

POSTER NO. P271

In-Hospital Morbidity, Mortality, and Economic Impact of Shoulder Versus Hip and Knee Arthroplasty

Brett Cascio, MD, *Baltimore, MD (n)*
Kevin W Farmer, MD, Baltimore, MD (n)
William Queale, MD, Lutherville, MD (n)
Jason Hammond, MD, Columbia, MD (n)
Dhruv Pateder, MD, Baltimore, MD (n)
Edward G McFarland, MD, Lutherville, MD (n)

Introduction: Patients frequently ask if shoulder arthroplasty (SA) carries the same risks as total knee (TKA) or hip arthroplasty (HA). We hypothesized that in-hospital morbidity and mortality would be lower for SA than for TKA and HA. Methods: Discharge data for all hospitals and all payor types for Maryland from 1994 to 2001 were reviewed from a statewide database. All primary knee, hip, and shoulder arthroplasties performed for osteoarthritis (OA) were studied. Outcomes studied using multivariate analysis included in-hospital complications and deaths, length of stay (LOS), and total charges. Results For 15,414 hip, 34,471 knee and 994 shoulder arthroplasties there were 27, 54, and 0 deaths respectively. SA were one-sixth as likely to have a LOS > 6 days compared to HA and TKA (OR, 0.16; 95% CI, 0.11-0.22). SA were one-tenth as likely to surpass $15,000 total charges compared to HA and TKA (OR, 0.11; 95% CI, 0.08-0.14). The risk of at least one complication in SA was half that of THA and TKA (OR, 0.46; 95% CI, 0.36-0.59). Discussion and Conclusions: This study demonstrates that SA for OA has a lower mortality and morbidity than HA or TKA. SA is less expensive, has a shorter length of stay, and is less likely to have in-hospital complications when compared to HA and TKA. This study demonstrates that SA should be considered as safe or safer than more commonly performed arthroplasties.

POSTER NO. P272

Extracorporeal Shock Wave Therapy for Chronic Lateral Epicondylitis: A Study of Efficacy and Safety

Rory Dunham, DO, *Oklahoma City, OK*
(a – Healthtronics)
Richard J Langerman, DO, Oklahoma City, OK (*)
Zane Uhland, DO, Oklahoma City, OK (a – Healthtronics)

Introduction: This multi-center, prospective, randomized, double-blinded, placebo-controlled, bi-phasic study was performed to assess the efficacy and safety of extracorporeal shock waves in treatment of chronic lateral epicondylitis. Methods: 225 patients (93 active randomized, 43 active training, 90 placebo randomized) participated in the study. Parameters for success included: 1)investigator assessment of point tenderness; 2)patient self-assessment of pain with activity; 3)patient use of pain medication as rare. Satisfaction of all parameters determined success. Patients failed a minimum six months of conservative treatment. Procedure protocol included 1500 shocks at18kV. Patients were evaluated pre- and post-treatment, four weeks, eight weeks, and twelve months. Initial success was determined and patients were un-blinded at eight weeks. The second phase was an open label study. All failures (active or placebo) could receive an active treatment. Results: 204 patients, 121 active and 83 placebo, were assigned success/fail criteria at eight weeks. Forty-one percent of the active, randomized patients and twenty-four percent of the placebo group met all success criteria (a statistically significant difference). At twelve month evaluation of the re-treatment groups, 87% of all actively treated, randomized patients met success criteria. Of those in the initial placebo group who received active treatment after un-blinding, 94% met all success criteria at 12 months. No unanticipated or serious adverse events occurred. Conclusion: Extracorporeal shock wave therapy is effective versus placebo for treatment of chronic lateral epicondylitis.

POSTER NO. P273

Interscalene Block Anesthesia is Safe and Effective for Shoulder Surgery

Julie Bishop, MD, *Cleveland, OH (n)*
Cathy Lee, MD, New York, NY (*)
Jonathan Gelber, MS, New York, NY (*)
Marina Krol, PhD, New York, NY (n)
James N Gladstone, MD, New York, NY (n)
Evan L Flatow, MD, New York, NY (n)

Introduction Despite a trend toward the use of regional anesthesia for orthopaedic procedures, there has been resistance to the use of interscalene regional block (ISB) for shoulder surgery due to concerns about failed blocks and potential complications. Methods A retrospective review was performed of 568 consecutive patients undergoing shoulder surgery in a tertiary referral practice. Complete anesthetic and orthopedic records were avail-

able for 547 patients. The surgical procedure, planned type of anesthesia, occurrence of block failure, and the presence of complications were notedResultsOf 547 patients, 300 underwent arthroscopic procedures and 247 underwent open surgery (including 80 arthroplasty cases). General anesthesia (GA) was the initial planned choice in 72 cases due to the complexity or anatomic location (e.g. scapular fractures, tendon transfers, infection). Thirty-seven of these 72 also received an ISB. ISB alone was planned for 475 patients. 462 (97%) were successful, while 13 (2.7%) required GA due to an inadequate block. 95% of arthroscopies and 72% of open cases received ISB alone. Among all 512 patients receiving ISB, there were no seizures, pneumothoraces, cardiac events, or other major complications. There was a 3% rate of minor complications, all of which were sensory neuropathies except for 1 complex regional pain syndrome, which resolved at 3 months. All but one of the neuropathies resolved by 6 months (mean 9 weeks). ConclusionISB provides effective anesthesia for most types of shoulder surgery, including arthroplasty and fracture fixation. When administered by an anesthesiologist committed to and skilled in the technique, block success is excellent (97% in this series) and complications are rare.

POSTER NO. P274

Open Rotator Cuff Repair without Acromioplasty: A Two to Ten Year Follow-up

Wren V McCallister, MD, *Seattle, WA (n)*
Ira M Parsons IV, MD, Seattle, WA (*)
Robert M Titelman, MD, Seattle, WA (*)
Frederick A Matsen III, MD, Seattle, WA (n)

Introduction: In his 1934 Book, The Shoulder, Codman described rotator cuff repair without acromioplasty. Over the last 30 years, most series of cuff repairs include acromioplasty as a part of the technique. This prospective study tests the hypothesis that substantial improvement in shoulder comfort and function can be realized from cuff repair without acromioplasty. Methods: We performed 96 consecutive primary repairs of full thickness cuff tears through a deltoid splitting incision preserving the integrity of the coracoacromial arch. All patients were invited to participate in a prospective end result study using periodic self-assessment. Sixty-one patients provided at least 2 years of follow-up. Fifty-six percent of these tears involved the supraspinatus alone, 26 percent involved the supra and infraspinatus, and 18 percent involved the supra, infra, and subscapularis. Results: The percentage of shoulders able to perform each of the 12 shoulder functions was significantly improved (p values from 0.0002 to 0.0000000000001). Men and women had different function preoperatively (p .00000001) and postoperatively (p .001), however the improvement in function was essentially identical. Improvement in shoulder function was best for one tendon tears (4.9), next best for two tendon tears (3.7) and worst for three tendon tears (3.3). Discussion and Conclusion: Significant improvement in self-assessed shoulder comfort and in each of 12 shoulder functions was observed after rotator cuff repair using a technique very similar to that described by Codman almost seventy years ago. These results suggest that acromioplasty may not be a necessary component of rotator cuff repair.

POSTER NO. P275

Use of Extracorporeal Shockwave Therapy for Lateral Epicondylitis

Brian Richard McCall, MD, *Bethesda, MD (n)*
Frank A Pettrone, MD, Arlington, VA (a – Siemen's Corp.)

Introduction: The purpose of this study is to evaluate the efficacy and safety of extracorporeal shockwave therapy for chronic lateral epicondylitis with one year follow-up. Methods: One hundred and fourteen patients with at least a 6-month history of chronic, resistant lateral epicondylitis were randomized into double-blinded active treatment and placebo groups. Treatment consisted of 3 weekly treatments of shockwave therapy, or a sham treatment. A visual analog scale was used to evaluate pain and the upper extremity function scale was used to assess function. Crossover to active treatment was initiated for non-responsive placebo patients after 12 weeks. Evaluations of patients were performed at 1, 4, 8 and 12 weeks, 6 months, and 1 year. Results: 108 of 114 randomized patients completed all treatments and follow-up to 12 weeks. Sixty-one patients completed the one year follow-up from the original cohort, while 34 placebo patients were crossed over to receive active treatment and were then followed for twelve weeks. A statistically significant difference (p=0.001) in pain reduction was observed at 12 weeks with 60.7% (34/56) of active treatment patients showing at least 50% improvement in pain, compared to 29.3% (17/58) in the placebo group. This improvement is found to persist in those followed to one year. Functional activity scores, activity specific evaluation, and overall impression of disease state all showed statistically significant improvement as well. Crossover patients also showed statistically significant improvement with 55.9% (19/34) reaching at least 50% improvement in pain. Conclusions: These results demonstrate shock wave therapy to be a safe and effective treatment for chronic lateral epicondylitis that persists at one year follow-up. Shockwave therapy may be a viable non-invasive, non-operative treatment for lateral epicondylitis.

POSTER NO. P276

Treatment of Acute Traumatic Elbow Instability Without Medial Collateral Ligament Repair

David Ring, MD, *Boston, MA (a – AO Foundation)*
Christopher L Forthman, MD, Brookline, MA (*)

Background: Surgeons treating acute traumatic elbow instability have been slow to adjust from the traditional focus on the medial collateral ligament (MCL) to the increasing importance placed on the lateral collateral ligament (LCL). Methods: Thirty-four patients with acute elbow trauma requiring operative treatment to restore stability were treated by a single surgeon according to a standard protocol and evaluated an average of 21 months after injury. The protocol consists of repair of the ulna and coronoid, repair or replacement of the radial head, and repair of the LCL. Repair of the MCL and external fixation are reserved for elbows that remain unstable after these initial measures. Results: The LCL origin was avulsed from the lateral epicondyle in all 34 patients. One patient had MCL repair due to persistent intraoperative instability and another had a second procedure for instability related to a malpositioned radial head prosthesis. A stable, mobile (average 101 degree arc) articulation was restored in all patients, five of whom required additional procedures for capsular contracture or heterotopic bone. Conclusions: In acute traumatic elbow instability, the lateral soft tissue failure occurs consistently as an avulsion of the LCL origin and (variably) the common extensor musculature from the lateral epicondyle. Using this damage to access and repair the articular fractures and

then repairing the lateral soft tissues back to the lateral epicondyle restored stability in nearly all of the patients. MCL repair is rarely necessary in the treatment of complex acute traumatic elbow instability.

POSTER NO. P277

Fracture-Dislocations of the Elbow: Can Injury Components be Predicted Based Upon Injury Patterns?

David Ring, MD, *Boston, MA (a – AO Foundation)*
Christopher L Forthman, MD, Brookline, MA (n)

Hypothesis: Elbow fracture-dislocations occur in recognizable patterns that are associated with predictable injury components. Methods: A single surgeon treated 58 consecutive fracture-dislocations of the elbow and characterized the injury pattern and injury characteristics based upon radiographs and operative exposure. Four patients had posteromedial varus rotational instability (PMVRI), 19 had fracture-dislocations of the olecranon (5 anterior [AOFD], 13 posterior [POFD], and one unique pattern) and 35 had posterior dislocation of the elbow with either fracture of the radial head alone (11 patients) or fractures of the radial head and coronoid process (24 patients). Results: The lateral collateral ligament (LCL) was ruptured in one of five AOFD's, 11 of 13 (84%) POFD's, 2 of 4 PMVRI's, and all of the posterior dislocations. The radial head was fractured in none of the AOFD's or PMVRI's and all of the POFD's and posterior dislocations. The coronoid was fractured in all AOFD, POFD, and PMVRI injuries. Conclusions: Our data suggest that bone and ligament injuries in the elbow occur in fairly predictable patterns. The following summations may help guide effective treatment: 1) anterior fracture-dislocations rarely have fracture of the radial head and only the most high-energy injuries have associated ligament injury; 2) posterior olecranon fracture-dislocations are usually associated with fracture of the radial head and coronoid and injury to the LCL; 3) LCL injury nearly always occurs at its origin from the lateral epicondyle; and 4) anteromedial facet coronoid fractures are associated with LCL injury only when the olecranon is not also fractured

POSTER NO. P278

Are Various Brands and Manufacturers of USP Number 2 Suture Equivalent?

Benjamin Goldberg, MD, *Chicago, IL (n)*
Zafar S Khan, MD, Louisville, KY (n)
George Branovacki, MD, Chicago, IL (*)

Purchase decisions of suture material are often made by assuming equivalency of sutures and choosing the lowest unit cost. Sutures are classified by the United States Pharmacopaeia (USP) based on suture diameter and minimum strength requirements. Suture failure can lead to failure of a surgical repair. The purpose of this study was to determine if USP No. 2 suture, which is commonly used in rotator cuff repairs and Achilles repairs, has significant variability in strength between brands and manufacturers. Six brands (20 sutures each) of No. 2 polyester (or polyblend of polyester/polyethylene) were tied by the same surgeon with a surgeon's knot and five alternating post half-hitches over flexible rubber tubing of the size specified by the USP. 20 comparison loops were also made for ultrasonically welded polypropylene. The loops were loaded in a blinded fashion on a mechanical testing apparatus. Biological failure (loop elongation greater than 3 mm) and ultimate failure (suture breakage) were recorded. All sutures met the criteria of the USP. Ethibond and Mersilene were significantly weaker ($p<0.05$) than Ticron, Surgidac, and Tevdek. Fiberwire had a significantly lower biological failure but higher ultimate failure. The USP minimum tensile strength for No. 2 suture is 34.5 Newtons. While all sutures exceeded this minimum, there were significant variations between brands and manufacturers. Higher ultimate failure loads do not always correlate to biological failure loads. Sutures of similar size and materials are not equivalent. This needs to be considered when choosing suture for tendon repair.

POSTER NO. P279

◆Hemiarthroplasty (HA) vs Reverse Shoulder Prosthesis (RSP) for Rotator Cuff Arthropathy (RCA)

Mark A Frankle, MD, *Tampa, FL*
(a,b,c,d,e – Encore Medical Corp)
Mark A Mighell, MD, Tampa, FL (*)
Scott Devinney, DO, Tampa, FL (*)
Matthew Vasey, BS, Tampa, FL (*)
Derek Pupello, BS, Tampa, FL (*)

INTRODUCTION We report results of 51 shoulders with RCA treated either with HA (21 shoulders) followed for 73 months (43-111 months) or a RSP (30 shoulders) (Encore) followed for an average of 31 months (24-73 months). METHODS Patients who underwent HA included 11 females (13 shoulders), and 6 males (8 shoulders) at an average age of 78 (63-84). Patients in the RSP group included 22 females (24 shoulders), and 4 males (6 shoulders) at an average age of 74 (62-89). All patients were assessed pre- and post-operatively with ASES scores, SST, VAS pain and function, SF-36, patient satisfaction, physical exam and radiographs. Analysis of outcomes included patients with the original prosthesis in place at most recent follow up. Six HA patients required revision to RSP (mean = 40 months postop, range 12-68); one patient required conversion from a RSP to HA (8 months postop). The outcomes of these seven patients were not included. RESULTS In the HA group, improvement in ASES pain was from 11.3 to 26.3 ($p<0.05$) and VAS pain from 7.6 to 4.8 ($p<0.05$). There was no evidence of radiolucent lines although 4/15 patients developed progressive glenoid erosion. Four of fifteen patients rated their outcome as either good or excellent, 5/15 as satisfied, and 6/15 as dissatisfied. In the RSP group, improvement in total ASES scores was from 34 to 70 ($p<0.05$), VAS pain from 6.7-2.3 ($p<0.05$), VAS function from 5.8-2.6 ($p<0.05$) and SST from 1.9-6.1 ($p<0.05$). Forward flexion improved from 71-121deg ($p<0.05$), abduction improved from 51 to 113deg ($p<0.05$) and external rotation improved from 10 to 45deg ($p<0.05$). Evidence of radiolucent lines or a shift in prosthetic position was not observed at most recent follow up (mean=31 months postop, range 24-73 months). Twenty-two of thirty shoulders were rated as good or excellent, 8 satisfactory and no dissatisfied patients. Complications included two acromion fractures. DISCUSSION Comparison of HA vs. RSP for RCA demonstrates comparable improvement in pain relief, whereas reliable improvement in function was only observed in patients receiving treatment with the RSP.

PAPERS, POSTERS & SCIENTIFIC EXHIBITS SHOULDER/ELBOW

POSTER NO. P280

SLAP Lesions are Associated with Shoulder Laxity in Throwing Athletes

Teruhisa Mihata, MD, *Takatsuki Osaka, Japan (n)*
Michelle H McGarry, MD, Long Beach, CA (n)
James E Tibone, MD, Los Angeles, CA (n)
Frank Alberta, Los Angeles, CA (n)
Muneaki Abe, Long Beach, CA (*)
Thay Q Lee, PhD, Long Beach, CA (n)

Introduction SLAP lesions are often associated with shoulder laxity in throwing athletes. The objective was to investigate the effects of pathologically created SLAP lesion and anterior capsular laxity and subsequent repair. MethodsSix cadaveric shoulders were nondestructively stretched to 20 percent beyond the maximum humeral external rotation (ER) at 60 degrees of glenohumeral abduction (A) to yield a superior labrum detachment. The pathologically created SLAP lesions were then repaired arthroscopically using two suture anchors placed anterior and posterior to the biceps tendon. Rotational range of motion was measured at 60 degrees of glenohumeral abduction. Glenohumeral translations were measured at 0, 30 and 60 degrees abduction and neutral rotation (NR) and 90 degrees external rotation. ResultsER was significantly increased after stretching by 20.8 (2.1) (mean (SEM) degrees. Following SLAP repair ER decreased by only 4.0 (0.73) degrees. Anterior translation was significantly increased after stretching at 60A/90ER and 30A/NR (2.4 (0.7) and 1.2 (0.4) mm) and decreased after repair only at 30A/NR (1.0 (0.2) mm). Inferior translation was significantly increased after stretching at 60A/90ER, 60A/NR, and 0A/NR (1.5 (0.4), 0.7 (0.2), and 1.1 (0.3) mm, respectively) and decreased after repair only at 60A/NR and 0A/NR (0.8 (0.1) and 1.3 (0.3) mm). ConclusionSLAP lesions associated with anterior capsular laxity result in an increased ER and subtle increase in glenohumeral translation. SLAP repair does not restore ER and only partially restores glenohumeral translation. Other procedures to reduce anterior capsular laxity may be needed in addition to SLAP repair in a throwing athlete.

POSTER NO. P281

Effects of Olecranon Resection on Elbow Laxity and Medial Ulnar Collateral Ligament Strain

Jess Alcid, MD, *Brick, NJ (n)*
YeonSoo Lee, PhD, Long Beach, CA (*)
Michelle H McGarry, MD, Long Beach, CA (*)
Christopher Ahmad, MD, New York, NY (*)
Thay Q Lee, PhD, Long Beach, CA (*)
Neal S ElAttrache, MD, Los Angeles, CA (*)

Introduction Treatment of posterior elbow impingement in the overhead athlete may include arthroscopic resection of posteromedial osteophytes. Excessive resection of the olecranon may have deleterious effects on the anterior band of the medial ulnar collateral ligament (AMUCL). The objective of this study was to quantify the strain field of the bone-AMUCL-bone complex and varus-valgus laxity with increasing amounts of posteromedial olecranon resection. MethodsSix cadaveric elbows were dissected and tested using varying amounts of elbow flexion (30, 60, 90 degrees), varus-valgus torque (1, 2, 3 Nm) and resection of the posteromedial olecranon (0, 4 and 8mm). A 3D digitizing system was used to measure elbow laxity and bone-AMUCL-bone strain. A video digitizing system was also used to quantify mid-substance strain. ResultsThere was no significant effect on AMUCL strain with respect to olecranon resection. The valgus angulation and varus-valgus laxity proportionally increased with olecranon resection. Specifically, at 90 degrees elbow flexion, varus-valgus laxity at 3 Nm of torque was (mean (SEM)) 14.1 (2.7) degrees, 15.4 (3.3) degrees and 17.9 (3.5) degrees for 0, 4 and 8mm of olecranon resection. Conclusion Posteromedial olecranon resection does not directly affect the strain in the AMUCL under valgus loading. However, throwers may be susceptible to AMUCL injury following posteromedial olecranon resection due to increased elbow laxity and altered biomechanics. When treating an overhead athlete with posteromedial olecranon impingement, the resection should be limited to osteophytic overgrowth.

POSTER NO. P282

Predictors of Satisfaction with Outcome after Anterior Shoulder Surgery

James O'Holleran, MD, *Jamaica Plain, MA (*)*
Mininder S Kocher, MD, Boston, MA
(e – Steadman Hawkins Sports Medicine Foundation)
Marilee P Horan, BS, Vail, CO (n)
David Zurakowski PhD, Boston, MA (*)
Karen K Briggs, Vail, CO (n)
Richard J Hawkins, MD, Vail, CO
(a - Steadman Hawkins Sports Medicine Foundation, c,e – DePuy, c, Hardcor Books, d – Opus Medical, e – US Surgical Sports Medicine)

The purpose of this study was to determine predictors of patients satisfaction(PS) with outcome after anterior shoulder stabilization.A cohort of 199 patients (56 women, 143 men) with mean age 30.4 +/- 11.3 years (range 15-73) undergoing anterior instability surgery was studied prospectively, with minimum 2-year subjective follow-up (n=199) and 1-year objective follow-up (n=45). PS with outcome was measured on a 1-10 point ordinal scale. Independent variables included various demographic, surgical, follow-up objective and subjective parameters. Stepwise linear regression was utilized to determine multivariate predictors of satisfaction with outcome.For all patients, median satisfaction was 9 points (interquartile range, 7-10). Prior surgery and type of surgical procedure were not multivariate predictors of satisfaction. Regarding objective variables, overall motion and apprehension were not predictive of satisfaction. For subjective variables, there was significantly decreased satisfaction for patients with pain, instability, and work disability. Reinjury after surgery ($p<0.001$) and pain at work ($p=0.02$) and during recreation ($p<0.001$) were multivariate predictors of satisfaction. Most patients indicated they would have surgery again ($p<0.001$) and would recommend surgery to another ($p<0.001$). Median ASES score was 97 (87-100). There was a positive correlation between PS and ASES score (Spearman rho = 0.72, $p<0.001$). While specific surgical and objective variables were associated with satisfaction, subjective variables of symptoms and function had the strongest associations with PS. Thus, in assessing the outcome of anterior instability surgery from the perspective of the patient's satisfaction with outcome, we would emphasize the importance of patient-derived subjective assessment of symptoms and function.

POSTER NO. P283

Effects of Glenoid Retroversion in Total Shoulder Arthroplasty

Todd Shapiro, MD, *Santa Ana, CA (n)*
Michelle H McGarry, MD, Long Beach, CA (*)
Ranjan Gupta, MD, Orange, CA (*)
YeonSoo Lee, PhD, Long Beach, CA (*)
Thay Q Lee, PhD, Long Beach, CA (*)

INTRODUCTION: Glenoid component failure is one of the main problems in total shoulder arthroplasty (TSA). The objective was to evaluate the effects of glenoid retroversion on glenohumeral joint (GHJ) forces, contact pressures and areas following TSA. MATERIALS & METHODS: Eight cadaveric shoulders and a custom shoulder testing system that permits anatomic loading of the muscles was used. Each shoulder was tested intact and after TSA with the components in neutral and with the glenoid component retroverted 15 degrees. GHJ forces were measured with a six degree-of-freedom load cell. GHJ contact pressures and areas were measured with Fuji pressure sensitive film. RESULTS: Significant increases in contact pressure and decreases in contact area were observed between the intact and arthroplasty groups in all positions (p less than 0.05). At 60 degrees of horizontal adduction, contact pressures significantly increased between the neutral (4.7 (1.1) MPa) (mean (SEM)) and retroverted groups (14.0 (0.9) MPa) (p-value 0.001). Contact area decreased between the neutral and retroverted groups at 0 and 60 degrees of horizontal adduction (p less than 0.05). TSA reproduced the GHJ compressive and posteriorly directed forces but not inferiorly directed forces. With the glenoid in the retroverted position, all three components of the glenohumeral joint force decreased with respect to the intact condition. (p less than 0.05) CONCLUSION: Glenoid component placement in fifteen degrees of retroversion significantly deviates GHJ forces to the inferior direction and increases the contact pressure, and decreases the contact area which results in eccentric loading of the glenoid component.

POSTER NO. P284

Patient-Oriented Outcome Following ORIF of Clavicular Shaft Nonunion: The Effect of Time to Repair

Michael D McKee, MD, *Toronto, ON Canada*
(a – Stryker Biotech, e – Zimmer)
Navpreet Singh, BSc, Toronto, ON Canada (n)
Emil H Schemitsch, MD, Toronto, ON Canada (n)
Alison McConnell, MSc Leng, Toronto, ON Canada (n)

PURPOSE: Using patient-oriented limb-specific outcome measures, we sought to determine the effect of time to repair on patient satisfaction following surgical fixation of nonunion of the clavicular shaft. METHOD, RESULTS and DISCUSSION: We identified 38 patients who had undergone open reduction, internal fixation of a nonunion of the clavicular shaft. There were 23 men and 15 women, with a mean age of 43 years. The mean duration of nonunion was 1.8 years. All patients underwent plate fixation, and 64% of patients also underwent iliac crest bone grafting. 36/38 (95%) healed after the index procedure. We assessed patient outcome using standard history and physical, radiographs, and the DASH and SF-36 outcome instruments. The mean DASH score (0 = perfect, 100 = complete disability, "normal" = 10) was 12.5 (range 0 to 58). SF-36 scores were within the normal control range. There was no significant difference in DASH or SF-36 scores between those fixed "early" (<6 months) and those repaired "late" (>6 months), p=0.30, p=0.78, respectively. Previous reports of clavicular nonunion repair have concentrated on radiographic or surgeon-based criteria. Our study shows that successful clavicular nonunion repair effectively restores upper extremity function and general health status to near-normal levels. CONCLUSION: As measured by the DASH and SF-36, patient satisfaction was high following clavicular nonunion repair with only minor degrees of residual disability. Time to repair did not have a significant effect on outcome.

POSTER NO. P285

Objectively Measured Strength Deficits Following Conservative Treatment of Clavicle Fractures

Michael D McKee, MD, *Toronto, ON Canada*
(a – Stryker Biotech Inc.)
Elizabeth Pedersen, BSc, Toronto, ON Canada (n)
Lisa Wild, RN, Toronto, ON Canada (n)
Emil H Schemitsch, MD, Toronto, ON Canada (n)

OBJECTIVELY MEASURED STRENGTH DEFICITS FOLLOWING CONSERVATIVE TREATMENT OF CLAVICLE FRACTURES PURPOSE: We used a patient based outcome questionnaire and objective muscle strength testing to evaluate a series of patients following conservative care of a displaced, midshaft fracture of the clavicle. METHODS, RESULTS and DISCUSSION: Using emergency department and trauma database records, we identified twenty-five patients (17 males, 8 females, mean age 39 years) who had sustained a displaced midshaft fracture of the clavicle. All patients were treated conservatively. Mean follow-up was 54 months, with a minimum of 10 months. Outcome measures included the Constant shoulder score and the DASH questionnaire. Patients also had objective shoulder muscle strength testing performed on the Baltimore Therapeutic Equipment (BTE) Work Stimulator. Range of motion was well maintained, with flexion of 170¢ª +/- 20¢ª, and abduction of 165¢ª +/- 25¢ª. Strength of the injured compared to the uninjured side was: flexion (maximal) 81%, flexion (endurance) 74%, abduction (maximal) 81%, abduction (endurance) 66%, external rotation 80%, external rotation (endurance) 84%, and internal rotation (maximal) 86%. The mean Constant score was 69, and the mean DASH score was 25.1, indicating significant residual disability. Patients with clavicular shortening of greater than 2 centimeters had significantly worse DASH scores than those with 2 centimeters or less of shortening (p=0.04). CONCLUSION: Using objective testing, we detected residual deficits in shoulder strength, especially endurance strength, in this patient population. Clavicular shortening of greater than 2 centimeters was associated with a worse outcome.

POSTER NO. P286

Anchor Design and Bone Density Affect the Pullout Strength of Suture Anchors in Rotator Cuff Repair

Markus Tingart, MD, *Regensburg, Germany (n)*
Maria Apreleva, PhD, Beverly, MA (n)
Janne Tapani Lehtinen, MD, Boston, MA (n)
David Zurakowski PhD, Boston, MA (*)
Jon J P Warner, MD, Boston, MA (n)

Introduction: Different metal and biodegradable suture anchors are available for rotator cuff (RC) repair. The aim of this study was to investigate the effect of bone mineral density (BMD) on the pullout strength of two types of suture anchors.Hypothesis: Higher BMD is associated with higher pullout strength. Pullout strength of biodegradable anchors is too low in some regions of the greater tuberosity. Methods: Trabecular and cortical BMD of

6 different regions of interest (ROI) within the greater tuberosity was determined. Metal screw-like and biodegradable hook-like anchors were inserted into each ROI and cyclically loaded until failure. ANOVA was used to determine differences in failure load of anchors depending on BMD, anchor-design and -placement (p 0.01). Results: Average failure loads of metal anchors (228N) were 66 percent higher than those of biodegradable anchors (137N) (p 0.01). For both types of anchors, failure loads were significantly higher in the proximal-anterior and proximal-middle part of the greater tuberosity than in all other ROIs of the greater tuberosity (p 0.01). A significant correlation was found between BMD and failure load for both types of anchors (p 0.01). Conclusion: Bone quality, anchor design and placement have a significant impact on anchor failure loads. Whenever possible, anchors should be placed in the proximal-anterior and -middle part of the greater tuberosity. Particularly, in the distal parts of the greater tuberosity no biodegradable hook-like anchors should be used to reduce the risk of anchor loosening and re-rupture of the repair.

POSTER NO. P287

Restoring Pronation/Supination Using Principles of Static Progressive Stretch/Stress Relaxation

Peter M Bonutti, MD, *Effingham, IL*
(e – Joint Active Systems)
Colleen M Kazmareck, BA, Baltimore, MD (n)
Margot McMahon, RN, Effingham, IL (n)

Introduction: Forearm pronation/supination can be a difficult motion to restore following elbow or wrist trauma or surgery. First line treatment has been physical therapy or custom orthotics based on the principles of Creep – stretching over 8-12 hours a day for up to 6 months. An innovative treatment utilizing the principles of stress relaxation (SR) and static progressive stretch (SPS) with a short 30-minute treatment session has been developed. The goal of the study was to evaluate this treatment protocol and to see if it can restore forearm P/S range-of-motion. Methods: Thirty consecutive patients were evaluated with a history of elbow trauma or surgery. All patients previously underwent physical therapy and either had no progress or reached a plateau with regards to this motion. The SPS/SR treatment protocol consisted of two 30-minute sessions per day with an average utilization of 1.8 months (4-8 weeks). All patients' motion was measured by an independent physical therapist and weekly results were recorded. Results: The total mean arc of motion increased 31 degrees (range 5-80 degrees). The mean increase in pronation was 16 degrees (range 5-55 degrees), increase in supination was 15 degrees (range 10-65 degrees). There was 100% compliance and no complications. All patients gained motion and no patient withdrew from the study. Discussion: Restoring range-of-motion utilizing principles of stress relaxation/static progressive stretch can be effective in restoring forearm rotation. Significant gains in motion can be obtained with a short 30-minute treatment protocol. This short protocol promotes a high degree of patient compliance.

POSTER NO. P288

Effects of Autotenodesisv of Long Head of Biceps Brachii on Passive Glenohumeral Range of Motion

William Michael Mihalko, MD, *Clarence Center, NY (n)*
Jennifer Gurske, MS, Buffalo, NY (n)
Robert S Nolan, MD, Snyder, NY (n)
William Wind, MD, East Amherst, NY (n)
Marc S Fineberg, MD, Buffalo, NY (*)
Philip M Stegemann, MD, Buffalo, NY (n)

Introduction: The tendon of the long head of the biceps brachii may become scarred within the bicipital groove secondary to local trauma or surgery. This "autotenodesis" in conjunction with an intact proximal segment may serve as a tether and significantly limit shoulder motion. This study investigates the effects of proximal biceps "autotenodesis" on passive range of motion of the shoulder. Methods: Passive range of motion was evaluated in eight thawed fresh frozen cadaveric shoulders both before and after surgical tenodesis within the bicipital groove. The intra-articular portion of the tendon was not released. The tenodeses were performed with shoulders in neutral, maximal internal, and maximal external rotation. Motions evaluated include flexion, extension, abduction, internal and external rotation. Range of motion was measured using a computer assisted electromagnetic system (Polhemus Isotrak II) that was designed to measure joint motion in the x, y and z axes. Results: An ANOVA revealed a significant decrease in passive flexion (p equal to 0.004) in all three positions of tenodesis. Extension (p equal to 0.04) and external rotation (p equal to 0.01) were also found to be limited in some trials. A Tukey's Post-Hoc Test (significance level 0.05) revealed no difference in passive range of motion between the three different positions of tenodesis. Discussion and Conclusion: Post-traumatic or iatrogenic autotenodesis of the long head of the biceps in conjunction with an intact proximal segment may cause significant loss of shoulder motion. A tethered long head of biceps should be considered a source of limited shoulder motion and may warrant exploration in the stiff shoulder.

POSTER NO. P289

Rotator Cuff Repair: The Effect of Double Row Versus Single Row Fixation on the Three-Dimensional Area of Repair Site

Steven W Meier, MD, *Hoboken, NJ (a,b – Mitek Worldwide)*
Jeffrey D Meier, DO, Tinley Park, IL (a,b – Mitek Worldwide)
Andrew Stuart Levy, MD, Summit, NJ (a,b – Mitek Worldwide)

Introduction: In rotator cuff repair surgery, increasing emphasis is being placed on maximizing the repair site contact area. Single row fixation repairs have been shown to fail in reproducing the area of the supraspinatus insertion or "footprint" on the greater tuberosity. The purpose of this study was to demonstrate that double row fixation provides a superior repair site contact area to single row techniques. Materials and Methods: A cadaveric study was performed using 7 fresh frozen human shoulders. Rotator cuff tears were created and repaired using 3 techniques: single row suture anchor fixation (SRSA), double row suture anchor fixation (DRSA), and transosseous suture technique (TOS). The repair footprint for each technique as well as the original tendon insertion site was compared after determination by 3 dimensional digitation using the MicroscribeG2X digitizer. Statistical analysis was performed to insure adequate sample size and statistical significance of detected differences. Results: The supraspinatus footprint area of DRSA was larger than that of the

other two techniques. These findings were statistically significant. Furthermore, DRSA consistently reproduced 100 percent of the original supraspinatus footprint area while SRSA and TOS reproduced only 46 and 71 percent of the insertion site, respectively. Conclusion and Discussion: Double row fixation in rotator cuff repair fully restores the native supraspinatus footprint while traditional single row techniques do not. Double row fixation may provide a tendon bone interface better suited for biologic healing and recreating normal anatomy.

POSTER NO. P290

Force Across Coracoclavicular Ligament With Glenohumeral Range of Motion: A Biomechanical Study

Steven Lee, MD, *New York, NY (n)*
David P Rudman, MD, Englewood, CO (*)
Malachy P McHugh, PhD, New York, NY (*)
Tim Tyler, MD, Poughkeepsie, NY (*)
Stephen J. Nicholas, MD, New York, NY (*)

Purpose: To determine forces across coracoclavicular ligaments with glenohumeral joint motion and to relate those forces to failure strengths of reconstructive procedures. Material and Methods: 8 fresh frozen upper extremities were thawed, the AC and CC ligaments were sectioned, and suspended from the clavicle. A #5 Ethibond suture was placed around the coracoid, through a 6 mm drill hole in the clavicle and attached to a force transducer. The glenohumeral joint was placed into 6 positions: gravity (GR), arm in sling (SLG), extension (EXT), scapular elevation (SE), external rotation (ER) and internal rotation (IR). Force measurements were continuously recorded. Results: Forces in EXT (70 N) were higher than all other positions. Forces with GR (28 N) were reduced with the SLG(14 N). The SLG had the lowest forces (14 N), but was not different from ER (26 N), IR (26 N) and SE (22). Forces with SLG were 20% of documented Weaver Dunn failure force but were less than 3% of tendon graft failure force. Forces in EXT were 100% of Weaver Dunn failure force and 11% tendon graft failure forceConclusion: This study implies that scapular elevation, glenohumeral internal and external rotation is safe following CC ligaments injury or reconstruction as forces did not differ significantly from a sling while extension should be restricted until sufficient ligament healing. Extension produced forces equal to initial Weaver Dunn failure force and would be sufficient to disrupt this repair.

POSTER NO. P291

Endoscopic Treatment of Suprascapular Nerve Entrapment

Laurent Lafosse, MD, *Annecy, France (n)*
Andrea Tomasi, MD, Annecy, France (*)
Youri Reiland, Munich, Germany (*)
Bruno Toussaint, MD, Annecy, France (*)

Suprascapular nerve entrapment will most probably occur in the Suprascapular notch area. Often the athletic patient practising overhead sports will be affected. The extent of the resulting supra- and/or infraspinatus muscle atrophy is variable. If conservative treatment is refractory or if the consequences are severe, a surgical neurolysis is indicated. The current techniques to release the Suprascapular nerve are done by open surgery and the results are often dismal. The purpose of this poster is to demonstrate an completely endoscopic performed neurolysis of the Suprascapular nerve. 5 cases of endoscopic suprascapular nerve releases at the suprascapular notch have been performed on patients with refractory entrapment syndromes. The technique allows a total endoscopic operation with release of the ligamentum transversum scapulae superius. This poster proposes a different technique to treat suprascapular nerve entrapment with endoscopy.

POSTER NO. P292

Minimally Invasive Reconstruction of the 4-part tValgus Impactedv Fractures of the Humeral Head

Panayotis Dimakopoulos, MD, *Patras, Greece (n)*
Andreas Panagopoulos, MD, Rio Patras, Greece (*)
Georgios Diamantakis, Rio-Patras, Greece (*)
Michalis Chanos, Rio-Patras, Greece (*)
Elias Lambiris, MD, Rio, Greece (n)

Introduction: The evaluation of outcome of 4-part valgus impacted fractures of the proximal humerus after reconstruction with stable transosseous suturing fixation. Methods: 52 patients (34 male, 18 female, mean age 49,5y) with displaced 4-part "valgus impacted" fractures of the proximal humerus, were operatively treated between 1993-2002. The average impaction angle was 42.4o and the lateral displacement of the humeral head between 1-7 mm. In situ, stable fixation of the tuberosities to each other, to the articular part of the humeral head and to the metaphysis at a level below the top of the head, was achieved with heavy non-absorbable sutures, avoiding reduction maneuvers and any use of hard material. Early passive motion with pendulum exercises was applied at the 2nd postoperative day, followed by active assisted exercises after the 6th postoperative week and final strengthening exercises after the 3rd postoperative monthResults: Long term results (mean follow up 5.6 years), were evaluated according to Constant-Murley Scoring System. 45 patients (86.5%) had very good result (Constant score > 80) without pain and satisfactory motion (up to 160o forward elevation, 60o to 80o external rotation and internal rotation up to T12). The incidence of avascular necrosis was 5.7 %. Complications developed in 6 patients: 1 malunion of the great tuberosity, 3 heterotopic ossifications and 2 nonunions revised to hemi-arthroplasty and plate osteosynthesis respectively. Conclusions: Advantages of this minimally invasive technique are shorter operative time, no use of hardware, less soft tissue damage, low incidence of avascular necrosis, stable fixation with tension band effect and adequate rotator cuff repair, allowing for early joint motion

POSTER NO. P293

Comparison of the Subjective Shoulder Value and the Constant Score

Michael Gilbart, MD, *Pittsburgh, PA (n)*
Christian Gerber, MD, Zurich, Switzerland (n)

Introduction:The purpose of this study was to determine the correlation between the Subjective Shoulder Value (SSV) and the Constant score (CS). Methods: Patients who underwent surgical treatment for rotator cuff repair (RTC, n=247), arthroplasty for osteoarthritis (OA, n=83), and Bankart repair for anterior instability (n=111) were included in the study. The SSV was determined by asking patients to give an "overall impression of their affected shoulder by assigning it a percentage in comparison to a normal shoulder". Paired t-tests, correlation coefficients, ANOVA and linear regression analyses were performed on preoperative and postoperative values. Results: The average patient ages were 56 in the rotator cuff group, 60 in the arthroplasty group, and 27 in the instability group. Postoperative values of CS and SSV were statistically higher than preop for all patients ($p<0.05$).

PAPERS, POSTERS & SCIENTIFIC EXHIBITS SHOULDER/ELBOW

Postoperative correlations of SSV and CS(ab) were highest in the RTC group (0.78), and were moderate in the OA (0.66) and instability groups (0.59). The SSV can predict a moderately high percentage of the postoperative variance in CS(ab) for the RTC group (61 percent). Patients in the instability group had significantly higher CS(ab) values than SSV values, unlike the rotator cuff and arthroplasty groups (p less than 0.005). Discussion/Conclusions: The Subjective Shoulder Value is a simple assessment tool that may be quickly administered. It is a reliable measure of shoulder function, especially in rotator cuff tendon and arthroplasty patients. It may offer an improvement over the CS in instability patients, as the CS may overestimate postoperative patient results.

POSTER NO. P294

Arthrolysis of Post-Traumatic Elbow Contracture

Jin Soo Park, MD, *Kangwon-Do, Korea, Republic of (n)*
Moon Sang Chung, MD, Seoul, Korea, Republic of (n)
Goo Hyun Baek, MD, Seoul, Korea, Republic of (n)
Yung Khee Chung, MD, Seoul, Korea, Republic of (*)
Jung-Han Yoo, MD, Seoul, Korea, Republic of (*)
Yang-Bum Cho, Seoul, Korea, Republic of (*)

The purpose of this study was to evaluate the effectiveness of open debridement arthroplasty for the treatment of post-traumatic elbow contracture and the factors affecting final results. Forty seven patients who underwent open debridement arthroplasty of the elbow were reviewed retrospectively. There were 26 males and 21 female patients with an mean age of 34 (15-60) years. We performed open arthrolysis including olecranonplasty (partial excision of olecranon tip) and removal of scar tissue within the olecranon fossa in order to correct flexion contracture as well as the restriction of further flexion. Residual soft tissue contracture was released by gentle manipulation. When sufficient range of motion was not achieved by these procedures, anterior release - capsulotomy and/or resection of bony spurs around the coronoid process - was added. Tardy ulnar nerve palsy was combined in 23 patients of whom 22 received anterior transposition of the nerve. With a mean follow up of 49 (30-104) months, extension improved from a mean of 36 degrees to 12 degrees , and flexion improved from a mean of 101 degrees to 123 degrees. The mean arc of motion increased to 46 degrees. Three cases showed poor results because of wide spread myositis ossificans and pain. Open debridement arthroplasty and manipulation was considered still an effective method for the treatment of post-traumatic contracture of the elbow.

POSTER NO. P295

Supraspinatus Outlet Area in Acromioclavicular Joint Degeneration: MRI Study of Rotator Cuff Disease

Soheil Motamed, MD, *Foster City, CA (n)*
John Minoru Itamura, MD, Los Angeles, CA (*)
Suketu Vaishnav, BS, Los Angeles, CA (n)

Introduction: Ever since Neer introduced the concept of impingement, anatomic studies have contributed to our understanding of rotator cuff disease. As much attention focused on acromial morphology, few authors addressed the influence of acromioclavicular joint degeneration on rotator cuff tears. Methods: An MRI measurement model was used to define the anatomic relationship of acromioclavicular joint degeneration to supraspinatus outlet impingement. By measurement of supraspinatus outlet area and comparison to a younger control population, encroachment by acromioclavicular degeneration was quantified.Sagittal oblique MR images for 88 shoulders in 87 patients treated between 1997 and 2001 were evaluated. Group I consisted of consecutive 57 patients (age 35-85, mean 58) treated surgically for impingement with or without rotator cuff tears. Group II consisted of 30 younger control patients treated for shoulder instability (age 16-44, mean 27). Using anatomic reference points, supraspinatus outlet areas were measured. Results: The mean supraspinatus outlet area in patients treated for impingement was 505 mm2 with a subgroup treated for full thickness rotator cuff tears measuring 473 mm2. The mean supraspinatus outlet area for patients treated for instability was 580 mm2. Comparison of mean supraspinatus outlet areas for patients treated for impingement, Group I, to mean supraspinatus outlet areas for patients treated for instability, Group II, demonstrated a 13% reduction in area (p=0.031). Moreover, comparison of the Group I subgroup with full thickness rotator cuff tears to Group II controls demonstrated a 18% reduction in area (p=0.006). Conclusion: For appropriate treatment of the symptomatic rotator cuff, it is important to identify areas of impingement. Our MRI measurement study provides evidence that acromioclavicular degeneration contributes to the impingement seen in rotator cuff disease.

POSTER NO. P296

Relationship of Tear Size to Outcomes of All-Arthroscopic Rotator Cuff Repair: A Prospective Study

Jay Brad Butler, MD, *Lake Oswego, OR (n)*
C Ken House, Portland, OR (n)

Introduction: Each year in the United States, more than 100,000 surgeries are done to repair rotator cuffs. Studies of all-arthroscopic rotator cuff repair have been inconsistent regarding the relationship between tear size and outcome. This study's null hypothesis is that outcome of all-arthroscopic rotator cuff repair is independent of tear size. Methods: Comprehensive preoperative, intraoperative, and postoperative data are collected using validated outcomes assessment tools. Postoperative assessments at one, six, twelve, and twenty-four weeks are compared to preoperative scores to evaluate change in shoulder function, pain, stability, and general physical and mental health. This ongoing study contains fifty-two participants as of September, 2003. Expected enrollment by March, 2004 is approximately eighty patients from two surgeons. Results: Preliminary findings support the null hypothesis. Patients with small/medium tears (<3 cm) and patients with large (>3 cm) tears both have statistically significant (P<.05) improvements in pain levels and UCLA scores. Patients with large tears also have statistically significant improvements in their ASES index, SF-36 Mental Component Scale, shoulder stability, and functioning relative to normal. Discussion: Preliminary findings suggest all-arthroscopic repair is appropriate regardless of rotator cuff tear size. Patients with large tears may actually perceive more improvement following all-arthroscopic surgery than patients with smaller tears.

POSTER NO. P297

Shoulder Septic Arthritis - 13 Cases Treated with Delayed Exchange Arthroplasty

Gerhard E Maale, MD, *Dallas, TX (n)*
Brian K Vickaryous, MD, El Paso, TX (n)
Joseph P Vickaryous, MD, El Paso, TX (n)

Introduction: Delayed exchange arthroplasty for shoulder sepsis can bea successful alternative for fulminant septic shoulder arthritis. The purpose of this study is to outline a treatment

strategy and assess the outcomes of shoulder hemiarthroplasty in the setting of septic arthritis. Methods: 13 patients with septic arthritis of the shoulder treated from 1989 to 1998 were retrospectively reviewed. The average age was 66 years. 7 were postoperative complications, 2 were hematogenous, and 3 were from direct extension. 4 were acute, 9 were chronic. Follow-up averaged 6.4 years (4-8.7 years). All had positive intraoperative confirmation. All patients underwent an exchange hemiarthroplasty with antibiotic impregnated cement, debridement, and antibiotic therapy. 12 were treated as 2-stage and 1 as single-stage exchanges. 7 patients had deltoid, split thickness and/or latissimus, and pectoral grafts for soft tissue coverage. 2 patients received composite proximal humeral allografts. All patients underwent physical therapy and antibiotic therapy for 6 months. Results: There were 12 successful implantations and one failure 6.6 years postoperatively. All skin grafts and composite bone allografts healed. There were 13 complications. Abduction averaged 74.5 degrees and forward flexion 86 degrees. 7 patients were very satisfied and 2 satisfied. 2 patients admitted to residual pain. Discussion and Conclusion: Delayed exchange arthroplasty for septic arthritis involving a painful shoulder is a successful method of treatment. Local flaps are successful in managing soft tissue defects. Function and pain is better than in other treatment options.

POSTER NO. P298

Pressure Localization and Core Decompression of Humeral Head Avascular Necrosis

Carl J Basamania, MD, *Durham, NC (n)*
Allston Julius Stubbs, IV, MD, Durham, NC (n)
Hardayal Singh, MD, Durham, NC (n)
Joseph Guettler, MD, Bingham Farms, MI (n)

INTRODUCTION: Core decompression has been advocated as a treatment option for patients with Stage I – III AVN of the humeral head. Several methods have been used to identify the areas of necrotic bone. This study hypothesized that areas of AVN could be accurately identified intra-operatively by use of intramedullary pressure monitoring to improve success of core decompression. METHODS: 12 shoulders in 10 patients with stage II or III AVN were examined. All patients had preoperative plain radiographs and MRI. After diagnostic arthroscopy, intramedullary pressure measurements were made using a Jamshidi biopsy needle connected to an arterial pressure transducer. The needle was advanced into the area of highest pressure under fluoroscopic guidance. A guide wire was then passed through the needle into the area of greatest pressure. The area was then decompressed using a cannulated reamer. RESULTS: Average introductory intramedullary pressures were 41 mmHg. Average peak pressure was 200mmHg (range 134-257mmHg) and absolute differences between peak and introductory pressures was 159mmHg. All but one patient reported significant decreases in pain postoperatively. Average VAS pain scores were 9.5 preoperatively and 1.5 postoperatively. Only one patient required hemiarthroplasty for progression of her disease but was pain free for 1 year after core decompression. CONCLUSION: Our data suggests a five-fold increase in intramedullary pressure between normal bone and that affected by AVN. This appears to be a simple, accurate localization method for improving the results of core decompression for AVN of the humeral head.

POSTER NO. P299

Hagie Pin Fixation of Acute Displaced Middle 1/3 Clavicle Fracturesy Early Experiences and Results

Edward D Arrington, MD, *University Place, WA (n)*
Karin A Johnson, MD, Harker Heights, TX (n)

Background: Middle one-third clavicle fractures account for 4% of all fractures. Historically, patients with displaced middle one-third clavicle fractures are treated with a sling or a figure of eight bandage for 8-12 weeks. With closed non-operative treatment of displaced middle one-third clavicle fractures, the incidence of symptomatic malunions approaches 30%, and the incidence of nonunion is 1.5-2%. The malunited middle one-third clavicle fracture is associated with shortening of the clavicle, a bony prominence, medial rotation of the gleno-humeral joint, and overall shoulder dysfunction. Correcting acute clavicular deformity with a minimally invasive surgical technique is extremely attractive, especially in occupations that require the wearing of a harness or a rucksack. Early results of Hagie pin fixation of acute, closed, displaced middle 1/3 clavicle fractures have been promising.Objective: We prospectively sought to evaluate our early experiences, results and complications with the use of the intramedullary Hagie pin fixation of displaced middle 1/3 clavicle fractures. Methods: Each patient sustaining a displaced middle 1/3 clavicle fracture and undergoing intramedullary Hagie pin fixation by a single surgeon were included. The mechanism of injury, patient demographics, fracture displacement and configuration, and intra-operative complications were documented from the surgical record. The post-operative course, fracture healing, hardware removal, and complications were recorded from the outpatient records. Results: Thirty-seven patients who sustained displaced middle 1/3 clavicle fractures and underwent Hagie pin fixation were included in this review. The mechanism of injury was military training, athletic training or a fall from a height in 35/37 patients. Intra-operative complications have included anterior clavicular cortex pin penetration (2), intramedullary drill bit breakage with reaming (1), Hagie pin breakage with insertion (1), no fracture site compression (1), and fracture propagation with intramedullary reaming (1). Post-operative complications have included locking nut skin irritation (16), loss of anatomic fracture site reduction > 5mms (8), and locking nut cellulitis requiring antibiotics (2). All fracture sites have healed at a mean of 12 weeks, and all pins have been removed without difficulty at a mean of 14 weeks. At a minimum of 12 month follow-up, all patients have returned to their pre-injury activity level without restrictions. CONCLUSION: Intramedullary fixation of displaced middle 1/3 clavicle fractures using Hagie pin fixation provides excellent fracture union results. Our early intra-operative and post-operative complications have been minimal. Intramedullary Hagie pin fixation should be considered in patients sustaining a displaced middle 1/3 clavicle fracture, especially in occupations that require the wearing of a harness or a rucksack.

POSTER NO. P300

Glenoid Stress Distribution Visualization in Anatomic, Labral-Deficient and Resurfaced Shoulders

Douglass Stull, MD, *Charlotte, NC (n)*
Richard Dennis Peindl, PhD, Charlotte, NC (n)
Edward Coley, MS, Charlotte, NC (n)
Patrick Michael Connor, MD, Charlotte, NC (a, e – Zimmer)
Donald F D'Alessandro, MD, Charlotte, NC (*)

Introduction: The current study involves a comparative visualization of glenoid surface stresses experienced with normal, posterior and superior loading conditions for anatomic, hemiarthroplasty, labral deficiency and total shoulder replacement conditions. It further compares internal cancellous bone stresses for the anatomic case versus glenoids resurfaced with keeled and in-line pegged components (Bigliani/Flatow System, Zimmer, Inc.). Methods: Two newly-developed types of cortico-cancellous photoelastic models for anatomically-correct glenoids were utilized in the study. Reflective photoelasticity, which visualizes glenoid surface stresses, was used for examination of the effects of progression from the anatomic case to labral deficiency to TSR, particularly with regard to posterior, superior and rim stresses. Stress-freezing techniques, which allow visualization of stresses on internal sections provided comparisons of stress distributions for the two component anchoring geometries versus physiologic stress distributions. Results: Hemiarthroplasty produced cortical stress distributions similar to the anatomic condition. Cortical posterior rim stresses increased to 3x anatomic levels with increasing labral insufficiency. With TSR, both components produced increased glenoid postero- and antero-superior cortical stresses with superior loading. Both components concentrated cortical stresses near the spino-glenoid notch with posterior loading. Cancellous stresses were generally shielded in the glenoid vault and increased in the glenoid neck under these same conditions. Conclusion: Biomechanically, keeled and in-line pegged components appear to produce similar internal and surface stress distributions. Increased postero-superior rim stress with superior loading would lend support to the previously-proposed "rocking-horse" theory of component loosening.

POSTER NO. P301

Cement Pressurization Decreases Glenoid Prosthetic Micromotion

Gregory Gramstad, MD, *Maywood, IL (n)*
Guido Marra, MD, Maywood, IL (*)
Mark Sartori, BS, Maywood, IL (*)
Gerard Carandang, BS, Hines, IL (*)
Jeremy J McCormick, MD, Rochester, MN (*)

INTRODUCTION-Glenoid component loosening is the most reported cause of failure in total shoulder arthroplasty. We hypothesized that cement pressurized implantation would increase the volume of cement in the glenoid cavity and would decrease the micromotion of pegged glenoid implants compared to thumb packing with axial and edge loading. METHODS-Five matched pairs of fresh frozen scapulae were implanted with a pegged glenoid prosthesis. One glenoid was cemented with thumb packing and the other with sponge pressurization. A 1000 Newton load was applied to the glenoid prosthesis centrally and then to the anterior, posterior and superior edges. Total prosthetic micromotion was recorded as a sum of the deflections of the prosthesis at each edge under each loading position. At the completion of testing, the volume of cement in each glenoid cavity was measured. RESULTS-Cement pressurization decreased the total prosthetic micromotion as compared to thumb packing by an average of thirty-one percent for all loading positions. The volume of cement was found to be significantly greater in the sponge pressurized glenoids (p less than 0.05). DISCUSSION AND CONCLUSION-Initial implant stability can be improved by sponge pressurization of cement prior to pegged glenoid prosthetic insertion. The volume of cement pressurized into the glenoid cavity appears to directly influence implant stability.

POSTER NO. P302 – WITHDRAWN?

POSTER NO. P303 – ORS

Detection Of Myofibroblasts In Adhesive Capsulitis Of The Shoulder Joint

Frank N Unterhauser, MD, Berlin, Germany (n)
Ariane Gerber, MD, Berlin, Germany (*)
Sven U Scheffler, MD, Berlin, Germany (*)
Norbert P Haas, MD, Berlin, Germany (*)
Andreas Weiler, MD, Berlin, Germany (*)

Introduction: We hypothesized that ASMA expressing fibroblasts are involved and responsible for the contraction of joint capsule and scar tissue formation in adhesive capsulitis of the shoulder joint. Methods: Samples were taken from the posterior capsule of the glenohumeral joint of 5 patients with idiopathic adhesive capsulitis. Control tissues were taken from the same region of 5 asymptomatic patients. Sections were immunostained with anti-a-smooth muscle actin. Analysis of total cell count, ASMA containing myofibroblasts and vessel cross sections was performed. Results: The expression of ASMA containing fibroblasts was significantly higher in the study group than in the control group (147 ± 137/ mm? vs. 5 ± 5/ mm?, $p < 0.001$). This equals a tenfold upregulation. The study group showed also significantly higher total cell content (737 ± 183 per mm? vs. 278 ± 104 per mm?, $p < 0.001$) and vessel cross sections (35 ± 17 per mm? vs. 11 ± 11 per mm?, $p < 0.001$) per mm2 in comparison to the control group. Discussion: The present study shows a significant increase in myofibroblast content in the tissue of adhesive capsulitis. We conclude that myofibroblasts may also play an important role in the contraction of the joint capsule and consecutive limitation of motion in adhesive capsulitis of the shoulder. Recent investigations have shown that antifibrotic agents such as decorin or TNF-a are able to suppress the expression of myofibroblasts. Therefore we believe that myofibroblasts may become a target in future therapeutic modalities of adhesive capsulitis.

SCIENTIFIC EXHIBIT NO. SE053

Posttraumatic Stiffness of the Elbow: Arthrodiatasis Using Unilateral Hinged External Fixation

Konrad Mader, MD, *Cologne, Germany (n)*
Thomas Gausepohl, MD, Cologne, Germany (n)
Thomas C. Koslowsky, MD, Cologne, Germany (n)
Andreas P. Wulke, MD, Cologne, Germany (n)
Dietmar Pennig, MD, Cologne, Germany (c – Orthofix)

INTRODUCTION: The effectiveness of closed intraoperative distraction of the elbow joint with an external distractor followed by unilateral humeroulnar external fixation with motion capacity for treatment of posttraumatic elbow stiffness was evaluated in a prospective study. METHODS: Between September 1994 and March 1998 twenty patients with posttraumatic stiffness of the elbow were treated according to a prospective protocol. After intraoperative distraction (15mm) and a subsequent relaxation phase, mobilisation of the elbow joint under distraction was employed for a mean of 7 weeks. RESULTS: The mean preoperative arc of total motion was 36 degrees (mean: 25 to 70 degrees). At follow-up examination (minimum 5 years postoperatively) of all patients, the mean arc of total motion was 105 degrees (mean: 100 to 130 degrees). There were two complications in one patient, notably pullout of fixator pins of the ulna requiring resiting and ulnar nerve paresthesia managed by ulnar nerve decompression. There were no deep infections, pin track drainage and all elbows except one were stable. Two patients developed moderate humeroulnar degenerative changes. All patients were satisfied with the results of the procedure because of an improved facility in carrying out activities of daily living. At final follow-up the mean Morrey Performance Index was 91 (70 to 96). This translated into one fair, 12 good and 7 excellent results. DISCUSSION AND CONCLUSION: Closed distraction of the elbow joint followed by monolateral external fixation with motion capacity shows gratifying results with few complications.

SCIENTIFIC EXHIBIT NO. SE054

Cuff Tear Athropathy: Pathogenesis, Classification and Algorthms for Treatment

Jeffrey L Visotsky, MD, *Des Plaines, IL (e- DePuy) (n)*
Carl Basmania, MD, Chapel Hill, NC (c – DePuy) (n)
Ludwig Seebauer, MD, Munchen, Germany (e – DePuy) (n)
Charles A. Rockwood, Jr, MD, San Antonio, TX (c – DePuy) (n)

INTRODUCTION: Cuff tear arthropathy (CTA) is a pathology of those primarily over the age of sixty; and is a significant functional impairment affecting activities of daily living. CTA has unique mechanical problems; superior migration of the humeral head , instability, erosion of acromium/ head and ostoeposis / collapse of humeral head subchondral bone. Traditional arthroplasty techniques have failed to adequately treat this population. METHODS: This exhibit will review pathogenesis , outline a classification system, treatment algorithm and review results of prosthesis designed for cuff tear arthritis. Between Jan 2000 and April 2001, 60 shoulder arthroplasties for patients with cuff tear arthritis. All patients had significant functional deficits and failed conservative treatment regiments. This patient population received standard stem techniques with an extended CTA head prosthesis. All patients were evaluated with ASES, simple shoulder and SANE scoring systems. RESULTS: In all cases the surgery was carried out to improve activities of daily living and pain. All patients noted significant improvement in pain and substantial improvement in functional scores. ASES and simple shoulder scores noted significant improvement in pain, ROM and functional elements. All patients had positive SANE responses. Radiographic results showed no further wear of the glenoid occurring opposite the prosthesis. Significant reductions noted in recurrent synovial hemarthrosis, acromioclavicular cysts and CTA progression. DISCUSSION / CONCLUSIONS: The established treatment algorithm and prosthesis designed for the diagnosis leads to positive results in the patient population. The classification and appropriate selection of extended low friction surface prosthesis offers improvement over traditional techniques.

PAPERS

PAPER NO. 121

Use of Intraoperative Electromyographic Monitoring in Insertion of Posterior Cervical Screws

Mladen Djurasovic, MD, *New York, NY (a – Medtronic Sofamor Danek)*
John R Dimar II, MD, Louisville, KY (*)
Steven D Glassman, MD, Louisville, KY (n)
Harvey L Edmonds, Phd, Louisville, KY (n)
George H Raque Jr, Louisville, KY (*)

Purpose: Lateral mass and pedicle screws are increasingly being used in the cervical spine. Malposition can lead to adverse clinical effects but is often difficult to detect intraoperatively. This study describes evoked electromyographic assessment of posterior cervical screw placement. Methods: In 26 patients, posterior cervical screws (n=148) were electrically stimulated to evoke compound muscle action potentials. Stimulation thresholds were defined as >15mA, 10-15mA and <10mA. Fine cut CTScans were taken postoperatively and screw position was graded as either acceptable or unacceptable by three blinded spine surgeons. Electromyographic thresholds and CT data were compared to assess the accuracy of EMG in predicting acceptable screw position. Results: 125 screws that stimulated at >15mA, 124 were in acceptable position. 16 screws that stimulated at 10-15mA, 14 were in acceptable position. 7 screws stimulated at <10mA. 5 screws were in unacceptable positions. The predictive value of screw stimulation >15mA for an acceptable screw position was 99.2%. Discussion: This study demonstrates the use of evoked EMG to assess posterior cervical screw position. The accuracy of this technique was confirmed with postoperative CT. Stimulation thresholds greater than 15mA reliably indicate acceptable screw position, while thresholds less than 10mA should prompt screw exploration and repositioning.

PAPER NO. 122

Platelet Gel (AGF) Fails to Increase Fusion Rate

Yoram Anekstein, MD, *Tel Aviv, Israel (n)*
Steven D Glassman, MD, Louisville, KY (a, c, e – Medtronic Sofamor Danek)
Rolando M Puno, MD, Louisville, KY (a, c, e – Medtronic Sofamor Danek)
Leah Yacat Carreon, MD, Louisville, KY (n)

Hypothesis. Platelet gel is an osteoinductive material prepared by ultraconcentration of platelets and contains multiple growth factors. It is commercially available as graft supplement in spine fusions. This study aims to determine the effect on fusion of adding platelet gel to autologous iliac crest graft. Methods. We reviewed 76 consecutive patients who underwent instrumented posterior lumbar fusion with autologous iliac crest bone graft mixed with Autologous Growth Factor (AGF). A control group was randomly selected from patients who underwent instrumented posterior lumbar fusion with autologous bone graft alone. The groups were matched for age, sex, smoking history and number of levels fused. Demographic, surgical and clinical data were collected from medical records. Diagnosis of nonunion was based on exploration during revision surgery or evidence of nonunion on CT. Fisher's exact test was used to compare fusion rates. Results. In both groups the mean age was 50 years, 24% were smokers. The nonunion rate was 19.7% in the AGF group and 11.8% in the control group. This difference was not statistically significant (p=0.18). Discussion. Platelet gel preparation requires blood draws from the patient. This adds to the risk and cost of surgery. AGF has the highest concentration of platelets among the commercially available gels. Despite this, we demonstrated that platelet gel failed to enhance fusion rate when added to autograft in patients undergoing instrumented posterior spinal fusion. Conclusions. The authors do not recommend the use of platelet gel to supplement autologous bone graft during instrumented posterior spinal fusion.

PAPER NO. 123

Correlation of Radiographic Parameters and Clinical Symptoms in Adult Scoliosis

Steven D Glassman, MD, *Louisville, KY (a, c, e – Medtronic Sofamor Danek)*
Keith H Bridwell, MD, Saint Louis, MO (a – Medtronic Sofamor Danek)
Sigurd H Berven, MD, San Francisco, CA (n)
William C Horton III, MD, Decatur, GA (a – Medtronic Sofamor Danek)
John R Dimar II, MD, Louisville, KY (a, c, e – Medtronic Sofamor Danek)

Introduction: This study correlates radiographic variables with patient-based outcome measures in adult scoliosis. The 298 patients studied include 176 with no prior surgery and 126 with prior spine fusion. Assessment consisted of demographics, 36 radiographs, SRS-22, SF-12 and Oswestry (ODI) profiles. No Prior Surgery Group: Thoracic curves had more favorable scores versus other curves [SRS-22 pain and function (p=0.01), SF-12 bodily pain and physical function (p=0.03), and ODI (p=0.04)). Coronal shift greater than 4 cm. resulted in poorer function SRS-22 (p=0.03) and greater pain SF-12 and ODI (p=0.05)]. Patients with positive global sagittal balance reported greater pain [SRS-22 (p=0.01), SF-12 and ODI (p= 0.00)], diminished physical function [SRS-22 and SF-12 (p=0.00)], poorer self-image (SRS-22 (p=0.03)], and social function [SF-12 (p=0.02)]. Prior Surgery Group: Thoracic curves demonstrated less pain on ODI (p= 0.03), better function [SRS-22 and SF-12 (p=0.01)] and better self-image on SRS-22 (p=0.02) versus thoracolumbar or lumbar curves. Patients with positive sagittal balance had poorer outcomes in pain, function, and self-image domains of the SRS-22 (p=0.00), bodily pain, physical function, vitality (p=0.00) and social function (p=0.02) on the SF-12, and pain on the ODI scale (p=0.00). Conclusion: Positive sagittal balance was associated with inferior measures of pain, function and self-image in patients with and without prior surgery. Significant coronal imbalance was associated with pain and dysfunction for the unoperated patients only. Thoracolumbar and lumbar curves yielded less favorable scores versus thoracic curves.

PAPER NO. 124

Anterior Fusion After Thoracoscopic Disc Excision: Analysis of 112 Consecutive Deformity Cases

Peter O Newton, MD, *San Diego, CA (n)*
Frances Faro, MD, San Diego, CA (n)
Tracey P Gaynor, MD, San Diego, CA (n)
Klane Keele White, MD, San Diego, CA
(a – Medtronic Sofamor Danek)

Introduction: The rate of anterior arthrodesis after thoracoscopic anterior release and fusion has not been studied. The purpose of this analysis was to examine the rate of anterior thoracic fusion following thoracoscopic disc excision and bone grafting in patients with spinal deformity. Methods: 112 patients treated with thoracoscopic anterior release/fusion and posterior instrumentation/fusion were reviewed. Two authors rated fusion on radiographs > 2 years postoperatively. An existing grading system for anterior lumbar fusion was modified: Grade I – Definite fusion with bridging trabecular bone; Grade II – Probably fused, bone >50% of the width on PA or lateral radiograph; Grade III – Probably not fused, bone <50% of the width; Grade IV – Definitely not fused, no bridging bone. Results: Of 112 patients, 79 had radiographs for review. The anterior bone graft was allogenous in the majority of cases. The mean preoperative scoliosis of 64° (40° – 108°) was corrected to 28° (1° – 65°) (50% correction; range 10 – 98%), while kyphosis was corrected from 77° (50° – 120°) to 58° (30° – 108°). Of the 470 disc spaces, 32% were Grade I, 36% Grade II, 18% Grade III, 9% Grade IV, and 5% were not ratable. Intraobserver reliability was moderate _=.47. Of the Grade IV ratings, 57% were at the thoracolumbar junction (T11-L2). Three patients required re-operation due to pseudarthrosis. Discusion and Conclusion: Thoracoscopic disc excision and bone grafting resulted in fusion (Grade I or II) in 75% of the ratable disc spaces. The region of the spine most difficult to achieve anterior arthrodesis was the thoracolumbar junction.

PAPER NO. 125

The Effect of Alendronate Sodium on Posterolateral Intertransverse Process Fusion in a Rabbit Model

Ronald Lehman, MD, *Silver Spring, MD (b – Merck)*
Timothy R Kuklo, MD, Rockville, MD
(a – Medtronic Sofamor Danek)
Brett Freedman, MD, Bethesda, MD (*)
Jerry Cowart, MD, Washington, DC (*)
K Daniel Riew, MD, Saint Louis, MO (n)

Introduction: To evaluate the effect of alendronate sodium following an intertransverse process spinal fusion in a rabbit model. Methods: 50 New Zealand white (NZW) rabbits underwent a posterolateral L5-L6 intertransverse process arthrodesis with autogenous ICBG. The rabbits were then randomly divided into 2 groups. Group I received 3-cc of saline placebo per oral gavage, while Group II received 200ug (approximately 0.05mg/kg/d) of alendronate sodium dissolved in 3-cc of saline per day for 8 weeks. Upon completion, the rabbits were sacrificed and the lumbar spines harvested, radiographed and graded for motion across the fusion site with manual palpation. Two independent pathologists then prepared and sectioned each left and right fusion mass. Three random 10x fields were examined and graded for both the cephalad and caudad ends of each section (516 fields). Fusion quality was graded using an established histological scoring scale (score 0 to 7 based on fibrous and bone content of the fusion mass). Results: 2 rabbits died on the day of operation, while 48 rabbits survived. 5 additional rabbits died within the first 2 post-op weeks. Thus, 43 rabbits (21 in Group I, 22 in Group II) completed the 8 week course of treatment. Fusion masses in Group I, 26 of 42 (62%) and 24 of 44 (55%) fusion masses in Group II had radiographic evidence of fusion (P=0.76). With gross palpation, 11 of 21 (52%) motion segments in Group I versus 13 of 22 (59%) motion segments in Group II were determined to have a solid fusion (P=0.76). Histologically, Group I had a higher median score (6.0; range, 0-7 vs. 1.0; P<0.0001) and a higher fusion rate (76% vs. 45%; P=0.004) than Group II. Discussion: Alendronate sodium appears to inhibit or delay bone fusion in a rabbit model. Gross palpation and radiographic evaluation are poor predictors of fusion. Conclusions: These findings suggest that a discontinuance of alendronate sodium postoperatively during the acute fusion period may be warranted.

PAPER NO. 126

An Analysis of Proximal Junctional Kyphosis after Posterior Spinal Fusion for Adult Spinal Deformity

R Christopher Glattes, MD, *Kansas City, KS (n)*
Keith H Bridwell, MD, Saint Louis, MO
(a – Medtronic Sofamor Danek)
Anthony Rinella, MD, Hinsdale, IL (n)
Charles Cannon Edwards II, MD, Ruxton, MD (n)
Lawrence G Lenke, MD, Saint Louis, MO
(a – Medtronic Sofamor Danek)

PURPOSE: To analyze patient outcomes and risk factors associated with proximal junctional kyphosis (PJK) in adults undergoing long posterior spinal fusion. Proximal junction defined as the caudal endplate of the upper instrumented vertebra (UIV) to the cephald endplate two vertebrae proximal. PJK was defined as sagittal Cobb angle greater than or equal to plus 10 degrees and at least 10 degrees greater than preop. HYPOTHESES: 1. Patients with PJK will have significantly lower SRS-24 outcomes scores. 2. PJK leads to a more positive in the sagittal C7 plumb. 3. Patient characteristics and instrumentation variables are associated with PJK. METHODS: 81 adult deformity patients with complete radiographic follow-up (minimum 2 year followup, mean 5.3 years) treated with instrumented segmental posterior spinal fusion at a minimum 6 motion segments were studied. Radiographic measurements, instrumentation variables and SRS-24 scores were analyzed. RESULTS: Incidence of PJK was 26 percent. Patients with PJK did not have lower SRS-24 outcomes scores (89.5 no PJK vs 96.5 PJK). PJK did not produce significant increases in the sagittal C7 plumb at final followup (plus 20mm no PJK vs plus 9mm PJK). PJK was more common with an upper instrumented vertebrae at T3. CONCLUSIONS: Incidence of PJK is high, but does not adversely affect patient outcome per the SRS-24. PJK does not lead to more positive sagittal balance. Causes and risk factors for PJK are not straight forward.

PAPER NO. 127

Lumbar Root Deficits Undetected by Monitoring for Complex Spinal Surgeries: A Ten-Year Experience

Upshur M Spencer, MD, *Anchorage, AK (n)*
Anne Padberg, MD, Saint Louis, MO (*)
Barry L Raynor, BA, Saint Louis, MO (*)
Lawrence G Lenke, MD, Saint Louis, MO (n)
Keith H Bridwell, MD, Saint Louis, MO (n)

INTRODUCTION: To characterize postoperative lumbar nerve ROOT deficits not detected by neurophysiologic monitoring. Our postulate was that no one neurophysiologic monitoring method was entirely reliable, including spontaneous EMGs. Our second postulate was that most of these deficits would recover with time. METHODS: In 2,964 consecutive spinal surgeries (one institution), lumbar nerve root deficits were identified in the immediate postoperative period in 23 cases; an additional 7 deficits developed in a delayed fashion (more than 12 hrs post-op). Tibial and peroneal SSEPs were used in all 30 cases. Neurogenic mixed evoked potentials (NMEP) were utilized in 17/30 due to inclusion of thoracic spinal levels. Spontaneous EMG monitoring was employed in 14/30 cases, and dermatomal SSEPs (DSEP) in 6/30. During this same ten-year period, spinal CORD monitoring demonstrated 5 true positives, and only a single false negative outcome. RESULTS: The incidence of lumbar nerve root deficits was 0.69 percent of the 2,044 primary surgeries, and 1.74 percent of 920 revision surgeries. 14 procedures were complex primary cases, and 16 were revision cases. Electrophysiologic data failed to identify deficits in 82.6 percent (19/23) of patients (false negative outcomes). Four immediate deficits were predicted by monitoring (true positive). Of the 30 patients, 23 recovered substantially within a year. DISCUSSION: Currently available neurophysiologic monitoring techniques (including EMG: 70 percent false negative) are not uniformly predictive of postoperative lumbar nerve root function, in sharp contrast to spinal cord monitoring. Use of intra-operative wake-up tests should be considered for certain highly complex lumbar cases.

PAPER NO. 128

Minimum 20-year Results of Harrington Rod Fusion for Idiopathic Scoliosis

Olimpio Galasso, MD, *Naples, Italy (n)*
Massimo Mariconda, MD, Naples, Italy (n)
Carlo Milano, Catamzaro, IT Italy (n)
Paolo Barca, Naples, Italy (n)

The present study was performed to evaluate the minimum 20-year outcome of spinal fusion with single Harrington distraction rod in patients with idiopathic scoliosis. Twenty-eight consecutive patients operated on by the same surgeon were selected. The S.R.S. questionnaire, along with an invitation for a follow-up visit, was mailed to all patients. Two patients died for causes unrelated to surgery and twenty-four of the remnants (92 percent response rate) sent back the questionnaire. Sixteen participated in the clinic and roentgenographic follow-up. The follow up period averaged 22.9 years (20.2-28.6). The mean age at surgery and follow-up was 15.8 (13-22) and 38.96 (34.3-47.9) years, respectively. The follow up examinations were carried out by a trained spine surgeon not involved in the care of patients. The average follow-up SRS score was 99.5/120 (78-110). No significant differences were observed comparing the patients self-reported quality of life data with the national age-matched normative data. Seven patients (29 percent) complained of mild to moderate pain and 23 patients (88 percent) would have had the same procedure again. In the patients with follow-up visit, the mean Cobb angle and rib cage deformity before surgery were 70.46 degrees (40-120) and 41 mm (22-78 mm), respectively, whereas on follow-up they were 41.23 degrees (16-75) and 30.2 mm (10-62), respectively. An unexpected high rate (15 percent) of HCV infection subsequent to surgery was detected. These long-term results let us to consider Harrington fusion as a procedure not affecting the self-reported quality of life. Long-lasting clinical and roentgenographic improvement was observed.

PAPER NO. 129

Critical Analysis of Trends in Fusion for Degenerative Disc Disease Over the Last Twenty Years

Christopher Bono, MD, *Boston, MA (n)*
Casey K Lee, MD, Roseland, NJ (a – Stryker Spine)

Introduction: Various surgical options for lumbar fusion for degenerative disc disease (DDD) have been introduced over the past 20 years. However, a fundamental question still remains: what has been their impact on surgical results? This study's purpose was to evaluate if these "advancements" have impacted the outcome of lumbar fusion for DDD by critically analyzing the available literature from the past two decades. Methods: A literature search of lumbar fusion series for DDD was performed. Data collected were use of internal fixation, bone graft source, fusion location (interbody [IB], posterolateral [PL], circumferential), and clinical outcomes scores (excellent, good, fair and poor). Data were pooled and compared to detect statistically significant (ss) differences. Results: 84 papers (7043 patients) were eligible for review. Use of internal fixation increased from 23 to 41 percent; autograft alone decreased from 82 to 52; IB fusion decreased from 44 to 22; PL fusion increased from 36 to 58. Fusion rate was 88 percent in the 1980s and 85 percent in the 1990s (not ss). Internal fixation increased fusion rates from 85 to 90 percent (ss). Posterior IB and circumferential fusion had higher fusion rates than PL and anterior IB groups (ss). Discussion and Conclusions: Significant shifts in trends of lumbar fusion have occurred over the past two decades. However, the data indicate that neither the fusion rate nor clinical outcomes have been improved. These data may be useful in directing further attempts to improve surgical results for this challenging clinical disorder.

PAPER NO. 130

◆Two Years Experiences with the BryanTM Cervical Disc Prothesis

Rafael Donatus Sambale, *Hessisch Lichtenau, Germany (e – Medtronic Sofamor Danek)*
Marion Andrea Saur, Hessisch Lichtenau, Germany (n)

Study Design. Prospective , consecutive study, enrolled. Objective. The purpose of the study is to evaluate whether the Bryan disc prothesis is able to maintain intervertebral mobility, relieves the signs and symptoms associated with degenerative disc disease (C3-7), influences the degeneration of the adjacent disc level. Methods. 6/2001-4/2003 we performed the Bryan disc prothesis in 45 patients. We used MRI, CT, SF-36 questionnaire, neck pain and disability scale and visual analogue scale. The chronicity of the pain was measured by the Gerbershagen scale. The contentment with the operation was categorized using Odom`s criteria. A cervical measurement system was used to monitor the cervical spine motion. The grip strength was examined with the Jamar Dynamometer. The device position and ROM was monitored on anteroposterior, lateral, oblique and lateral bending films. Follow –up periods 6 weeks, 3 months, 6 months, 1 year, 2 years after the operation. Results. Analysis of

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

the data shows a significant reduction of the pain. No operative or post-operative device related complications. No device subsidence or migration, no spondylotic bridging, no heterotopic ossification. ROM at the operated level 1 year after surgery was 7 degree median. Functionally improvement of the ROM in all directions. 4 satisfied, 41 good or excellent, no poor results. Conclusion. Short term results show a significant improvement of function and excellent outcome of all patients. Long-term studies are necessary to determine whether the Bryan disc prosthesis is an alternative to anterior fusion, keeps mobility and protects the adjacent level of exacerbated degeneration.

PAPER NO. 181

Percutaneous Dorsal Instrumentation in Thoracolumbar Fractures

Bjoern Zeifang, *Germany, Germany (n)*
Klaus Wenda, MD, 65 Mainz, Germany (n)
Michael Wild, Wiesbaden, Germany (n)
Markus Glees, MD, Wiesbaden, Germany (n)

INTRODUCTION: The conventional posterior approach for dorsal instrumentation of thoracolumbar fractures damages muscles, nerves and ligaments considerably. Dorsal instrumentation without anterior buttress is followed by a certain loss of correction. The hypothesis of this paper is: Percutaneous dorsal instrumentation of thoracolumbar fractures is advantageous compared to conventional insertion. METHODS: In 1997 21 unstable thoracolumbar fractures (Type A.3 and B) were stabilized by dorsal instrumentation with a titanium implant.(universal spine system) without addition anterior procedure. 11 patients were operated on by a conventional dorsal approach, in 10 patients the instrumentation was performed percutaneously. After marking the localisation of the pedicle entrance on the skin under fluoroscopy the pedicle screws were placed through four 2 cm incisions. Then the clamps were placed over the screws and the rods inserted by the incisions, lordosation and distraction were possible like in the conventional technique. Postoperative blood loss, operation time, achieved reduction (angle between the adjacent endplates) and loss of correction after five years were evaluated. 5 years after removal of the instrumentation (about 9 months postoperatively) 20 patients (95 % follow up) were investigated clinically and radiologically. RESULTS: Operation time was 72 ± 21 minutes in the conventional instrumentation and 81 ± 28 minutes in percutaneous instrumentation. Blood loss (intraoperative and per drainage) was 980 ± 270 ml in conventinal and 225 ± 42 ml in percutaneos technique (p=0,05). Reduction was evaluated by the angle between the endplates of the adjacent vertebra. Reduction was slightly better in the conventional technique (mean 9,8° vs. 7°). Loss of correction 5 years after removal of instrumentation was slightly less in the percutaneous technique (mean 6,15° vs. 5,5°). Statistic analysis revealed no differences between both techniques. DISCUSSION AND CONCLUSION. The presented percutaneous dorsal instrumentation of thoracolumbar fractures was investigated in comparison with the conventional technique concerning blood loss, reduction and loss of correction five years after removal of the instrumentation. Blood loss was significantly less in the percutaneous technique, reduction and loss of correction revealed no statistic relevant differences. The study demonstrates, that the less invasive technique of dorsal percutaneous instrumentation is possible and has the same results as the conventinal technique. For detecting possible advantages in terms of faster mobilisation and less pain the study group was to small.

PAPER NO. 182

Cervical Laminoplasty: Radiographic and Functional Outcome Study in North American Patients

Gerard Jeong, MD, *New York, NY (n)*
Ronald Moskovich, MD, New York, NY (n)
Peter Bono, DO, Birmingham, MI (*)
Frank Liporace, MD, New York, NY (*)

INTRODUCTION: This study evaluates the effect of the "French-Door" cervical laminoplasty in a mainly caucasian North American population with cervical spondylotic myelopathy on the basis of functional outcome, radiographic flexibility, and sagittal contour. To our knowledge, this is the largest series of patients with cervical laminoplasty due to CSM in North America. MATERIALS AND METHODS: 74-of-80 patients with cervical spondylotic myelopathy who underwent a "french-door" cervical laminoplasty between 1991 and 2000 were prospectively studied. Patients were evaluated preoperatively, at one year follow-up and at most recent follow-up. Follow-up ranged from 12 - 102 months (average 37.9 months). Functional outcome was measured using the modified Japanese Orthopaedic Association (mJOA) score and reported as percentage "rate of recovery". Lateral neutral, flexion, and extension radiographs of the cervical spine were performed to evaluate flexibility (ROM) and sagittal contour. RESULTS: Mean rate of recovery was found to be 74.6% At one year, 65 patients improved their mJOA score.($p < .01$) At last follow-up, 6 worsened their scores; the rest unchanged($p = .03$) There was a significant loss of sagittal alignment in extension only (10d) ($P<.01$). Cervical flexibility was 30∞ preop and 15∞ postop.($p<.01$) CONCLUSION: French-door cervical laminoplasty improved functional outcomes in North American patients. There was no improvement beyond one year after surgery. It affected sagittal alignment only in extension. It diminished cervical flexibility by approximately 50%.

PAPER NO. 183

The Differential Expression of the TGF-Q? Isoforms in Herniation of Lumbar Intervertebral Disc

Sung Taek Jung, MD, *Gwangju, Korea, Republic of (n)*
Jae Yoon Chung, MD, Gwangju, Korea, Republic of (n)
Hyoung Yeon Seo, MD, Gwangju, Korea, Republic of (n)
Yeon-Sung Kim, MD, Kwangiu, Korea, Republic of (n)
Yang-Kyung Kim, MD, Kwangiu, Korea, Republic of (n)
Kye-Jin Kim, MD, Kwangiu, Korea, Republic of (n)

Introduction: This study was conducted to determine the cellular role of TGF-beta in HNP specimens using immunohistochemistry (IHS) and reverse transcriptase-polymerase chain reaction (RT-PCR). Material and Methods: Disc tissues including the nucleus pulposus were collected from 19 patients who underwent disc resection due to radiculopathy After performing IHS and RT-PCR on the HNP tissues, the correlation between TGF-beta isoform expression and other factors was investigated. The correlation with each factors was analyzed using Spearman's correlation coefficient and Chi-square test. Statistical analysis was done using SPSS 10.0. Results: No significant differences in histological grades and TGF-beta expressions were observed according to the patients' age, sex, degree of intervertebral disc degeneration, sensory and motor nerve involvement, or symptomatic duration. A higher level of TGF-beta expression could be seen on immunohistological staining according to the grade of HNP exposure, and higher expression was also noted according to mRNA level using RT-PCR compared with the extruded and

sequestrated types. Discussion and Conclusion: In this study, a higher level of TGF-beta expression could be seen on immunohistological analysis according to the degree of HNP exposure, and more expression was also noted according to mRNA level using RT-PCR compared with the extruded and sequestrated types. These results suggest that TGF-beta plays an important role in the repair process in nucleus pulposus damage, and may participate in the natural process of absorption through phagocytosis by promoting the formation of granulation tissue and the growth of new vessels in herniated disc material.

PAPER NO. 184

◆Kyphoplasty Using Bioactive Calcium Phosphate Cement for Osteoporotic Vertebral Fractures

R Takemasa, MD, *Kochi, Japan (n)*
Hiroshi Yamamoto, MD, Nankoku, Japan (*)
Toshikazu Tani, MD, Nankoku, Japan (n)
Hiroo Mizobuchi, MD, Nankoku City, Japan (n)
Kenichi Kitaoka, MD, Kochi, Japan (n)

INTRODUCTION: Vertebroplasty and kyphoplasty using polymethylmethacrylate (PMMA) have excellent clinical results for the treatment of osteoporotic vertebral fractures. However, adverse effects of the PMMA have been described. As an alternative to PMMA, we have used calcium phosphate cement (CPC) for kyphoplasty. METHODS: The CPC is injectable, non-exothermic, self-setting, bioactive, and osteoconductive, and it sets by hydration, changing composition into hydroxyapatite. Its compressive strength is about 80 MPa, which is strong enough to reinforce the osteoporotic vertebral body. We treated 20 vertebrae (10 acute fractures, and 10 pseudarthroses) in 19 cases with minimum 2-years follow-up. The average age was 70 years, and the follow up was 35 months on average. We evaluated the pain intensity using a 10-point pain rating scale and deformity correction using a wedging rate, which is the anterior vertebral height as a percentage of the posterior vertebral height. RESULTS: Average preoperative pain was 7.5, and it significantly improved to 1.0 immediately after surgery, and the pain relief was maintained at the final follow up. The preoperative wedging rate was 46 percents, and it was corrected to 73 percents postoperatively. In 63 percents, the correction was maintained at the final follow-up. We had 1 case with asymptomatic epidural leak, but there were no other significant complications. DISCUSSION: These results demonstrated that the CPC vertebroplasty was minimally invasive and safe, and provided early significant pain relief and good correction of the deformity. This procedure might have potential advantages over the PMMA vertebroplasty and kyphoplasty, because of the excellent biocompatibility of the CPC.

PAPER NO. 185

Risks of Adding-On Syndrome after Spinal Instrumentation Surgery in Patients with Osteoporosis

Manabu Ito, *Sapporo, Japan (n)*
Kuniyoshi Abumi, MD, Sapporo, Japan (*)
Yoshihisa Kotani, MD, Sapporo, Japan (*)
Akio Minami, Sapporo, Japan (*)
Kiyoshi Kaneda, MD, Hokkaido, Japan (n)

Introduction: Osteoporotic vertebral fracture is one of the major social problems in developed countries. There are conservative measures to reduce the risks of osteoporotic vertebral fractures. However, once vertebral fractures and neurological problems occur, surgical decompression and stabilization with spinal instrumentation are indicated. The purposes of this study were to investigate the risks of adding-on syndrome after spinal reconstruction surgery and to discuss the optimal spinal reconstruction surgery in patients with osteoporosis. Methods: A total of 101 patients who underwent spinal decompression and reconstruction surgery at the thoracolumbar spine were involved. All of them were followed-up for more than 6 years. All patients had preoperative neurological compromise due to psuedoarthrosis after vertebral compression fractures. All patients underwent anterior decompression and fusion with anterior and/or posterior spinal instrumentation. Relationship between fusion levels and adjacent vertebral fractures was investigated on radiographs. Also the incidence of adding-on syndrome was investigated in patients with steroid-induced osteoporosis. . Results: Twenty-seven percent of the patients with 2 level fusion using spinal instrumentation had additional vertebral fractures during follow-up. Seventy-three percent of the patients with more than 2 level fusion had additional vertebral fractures. Patients with steroid-induced osteoporosis had higher risk of adding-on syndrome than those of senile or postmenopausal osteoporosis. Discussion and Conclusions: It became clear that as the fusion level increased, the risk of adding-on syndrome increased. Minimization of fusion levels may reduce the risk of adding-on syndrome. Steroid-induced osteoporosis is at a high risk of adding-on syndrome after spinal instrumentaion surgery.

PAPER NO. 186

Unsuspected Myeloma and Low-Grade Osteomalacia in Patients with Vertebral Compression Fractures

Daisuke Togawa, MD, *Cleveland, OH (a – Kyphon Inc)*
Isador H Lieberman, MD, Cleveland, OH (a, b, e – Kyphon Inc)
Thomas W Bauer, MD, PhD, Cleveland, OH (*)
Hiroshige Sakai, MD, Cleveland, OH (n)
Mary Kay Reinhardt, RN, Cleveland, OH (*)

INTRODUCTION: The purpose of this study is to describe the nature of biopsies obtained at the time of vertebral augmentation in presumed osteoporotic vertebral compression fractures, with special reference to the presence of unmineralized bone (osteomalacia). METHODS: As of March 2003, 139 of 107 patients with vertebral compression fractures underwent biopsies during 196 kyphoplasty procedures. Patients included 33 men and 74 women with an average age of 72 years. The patients were informed, agreed with this procedure and 25 patients received tetracycline (1g/day, in two doses separated by 6 days). Vertebral body biopsies were taken using a trephine just before the kyphoplasty procedure. The biopsies were viewed with transmitted and fluorescent light. RESULTS: All specimens showed fragmented bone with variable amounts of unmineralized bone (osteoid), suggesting bone remodeling and/or fracture healing. Woven bone and cartilaginous tissue were often present, representing fracture callus formation. Twenty samples showed significantly increased osteoid. Most of these samples showed single or absent labels of tetracycline, suggesting either a mineralization defect (osteomalacia) or increased bone remodeling but or insufficient tetracycline ingestion prior to biopsies. The biopsies provided definite diagnosis of plasmacytoma in four cases (4%) in which previous studies had been inconclusive. CONCLUSIONS: Evaluation of biopsies at the time of vertebral augmentation revealed a relatively high proportion of patients with increased osteoid, and was helpful in recognizing unsuspected

plasmacytomas. We advocate biopsy in all cases of vertebral augmentation as the results have led to more appropriate systemic treatment in this patient population.

PAPER NO. 187

◆Kyphoplasty for Acute Vertebral Fractures with an Injectable Calciumphosphate Cement

Joachim Siegfried Hillmeier, MD, *Heidelberg, Germany (a – Biomet Merck BioMaterials, b – Kyphon Inc)*
Peter Jurgen Meeder, MD Prof, Heidelberg, Gibraltar (a – Biomet Merck BioMaterials, b – Kyphon Inc)
Hans Christian Kasperk, MD, Heidelberg, Germany (a – Merck Darmstadt)

Problem: Kyphoplasty is a new operative technique in spine surgery that has most recently been indicated for patients with osteoporotic vertebral compression fractures (VCF). For younger patients with acute traumatic fractures, the gold standard has historically been osteosynthesis with internal fixation. Kyphoplasty seems to be an excellent alternative technique, which requires a short operative time and excellent height restoration.The main difference between kyphoplasty for osteoporotic VCFs and for patients with traumatic VCFs is the choice of bone void filler material. PMMA is not biocompatible, polimerization occurs under high temperature and toxic monomers are released.Therefore, we have elected to use a bioactive calciumphosphate cement for augmentation in younger patients. Objective: In kyphoplasty procedures: Can we achieve similar positive results with a calciumphosphate material as compared to with PMMA? Patients and Methods: Prospective, interdisciplinary study with a mean follow-up period of 6 months. All patients were treated operatively with kyphoplasty. For augmentation we used either PMMA cement or a new injectable calcium phosphate cement. This cement has been CE Marked, but has not yet received FDA approval. Overall, we treated 190 vertebral fractures in 104 patients with kyphoplasty.(25 Patients after acute trauma). Mean patient age was 56 years. All fractures were evaluated using the AO-classification. Clinical outcome data were observed using a VAS spinescore and by radiomorphometric evaluation Results: We noticed a significant improvement of pain and function in 23 of the trauma patients (92percent). Among the patients treated with PMMA or Calcibon, there was no significant difference. In acute trauma cases, the regained height was 35 percent on average, in osteoporotic patients 13 percent There was no evidence of increased retropulsion of the fractured dorsal vertebral wall post kyphoplasty.We noticed no severe complications. Conclusion : Specifically for young trauma patients with vertebral fractures, the use of a bioactive bone cement in combination with kyphoplasty is a new interesting development.

PAPER NO. 188

Effects of Epidural Steroids in the Lumbar Spine: A Double Blind Randomized Control Trial

Daniel Steinitz, MD, *Belleville, Canada (n)*
Edward J Harvey, MD, Montreal, Canada (*)
Max Aebi, MD, Bern, Switzerland (*)
Philip Lander, MD, Montreal, Canada (*)
Vincent Arlet, MD, Montreal, Canada (*)
Dante Marchesi, Montreal, Canada (*)

Hypothesis The addition of steroid to epidural lumbar injection may provide a measurable functional improvement after treatment. Method The high incidence of lumbar pain syndromes has driven the search for an effective strategy for dealing with these patients. Much debate over the efficacy of lumbar steroid injection exists and many studies show conflicting results. Fifty patients were randomized by the even/ odd last digit of their hospital unit number. All patients with previous spinal injection or spinal surgery were excluded. All patients received an epidural injection of Xylocaine and Marcaine and the even group received additional 12mg of betamethasone. All injections were performed by the same interventional radiologist and all injections were confirmed with fluoroscopy and 2ml Omipaque dye. Patients completed all outcome measure questionnaires preinjection, two weeks post injection and two months post injection. All testing was performed by the same blinded research assistant. Summary of results: No differences were found between patients receiving steroids and those that did not, with reference to any outcome measure. Musculoskeletal Functional Assessment ($p < 0.29$, $p<0.68$), Bother Index ($p<0.50$, p,0.22), Functional Index ($p<0.22$, $p<0.73$), Oswestry Score ($p<0.16$, $p<0.11$), Visual Pain Analogue Score ($p<0.50$, $p<0.18$)Conclusion: No significant differences could be detected between patients that did or did not receive steroid injection. This study may provide evidence against the use of steroid in epidural lumbar spinal injection.

PAPER NO. 189

Subsequent Fracture After Kyphoplasty

David M Fribourg, MD, *Los Angeles, CA (n)*
Chris Tang, MD, Los Angeles, CA (*)
Hyun W Bae, MD, Santa Monica, CA (e – Kyphon Inc)
Rick B Delamarter, MD, Santa Monica, CA (n)

Introduction. Biomechanical studies show cement augmentation increases stiffness of fractured vertebrae and decreases ultimate load to failure of adjacent segments. However, there is little data on the rate of subsequent fractures after kyphoplasty. Methods. A retrospective review was performed of all consecutive patients who had kyphoplasty over 22 months at one center. Results. Thirty-eight patients (10 male, 28 female) had 47 levels treated initially. Patients' gender, smoking and medication history, location of fracture, and number of initial fractures did not correlate with risk of subsequent fracture. In total, ten patients had 17 subsequent fractures. Eight patients had subsequent fractures in the first two months, all with one or more fractures at adjacent levels. There were nine fractures adjacent-above, four adjacent-below, and four at remote levels. The remote fractures occurred at significantly greater time intervals after the index kyphoplasty. Discussion. Overall, this study demonstrates a higher rate of subsequent fracture than expected from natural history data. Most subsequent fractures occurred within two months of the index procedure, at an adjacent level. This confirms biomechanical studies suggesting that cement augmentation increases stress at adjacent levels.

PAPER NO. 190

◆Clinical Outcome of Vertebral Augmentation for Osteolytic Collapse

Isador H Lieberman, MD, *Cleveland, OH (a, b, e – Kyphon Inc)*
Mary Kay Reinhardt, RN, Cleveland, OH (*)
Mohammed Hussein, MD, Cleveland, OH (n)

Purpose;To assess the outcome of methylmethacrylate vertebral augmentation in patients debilitated by osteolytic vertebral collapse. Method; A consecutive prospective series of patients with osteolytic vertebral collapse without neurological findings were treated with percutaneous vertebral body reduction using

an inflatable bone tamp followed by methylmethacrylate augmentation. Peri-operative variables and complications were recorded and analyzed. X-rays and CT scans were compared to calculate vertebral morphology and cement leak. Outcome data was obtained using Visual Analogue Pain and SF-36 scores. Results; 264 vertebral bodies in 63 consecutive patients were treated. 52 had multiple myeloma, 11 had other lytic metastases. Symptom duration was 12 months. There were no complications associated with the technique or tools. Cement leaks were noted in less than 5% of treated vertebrae. Patients reported statistically significant improvement in SF-36 scores for Bodily Pain: 28.33 to 47.56, (p=0.0003) and Physical Function: 24.48 to 47.17, (p<0.0001), as well as improvements in VAS score: 6.18 to 2.84, (p<0.0001). Twelve patients (23%) sustained further vertebral collapse at other levels. Discussion: Advances in Oncologic treatment has improved survival where what was once life threatening could now be considered chronic disease. With increased survival and ongoing bone loss osteolytic vertebral collapse is more of a clinical and functional problem. Surgical intervention is regarded as difficult by virtue of the comorbid conditions and poor bone quality. To alleviate these issues, vertebral augmentation techniques have evolved and show promising results. Considering the sustained clinical improvement in pain and function, we advocate early augmentation of any collapsing vertebral body.

PAPER NO. 251

◆Results of a Prospective Randomized Trial of Total Disc Replacement Versus Fusion

Jack E Zigler, MD, *Plano, TX (a, b, d – Spine Solution)*
Timothy A Burd, MD, Omaha, NE (*)
Emiliano Vialle, Curitiba, Brazil (n)
Barton L Sachs, MD, Plano, TX (a, d – Spine Solution)
Ralph F Rashbaum, MD, Plano, TX (n)
Donna D Ohnmeiss, DrMed, Plano, TX (n)

Introduction: The hypothesis of this prospective, randomized study was that the results of total disc replacement (TDR) would be no worse than combined anterior/posterior fusion. Methods: This study represents 6-month follow-up data for the first 78 patients (55 ProDiscs and 23 Fusions), including 1 year data on 54 of those patients, enrolled at one center in a prospective randomized FDA approved study evaluating TDR using ProDisc versus a control (circumferential lumbar fusion). Pre- and post-operative outcome measures included visual analog scale (VAS), Oswestry Disability Questionnaire, patient satisfaction, and motion measured by finger-tip to floor distance during bending. Results: Estimated blood loss, operative time and hospital stay were significantly less in the TDR group (p<0.01). Oswestry scores improved significantly in both groups. At 3 months, the TDR group score was significantly less than the fusion group (p <0.05). VAS scores were better in the TDR patients but not statistically significant. There was a trend at 6 months in patient satisfaction favoring TDR (p = 0.08), which became more pronounced at 1 year. Forward and lateral bending were significantly greater in TDR patients at all follow-ups (p=.02). There were no cases of implant failure. Discussion: TDR demonstrated shorter operative time and hospitalization, and greater motion. These results are encouraging. Longer-term follow-up data continues to be collected.

PAPER NO. 252

◆Prospective Outcome Evaluation of a Lumbar Total Disc Replacement

Richard D Guyer, MD, *Plano, TX (a, b – LINK)*
Stephen Howard Hochschuler, MD, Plano, TX (*)
Donna D Ohnmeiss, DrMed, Plano, TX (n)
Scott L Blumenthal, MD, Plano, TX (*)

Introduction: The hypothesis of this study is that total disc replacement provides significant improvement in patients with symptomatic disc degeneration unresponsive to non-operative treatment. Methods: This study is based on the first 70 patients receiving the SB Charité prosthesis at a single center as part of a prospective FDA approved study. Data were collected pre-operatively and up to 24 months post-operatively (the first 35 patients reached 24 month follow-up at the time data were analyzed for this abstract). Primary outcome measures included Oswestry Low Back Pain Disability Questionnaire and visual analog scale (VAS). Results: The mean operative time was 78.2 min and blood loss was 132.4 cc. The mean pre-operative VAS pain score was 68.6, which improved to 33.8 at 6 weeks (p<0.001). Improvement remained stable during 24 month follow-up. Oswestry scores improved 41.3% at 6 weeks (p<0.025) and remained improved throughout follow-up. There were no cases of device failure or displacement. Discussion: This study demonstrated significant improvement at 6 weeks which was maintained during the 24 month follow-up in patients undergoing a total disc replacement for symptomatic disc degeneration.

PAPER NO. 253

Does Ketorolac Predispose to Pseudarthrosis Following Posterior Fusion for Idiopathic Scoliosis?

Daniel J Sucato, MD, *Dallas, TX (n)*
Emily Elerson, MD, Dallas, TX (n)
Trudi Nelson, RN, Dallas, TX (n)

Purpose: Ketorolac, has been demonstrated to inhibit spinal fusion in adult L4 to sacral fusions. However, there is little data concerning this effect following posterior spinal fusions (PSF) for adolescent idiopathic scoliosis (AIS). Methods: A retrospective medical record review was performed from 1994 to 2000 of patients undergoing a PSF for AIS from a single institution. Demographic and operative data were recorded. The dose, and duration of ketorolac and other NSAIDS were recorded. Patients were divided into those who had postoperative ketorolac (group K) and those who did not (group NK). Patients who had a pseudoarthrosis were identified. Results: There were 133 patients in the K group and 131 in the NK group. There were no differences between the K and NK groups with respect to age, sex, race, curve type, levels fused (9.5 vs 9.6), and preoperative curve magnitude (58.3E vs 57.2E). Segmental spinal instrumentation and iliac crest bone graft were used in both groups. The average dose of ketorolac was 26.4 mg every 6 hours for an average duration of 46 hours postoperatively. The patients in the K group were more likely to have motrin (average 5.9 doses) compared to the NK group (average 0.1 doses). (P<0.01) No patient in the K group had a history of cigarette smoking compared to 2 patients in the NK group (neither developed a pseudoarthrosis). The number of patients who developed a pseudoarthrosis was 4 (3.0%) in the K group and 5 (3.9%) in the NK group. (P=0.7). Conclusions: When performing a PSF for AIS using segmental spinal instrumentation and iliac crest bone graft there does not appear to be an increased incidence of developing a pseudoarthrosis when ketorolac is used as an adjunct for post-operative analgesia.

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

PAPER NO. 254

Pseudarthrosis in Adult Idiopathic Scoliosis Primary Fusions

Yong Jung Kim, MD, *Saint Louis, MO (n)*
Keith H Bridwell, MD, Saint Louis, MO (a – MSD)
Lawrence G Lenke, MD, Saint Louis, MO (n)

Purpose: To analyze the incidence, characteristics, risk factors, and SRS 24 outcone scores of the pseudarthrosis in adult idiopathic scoliosis primary fusions. Methods: A retrospective chart and radiographic review of 96 patients (average age; 42.2 year, range 18.2- 62.9 year) with adult IS undergoing virgin instrumentation and fusion with a minimum 2-year follow up (average 5.9 years; 2-16.8 years) were analyzed. No revision cases were included in this study. Results; 16 patients had pseudarthroses (17%, average age 46.9 years). 59 percent occurred between T9 and L1 and 81percent presented with multiple levels involved. The number of fused vertebrae (>12) was siginificantly related with pseudarthrosis. (p=0.03) Results: Site of crosslinks or dominoes correlated with nonunion site. The higher preoperative Cobb angle and thoracic kyphosis did not demonstrated higher nonunion rate. The thoracolumbar kyphosis (>20 degree) demonstrated significantly higher nonunion rate. (p<0.001) Patient age at operation (>54years) significantly correlated with nonunion.(p=0.007) Smoking history and comorbidity did not increase the nonunion.Patients with pseudarthrosis had lower SRS 24 score than those without (p=0.01). Conclusion: The incidence of pseudarthrosis following adult idiopathic scoliosis primary fusion was 17%. The pseudarthrosis commonly presented at the thoracolumbar junction . The higher number of fused vertebrae(>12), older age (>54years), and especialy thoracolumbar kyphosis demonstrated significant risks to psedarthrosis. patients outcomes as measured by the SRS-24 were significantly affected by the psedarthrosis..

PAPER NO. 255

Posterior Instrumentation & Arthrodesis for Idiopathic Scolisois: 2-12 Year Follow-up

Douglas C Burton, MD, *Kansas City, KS (n)*
Marc Addason Asher, MD, Kansas City, KS
(b, c – DePuy AcroMed)
Sue Min Lai, PhD, Kansas City, KS (n)
Andrew Cooper, MD, Kansas City, KS (*)
Barbara Manna, RN, Kansas City, KS (n)

An observational retrospective case series to survey the safety and efficacy of an integrated wire, hook and pedicle screw anchor system utilizing torsional-counter torsional correction loads. METHODS: One hundred eighty-five (156F, 29M) consecutive, index case included, patients age 10 through 20 years, mean 14.6 years ±2.3, were operated. A minimum two year follow up was available clinically for 178 patients (96%) at an average of 6.0 years (± 3.1 years) and radiographically for 174 patients(94%) at an average of 4.9 years, (±2.6 years) post operative. RESULTS: There were no deaths, cord or spinal nerve complications, or acute post operative posterior wound infections. Three patients (1.6%) (3/185) required peri-operative reoperation, one for empyema and two for incision separation reclosure. Later reoperations were required in 14 patients (8%) (14/178); delayed deep wound infection 2 (1.1%), pseudarthrosis/malunion 3 (1.7%), implant prominence 1 (0.6%), late operative site pain 7 (3.9%), and peri adjacent spondylolisthesis 1 (0.6%). The largest Cobb was 63º (±13º) pre operative and 23 º (±10º) (63% correction) at latest follow up. SRS/HRQoL questionnaire results were available for 177 (96%) (177/185). The mean scores were function 4.18 (±0.68), pain 4.08 (± 0.90), self image 4.21 (± 0.69), mental health 4.10 (±0.77), satisfaction with management 4.55 (± 0.71), and total 4.18 (±0.61). CONCLUSION: This integrated wire, hook and pedicle screw instrumentation system and the torsional-counter torsional corrective loads recommended can be used safely and effectively for surgical treatment of idiopathic scoliosis.

PAPER NO. 256

Spinal vs. General Anesthesia in Lumbar Laminectomy. A Case-Controlled Study of 400 Patients

Robert F McLain, MD, *Cleveland, OH (n)*
Gordon R Bell, MD, Cleveland, OH (n)
Iain H Kalfas, MD, Cleveland, OH (n)
John E Tetzlaff, MD, Cleveland, OH (*)
Helen Yoon, Cleveland, OH (n)
Maunak Rana, Cleveland, OH (*)

Introduction: Spinal anesthesia is widely accepted for extremity surgery, but uncommon in spinal decompressions. We reviewed our Institutional experience to test the hypothesis that spinal anesthesia is as safe and effective as general anesthesia in lumbar decompression. Methods: This case-controlled study compared 400 patients undergoing either spinal or general anesthetic for lumbar laminectomy. Analysis was carried out by an independent observer. To determine perioperative and early postoperative outcomes, 200 spinal anesthesia (SA) patients were compared to 200 general anesthesia (GA) patients matched for anesthetic class, preoperative diagnosis, surgical procedure and perioperative protocols. All patients were treated in the same institution, in the same operating rooms, and recovered in the same perianesthetic environment, irrespective of anesthetic type. Data from the intraoperative period through hospital discharge were collected and compared. Results: Demographically, both groups were similar. Total anesthetic and surgical times were significantly longer for the general anesthetic group. Intraoperative hemodynamics were similar. Post-anesthetic care unit (PACU) stays were shorter for GA patients, but heart rate and mean arterial pressures were higher on PACU admission among these patients. GA patients had more nausea and required more antiemetics and pain medication in PACU. Complication rates, including urinary retention, were significantly lower in SA patients. Orthostatic headache occured in 1.5% of SA and 3.0% of GA patients (NS). Conclusions: Spinal anesthesia is at least comparable to general anesthesia for patients undergoing lumbar decompressive surgery. Specific advantages to spinal anesthetic include decreased anesthesia time, decreased nausea and antiemetic requirements and a decreased analgesic requirement in the early postoperative period.

PAPER NO. 257

◆Dynesys Stabilisation for Chronic Back Pain

John Shepperd, *St. Leonards on the Sea, United Kingdom (n)*
Andrew McKee, MRCS, St Leonards on Sea, United Kingdom (n)
Ford Qureshi, MD, St Leonards on Sea, United Kingdom (n)
Matthew Oliver, MRCS, St Leonards on Sea, United Kingdom (n)
Sam Rajaratnam, MD, East Sussex, United Kingdom (n)

Introduction: We report a series of 90 patients enrolled in a prospective study of Dynesys stabilisation reviewed at 24 to 36 months.The procedure involves, at each segment, cephalad and caudad pedicle screws connected with a polycarbourethane spacer and polyethylene cord. It achieves load relief and controlled flexion. Method: Indications are analogous to consideration for fusion.Where root compression was present, a midline approach and posterior screw placement was used in conjunction with open decompression.With back pain alone a bilateral Wiltse approach and posterolateral placement was used.All patients were assessed pre and post surgery with SF36,Oswestry Disability Index,pain analogue scores and Modified Zung.Clinical and radiological follow up was at 2,6,12,24 and 52 weeks in addition to this review. Results: Follow up was 100 percent. Mobilisation was achieved on day 1 and discharge usually by day 2.Good to excellent results were achieved in 74 percent.Screw loosening or breakage occurred in 8 percent and was associated with a poor result. Discussion: This technique offers a simple alternative to fusion with less potential for adjacent 'domino' failure.At this stage the results appear at least as good as a comparable cohort of fusion patients.The present series is early but is encouraging.Screw failures detract from the result and require further development.We are continuing to use the technique.

PAPER NO. 258

Thorascopic Anterior versus Open Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis

Baron Lonner, MD, *New York, NY (e – Medtronic Sofamor Danek)*
Dimitry Kondrachov, MD, New Hyde Park, NY (n)
Farhan Siddiqi, MD, New Hyde Park, NY (*)
Victor Hayes, MD, New Hyde Park, NY (n)

Posterior spinal fusion (PSF) with segmental instrumentation has been the gold standard for the surgical treatment of thoracic adolescent idiopathic scoliosis (AIS). More recently, anterior surgery, and thoracoscopic anterior spinal fusion (TASF) have become of interest. The purpose of this study is to compare radiographic and clinical outcomes as well as operative morbidity and pulmonary function in patients with AIS undergoing either posterior or anterior thoracoscopic surgery. Radiographic data, SRS-22 outcome questionnaires, pulmonary function, and operative records were reviewed for all patients in the study. A minimum of 24 months follow-up was required for the posterior group and 12 months for the thoracoscopic group. There were 25 patients in the PSF group (group 1) and 29 in the TASF group (group 2) with mean age 14 and 15 years and follow-up 30 and 20.6 months, respectively. 92% of patients in the PSF group had Lenke 1 curves, and 8% had Lenke 2 curves. All patients in the TASF group had Lenke 1 curves. Mean preop curve size in group 1 was 48 correcting to 21 degrees at f/u (55.5% cxn). Mean curve size was 47.9 in group 2 correcting to 20.2 degrees at f/u (58.4% cxn). Operative morbidity was low in both groups. EBL was 537cc in group 1 and 359cc in group 2. One revision surgery was required in each group. Vital capacity decreased initially in both groups, improving to baseline in group 2 and slightly diminished in group 1 at f/u. SRS outcomes were similar for both groups. TASF compared favorably to PSF for the treatment of thoracic AIS. The authors believe TASF will play an increasingly important role in the treatment of AIS as techniques are improved and the learning curve is overcome.

PAPER NO. 259

Preoperative Risk Factors and Outcomes after IDET: Retrospective Review with Cost Analysis

Nicholas Ahn, MD, *Overland Park, KS (n)*
William O Reed Jr, MD, Overland Park, KS (n)
Uri Ahn, MD, Bedford, NH (n)
Cody Stephen Harlan, MD, Overland Park, KS (n)
Harpreet Singh Basran, MD, Kansas City, MO (n)
Alexander S Bailey, MS, Toledo, OH (n)
Glenn M Amundson, MD, Overland Park, KS (*)

Introduction-IDET has become a popular alternative to fusion for discogenic pain. Prior studies have shown favorable success for pain relief but have not focused on functional outcomes or cost-analysis. Methods- 86 patients who had IDET were prospectively studied over 2 yrs. Group I were ideal candidates (nonsmokers, non-obese, age< 40, discogram-confirmed single level disease). Group II were all others. VAS and Oswestry scores were obtained pre- and post IDET. Patients were asked if they had or would still consider fusion after IDET. Cost analysis was performed to calculate R, the success rate IDET must achieve to be cost effective, assuming surgical alternative is instrumented fusion. Results- 82% of Group I and 96% of Group II patients had or were considering lumbar fusion after IDET. There was no difference in pre- and post-IDET VAS and Oswestry scores in Group II (52 patients, p>0.05). In Group I (34 patients), there was significant improvement in VAS (0.55 points, p=0.05) but not in Oswestry. R was calculated as 0.23. Thus for IDET to be cost-effective it must lead to avoidance of fusion in 23% of patients. Conclusion- There was no improvement in pain or function after IDET in non-ideal patients. Ideal candidates showed significant improvement in pain but not in function. Except for ideal patients, IDET is not cost-effective and should be avoided.

PAPER NO. 260

The Optimal Carrier for BMP Induced Fusion in a Thoracoscopically-Instrumented Animal Model

Daniel J Sucato, MD, Dallas, TX (a – Medtronic Sofamor Danek)
Hong Zhang, MD, Dallas, TX (a – Medtronic Sofamor Danek)
William Pierce, BS, Dallas, TX (a – Medtronic Sofamor Danek)
Scott Colby, BS, Dallas, TX (n)
Robert D Welch, DVM, Dallas, TX (a – Medtronic Sofamor Danek)

Introduction: BMP-2 provides for improved fusion in posterior spine fusion models using the collagen sponge. However, this may not be the ideal carrier for multilevel anterior fusion and for application using thoracoscopic techniques. Methods: 16 pigs were anesthetized and underwent a five level thoracoscopically-assisted instrumentation and fusion. The animals were

randomly assigned to four groups: Group C: control- no graft material; the remaining groups had recombinant human BMP-2 (rh-BMP-2) and one of 3 carriers: Group HA-TCP: hydroxyapatite-tricalcium phosphate; Group BSM- %bone substitute material® - a calcium phosphate cement; Group ACS: absorbable collagen sponge. The animals were euthanized at 4 months. Fusion mass was imaged using CT, biomechanical testing and histomorphometry. Results: All animals were successfully instrumented using the thoracoscopic approach. The CT fusion grade using a 4 point system (0- no fusion; 4-complete fusion) was: group C: 0.6; HA-TCP: 3.7; BSM: 2.4; ACS: 3.3. ($p<0.01$) Biomechanical testing demonstrated greater stiffness in the experimental groups compared to the control group.($p<0.01$) There was a trend in all modes tested toward greater stiffness in the HA-TCP groups compared to groups ACS and BSM. Histomorphometric analysis demonstrated total bone volume (% of the total disc space): group C: 55.1%; HA-TCP: 94.1%; BSM: 77.3% and ACS: 86.0%. ($p<0.01$). Conclusions: rhBMP–2, applied to all three carriers, significantly enhanced fusion at 4 months when compared to controls. HA-TCP was superior to the other two carriers when assessing fusion radiographically, biomechanically and histologically.

POSTERS

POSTER NO. P379

Cervical Spine Injury and Restraint System Use in Motor Vehicle Collisions

Brian S Claytor, MD, *Birmingham, AL (n)*
Paul MacLennan, PhD, Birmingham, AL (n)
Gerald McGwin, Jr, PhD, Birmingham, AL (n)
Loring W Rue, MD, Birmingham, AL (*)
John S Kirkpatrick, MD, Birmingham, AL (n)

Context- Motor vehicle collision (MVC) related cervical spine injury is a severe and often permanently disabling injury. Although advances in automobile crashworthiness have reduced both fatalities and some severe injuries, the impact of varying occupant restraint systems (seatbelts and airbags) on cervical spine injury is unknown. Objective- To investigate the relationship between the occurrence of cervical spine injury and occupant restraint systems among front seat occupants involved in frontal MVCs. Design, Setting, and Patients- A case-control study among subjects obtained from the 1995 to 2001 National Automotive Sampling System (NASS). Cases were identified based on having sustained a cervical spine injury of > 2 on the Abbreviated Injury Scale, 1990 Revision. Results- Approximately half (44.7%) of 8,412 cases of cervical spine injury were unrestrained occupants while belted only, airbag only and both restraint systems represented 38.2%, 8.8% and 8.4% of cases respectively. Overall, the combined use of airbag and seatbelt had the greatest protective effect, relative to unrestrained occupants, with an odds ratio (OR) of 0.19 and a 95% confidence interval (CI) of 0.12 to 0.30. Use of a seatbelt only also had a protective effect (OR=0.40, 95% CI=0.23 to 0.70). Occupant use of an airbag only neither increased nor decreased the risk of cervical spine injuries relative to unrestrained occupants (OR=1.02, 95% CI=0.57 to 2.13). Conclusions- The results of this study suggest that there is an increase in overall protection against cervical spine injury by combining airbag and seatbelt restraint systems relative to seatbelt alone.

POSTER NO. P380

Local Bone Graft in Instrumented Posterior-Lateral Fusion of Degenerative Lumbar Conditions

Robert W Gaines Jr, MD, *Columbia, MO (c – DePuy Spine)*
Thomas M Park, MD, Tallahassee, FL (*)
Jun Young Lee, MD, Gwangju, Korea, Republic of (*)

This study compares the use of autogenous locally harvested bone graft (laminae, facets, and spinous process) (N= 33), against autogenous iliac crest bone graft (N=64) for 97 posterior lateral fusions of degenerative lumbosacral spinal conditions using Variable Screw Placement (VSP) pedicle screws and plating. Radiographic and functional outcomes were assessed at a minimum follow up of 2 years. The fusion rate for local bone graft and iliac crest bone graft groups were 91% and 92.2%, respectively. The non-smokers who received local bone had a fusion rate of 88.5%; the fusion rate was 94.1% for the patients in the iliac crest bone graft group. For the smokers, the rates of fusion were100% and 90% for local bone graft and iliac crest bone graft groups, respectively. When comparing local bone graft to iliac crest bone graft and controlling for the number of levels fused, no significant difference was seen for a single level, two level or three to seven level fusion. When analyzing the postoperative pain and work levels with the modified Denis score, no statistically significant difference was seen between the 2 groups. Bone graft harvested from laminae, facets, and spinous process produces fusion rates and clinical outcomes equal to that of autogenous iliac crest bone graft in patients with degenerative lumbosacral conditions who had posterolateral spinal fusion with Variable Screw Placement(VSP) screws and plates.

POSTER NO. P381

Short Segment Anterior Apical Instrumentation for Scheuermann's Kyphosis

Robert W Gaines Jr, MD, *Columbia, MO (d – DePuy Spine)*
Hans Moller, MD, Stockholm, Sweden (n)
Kan Min, MD, Zurich, Switzerland (n)
Acke Ohlin, MD, Malmo, Sweden (*)
David S Marks, MD, Birmingham, England, United Kingdom (*)

Introduction The goal of operative treatment of Scheuermann's kyphosis is to obtain a solid fusion with correction of the deformity. The most widely used techniques are posterior only or combined anterior-posterior approaches. Both include a long posterior instrumentation. Our study aims to show that Scheuermann's kyphosis can safely be treated with anterior short segment fusion with the Kaneda Anterior Spinal System. Methods Anterior correction and fusion using KASS was performed in 27 patients with Scheuermann's kyphosi. Only the apical levels identified on hyperextension lateral radiographs were instrumented. In addition, femoral rings, carbon fibre or titanium cages were inserted as interbody spacers. The radiographs and clinical results were reviewed after a follow-up of 1 to 4 years. Results The reduction of the deformity ranged from 20 to 39 degrees, resulting in a postoperative thoracic kyphosis that was within normal limits (46 to 55 degrees). It was accomplished by instrumenting 6 to 8 vertebrae and fusing 5 to 7 discs. Five to 7 levels were saved in each patient compared to the traditional long posterior instrumentation and fusion. There were no peri- or postoperative complications. At latest follow up, no hardware failure, loss of correction or junctional kyphosis was

noted. The patients were satisfied with their pain relief. Discussion and Conclusion Using this technique, 5 to 7 levels were saved in each patient compared to the traditional long posterior instrumentation and fusion. The results suggest that Scheuermann's kyphosis can safely be treated with anterior short segment fusion with the KASS.

POSTER NO. P382

Complications of Single Level Posterior Lumbar Spine Fusion in the Elderly

Scott Klein, MD, *Louisville, KY (n)*
Steven D Glassman, MD, Louisville, KY
(a,c,e – Medtronic Sofamor Danek)
Sam Carter, MD, Louisville, KY (n)
Leah Yacat Carreon, MD, Louisville, KY (n)

Hypothesis. Elderly patients undergoing posterior spine fusion sustain fewer complications with single level than multiple level fusions. Methods. Medical records of 73 elderly patients (>65 years) who underwent single level posterior spine fusions were retrospectively reviewed. Complications were divided into major and minor categories. Major complications were those that altered the hospital course. Minor complications were all others. Variables assessed included: age, gender, co-morbidities, operative time, blood loss, length of hospital stay, and discharge disposition. Results. Mean age was 72 years. 66% were female. 63% had no complications, 12% had major and 25% had minor complications. Patients with complications had a longer hospital stay ($p<0.05$). No significant differences were seen for age, gender, pre-existing co-morbidities, operative time, blood loss, or discharge disposition between patients with complications and those without. Discussion. Complication rates after multi-level posterior spine fusions are higher in the elderly compared to the non-elderly. However, complication rates after single level spine fusion in the elderly have not been reported. Previously reported complication rates after multi-level spinal fusion procedures in elderly patients showed 28% major complications and 58% minor complications. In contrast, our study showed a 12% major complication rate and a 25% minor complication rate in the same patient population after a single level posterior spine fusion. Conclusions. Single level posterior spine fusions are substantially safer compared to multi-level spine fusions in elderly patients.

POSTER NO. P383

Reconstruction after Total Sacrectomy Using a New Instrumentation Technique

Hideki Murakami, MD, *Kanazawa, Japan (n)*
Norio Kawahara, MD, Kananzawa, Japan (*)
Akira Yoshida MD, Kanazawa, Japan (n)
Jiro Sakamoto, Iowa City, IA (*)
Juhachi Oda, PhD, Kanazawa, Japan (*)
Katsuro Tomita, MD, Kanazawa, Japan (n)

[INTRODUCTION] When a sacral tumor involves the first sacral vertebra, a total sacrectomy is necessary. It is mandatory to reconstruct the continuity between the spine and the pelvis after a total sacrectomy. One of the methods is a modified Galveston reconstruction (MGR) using the Galveston method. Another method is a triangular frame reconstruction (TFR) which has been performed in our institute. However, instrumentation failure or loosening often occurs and there has been no mechanical analysis of these reconstructions. We developed a novel reconstruction (NR). The purpose of this study was to evaluate three reconstruction methods after a total sacrectomy using a finite element analysis. [METHODS] Three-dimensional MGR, TFR, and NR models were reconstructed and a finite element analysis was performed. In the MGR, after the placement of pedicle screws into the L3-L5 vertebral bodies and two bilateral iliac screws into the bilateral iliac bone, these screws were connected by two spinal rods. In the TFR, L5 was affixed to the bilateral ilium with sacral rods. Another sacral rod extending into the pelvis was connected to the spinal rod, which was affixed to the pedicle screws of L3-L5. In the NR, posterior instrumentation consists of pedicle screws inserted into the L3-L5 vertebrae, iliac screws inserted into posterior iliac crest and two rods, which connected them. Anterior instrumentation consists of two screws inserted into inferior endplate of the L5 vertebra, a sacral rod connected with both sides of the pelvis through these screws and a sleeve augmentation of the pelvis. 480 N force was applied vertically to half of the upper surface of the L3 vertebra.[RESULTS] In the MGR, a maximum stress (1042 MPa) on the instrumentation was observed at a region of the spinal rod between the L5 pedicle screw and the iliac screw when 960 N was applied to the L3. In the TFR, a maximum stress of 126 MPa at the pelvis was observed at the medial cortical bone around the sacral rod which was inserted through L5 vertebra. With regard to instrumentation, the maximum stress (222 MPa) was observed at the region of the sacral rod where it inserted into the L5 vertebra between the L5 and the iliac bone. In the NR, the maximum stress (400 MPa) detected on the sacral rod just lateral of the connection with the vertebral screw inserted into inferior endplate of the L5. In the bones, stress concentration (77 MPa) was observed at the region of the insertion of the sacral rod in the pelvis.[DISCUSSION AND CONCLUSION] In MGR, excessive stress was concentrated at the spinal rod since all of the compressive load was transmitted to the pelvis by the spinal rods. There is the risk of fracture of the instrumentation. Breakage of the spinal rod at this juncture has been found clinically. On the other hand, no particular stress concentration was observed in the instrumentation of TFR. However, it is possible that the sacral rod loosening occurs due to higher stress than the yield stress of the cortical bone at interface with the pelvis and L5. If the patient were to stand or sit immediately after MGR or TFR, instrumentation failure or loosening may occur. In NR, excessive stress concentration was not detected in the rod or the bones since the compressive load was transmitted to the iliac bone through the anterior sacral rod and spinal rods. The NR has a low risk of instrument failure and loosening after a total sacrectomy. In principle, the patient who received the NR could stand or sit immediately after the surgery.

POSTER NO. P384

Atlantoaxial Fusion Using Anterior Transarticular Screw Fixation of C1-C2: A Biomechanical Study

Milan Sen, MD, *Louisville, KY (b – Synthes)*
Thomas Steffen, MD, Montreal, QC Canada (n)
Lorne Beckman, Montreal, QC Canada (*)
Rudolph Reindl, MD, Montreal, QC Canada (n)
Max Aebi, MD, Bern, Switzerland (*)

Introduction: Anterior transarticular screw fixation of C1-C2 for the treatment of atlantoaxial instability has advantages over posterior transarticular screw fixation as described by Magerl. The proper technique for insertion of these screws however has not been described and no information is available on the strength of this construct. The purpose of this study was to describe a new technique for anterior transarticular screw fixation of the atlantoaxial joints, and to compare the stability of this construct to posterior transarticular screw fixation with and

without laminar cerclage wiring. Methods: Nine human cadaveric specimens were included in this study. The C1-C2 motion segment was instrumented using either anterior transarticular screws (Group 1), or posterior transarticular screws alone (Group 2), or posterior screws with inter-laminar cerclage wires (Group 3). Using an unconstrained mechanical testing machine the specimens were tested in rotation, lateral bending, and flexion-extension using non-destructive loads of +/- 2 Nm. The specimens were also tested in translation using non-destructive loads of +/- 100N. Results: All values for the three groups with regards to anterior/posterior displacement, rotation, and lateral bending were similar as determined using a Kruskal-Wallis rank sum test with a significance level of $p < 0.05$. The only significant difference was registered in flexion/extension where the cerclage wire added some strength to the construct. Discussion: Anterior transarticular screw fixation of the atlantoaxial spine has several advantages over posterior fixation techniques, and is as stable as posterior transarticular fixation in all clinically significant planes of motion. The addition of posterior inter-laminar cerclage wiring only improves resistance to flexion/extension forces. Conclusion: Our biomechanical data support our clinical case experience, and we feel confident recommending this procedure as a surgical option for the management of atlantoaxial instability. The strength of the construct, ease of the surgical approach, and decreased risk associated with screw insertion make anterior transarticular screw fixation comparable, and in certain situations superior, to the Magerl screw technique. Anterior transarticular screw fixation of the atlantoaxial joint should therefore become the method of choice for C1-C2 stabilization.

POSTER NO. P385

Randomized Trial Of Grafton DBM Putty Composite vs. Autograft Bone In Lumbar Spine Fusions

Alexander Vaccaro, MD, *Philadelphia, PA*
(e – Educational Consultant)

Iliac crest may not provide an adequate amount of bone for multilevel spinal fusions and revision procedures, particularly in osteoporotic patients with insufficient bone stock. Grafton® Demineralized Bone Matrix (DBM) Putty (Osteotech, Inc., Eatontown, NJ 07724) is an osteoinductive and osteoconductive graft material. This study reports the 24-month fusion rates of a composite of Grafton® DBM Putty in posterolateral spine fusion patients. Methods: Patients (N=67) with degenerative spondylolisthesis or degenerative disc disease requiring one or two level posterolateral lumbar or lumbosacral fusion were randomly assigned to one of three groups: Grafton® DBM Putty mixed with bone marrow aspirate (BMA) and locally derived autologous bone (3:1:1 ratio), Grafton® DBM Putty mixed with iliac crest bone (1:1 ratio), or iliac crest bone alone. Only segmental fixation instrumentation was used in this study.A radiologist blinded to treatment assignment examined radiographs at several postoperative follow-up intervals through 24-months and rated the fusion mass as fused, or not fused. Results: Fusion was achieved in 11/18 cases (61%) in the Grafton® DBM, local bone and BMA group, in 16/25 cases (64%) in the Grafton® DBM and iliac crest group, and in 16/24 cases (67%) in the iliac crest control group. Conclusion: These findings indicate that there were no clinical or statistical differences among treatment groups. Thus, Grafton® DBM as a composite graft may eliminate or reduce the amount of second site bone needed for grafting thereby reducing associated morbidity and cost.

POSTER NO. P386

Lumbar Arthrodesis Surgery in Obese Patients-Morbidity and Outcomes

Daniel Alexander Capen, MD, *Manhattan Beach, CA (n)*
Russell W Nelson, MD, Westlake Village, CA (*)
John M Larsen, MD, Westlake Village, CA (*)
Laura Chavers, BS, Downey, CA (*)

Obesity is epidemic in many societies. Spinal diseases also are epidemic. The spine surgeons challenge is to treat many patients where obesity may complicate surgical intervention. The question of safety and efficacy of surgery in the obese patient was posed. Reconstructive arthrodesis of the lumbar spine was performed in 124 patients with documented obesity by Body Mass Index (kg weight/height in meters2)definition. Obesity is a BMI of 30 or greater. A retrospective analysis of surgical complications, outcomes, and arthrodesis rates was conducted.Outcomes were measured by a modified SF-36 model. Fusion was documented by Motion Radiographs and /or C-T study. Morbidity and mortality were quantified. There were 3 deaths, all at day 6 post surgery. Massive MI was noted on autopsy in two cases and Pulmonary Embolism occurred in one case. Superficial anterior wound separation and superficial infection occurred in 19cases. Surgical arterial embolism from anterior exposure was noted in seven patients. Overall complication rates of all cases was 22%. Severe complications in 11 patients (8.9%) presents different challenges for surgeon.Arthrodesis rates for single and multilevel lumbar procedures was not affected by obesity. In this group solid arthrodesis at an average of 9 months was noted in 115 of 124 cases. Outcomes measure indicated patient satisfaction in 98 of 124 cases.While there is clearly increased risk in lumbar surgery in the obese population and the surgery is more difficult and time consuming it appears that there can be successful fusion with improved life activity, reduced pain medication requirements and return to gainful employment.

POSTER NO. P387

Selective vs Nonselective Fusion of Lenke I Curves in Adolescent Idiopathic Scoliosis (AIS)

Peter O Newton, MD, *San Diego, CA (a,b – DePuy Spine)*
Frances Faro, MD, San Diego, CA (n)
Randal R Betz, MD, Langhorne, PA (a – DePuy Acromed)
Linda P D'Andrea, MD, Blue Bell, PA (a – DePuy Acromed)
David H Clements III, MD, Camden, NJ (a – DePuy Acromed)
Lawrence G Lenke, MD, Saint Louis, MO (a – DePuy Acromed)
Thomas G Lowe, MD, Wheat Ridge, CO
(b – Medtronic, Johnson&Johnson)
Andrew A Merola, MD, New York, NY (n)
Thomas Richard Haher, MD, New York, NY (n)

Introduction: To compare the preoperative radiographic factors of patients at five sites nationwide who were fused selectively (thoracic curve only) versus non-selectively (both curves fused) for Lenke type IB or IC curves in patients with AIS. Methods: In a series of AIS patients from the Harms Study Group who underwent surgical correction for a Lenke IB or IC curve, 41 patients treated with a nonselective fusion (below L1) were compared to 155 patients who were fused selectively. Data about the thoracic and lumbar curves was collected from preoperative radiographs. Results: Of the type IB curves, 89% were fused selectively; 63% of the type IC curves were fused selectively. Lumbar curve, bend and apical displacement from the central sacral vertical line were all significantly greater in the nonselective

PAPERS, POSTERS & SCIENTIFIC EXHIBITS SPINE

group (p<0.01). The percentage of non-selective fusions at the various centers ranged from 6% to 36%. Center-specific multivariate analyses revealed different patterns of significance in the above variables in patients fused selectively versus non-selectively, suggesting that surgeon style/philosophy have a significant effect on the decision to fuse the lumbar curve. Discussion and Conclusion: The characteristics of the "non-structural" lumbar curve played a significant role in the surgical decision-making process and varied substantially amongst members of the study group. Side bending correction of the lumbar curve to <25 degrees (defining these as nonstructural curves) was not sufficient criteria to perform a selective fusion in many of these cases. This variation between surgeons confirms that controversy remains about when the lumbar curve can be spared.

POSTER NO. P388

Anatomy of the Posterior Iliac Crest: A Study from the Hamann-Todd Collection

Joseph Smucker, MD, *Cleveland, OH (n)*
Sam Akhavan, MD, Cleveland, OH (n)
Varun Mahajan, BS, Cleveland, OH (*)
Jung U Yoo, MD, Cleveland, OH (n)
Christopher George Furey, MD, Cleveland, OH (n)

Introduction: Posterior iliac crest bone graft harvest is commonly utilized for obtaining autogenous bone graft in large volumes. The surgeon must appreciate the anatomy of this region to minimize risk. Methods and Materials: An anatomic study was undertaken using the Hamann-Todd collection, a collection of over 3500 human skeletons. Bilateral human ilia were examined from 50 males and 50 females 18-80 years old. Age, gender and side were recorded. Four parameters were recorded three times using digital caliper and averaged for accuracy: the shortest distance from the posterior superior iliac spine to the sciatic notch (PN), the shortest distance from posterior superior iliac spine to the sacroiliac joint (PS), the anterior-posterior length of the sciatic notch (P90) and the length of the sacroiliac joint (SI). Results: Right and left ilia were compared and no significant difference was found. The mean for all 4 measurements was slightly larger in males and statistically significant (PN: male 43.7mm +/-4.6 vs. female 39.7mm+/-5.8; PS: 21.5mm +/-7.8 vs. 16.9mm +/-5.3; P90: 16.7mm+/-3.8 vs. 15.3mm+/-3.6; SI: 60.0mm+/-5.9 vs. 55.2mm+/- 5.8). The ranges and distribution of data within the ranges were compared. Males had higher maximum limits although the lower limits were similar (PN: male 28.7mm-62.7mm vs. female 28.0mm-51.0mm; PS: 7.3mm-43.3mm vs. 4.7mm-34.3mm; P90: 9mm-25.3m vs. 7.7mm-22.7mm; SI: 42.3mm-69mm vs. 50.0mm-79.0mm). Discussion/Conclusion: Our results indicate that males and females have similar means and lower ranges in all four measurements, with the largest mean difference being 5mm. This study defines distances in the posterior iliac crest beyond which the risk of injuring important structures is present.

POSTER NO. P389

Influence of Diagnosis on Outcome after Lumbar Fusion for Degenerative Disc Disease

Christopher Bono, MD, *Boston, MA (n)*
Casey K Lee, MD, Roseland, NJ (a – Stryker Spine)

Introduction: Numerous stages along the degenerative cascade can be considered diagnostic subgroups, however, few studies have compared lumbar fusion results between them. It was the authors' purpose to critically analyze the literature from the past 20 years to examine the influence of diagnostic subgroups on lumbar fusion results for degenerative disc disorders (DDD). Methods: Published results were organized into groups: degenerative spondylolisthesis (DDDsp), herniated disc (DH), scoliosis (DDDsc), stable DDD (DDDs), unstable DDD (DDDu), and DDD not otherwise specified (DDDn). Instrumentation, fusion location and rate, clinical outcome, and complication rate were recorded. Data was pooled and statitistically analyzed. Results: 78 articles (4454 patients) were eligible for review. The most common diagnosis was DDDn (50 percent), followed by DDDsp (25), DH (14), DDDu (6), DDDs (3), and DDDsc (2). Fusion rates were 87, 76, 95, 88, 91, and 87 percent. Good/excellent outcomes were recorded in 73, 80, 78, 67, 71, and 82 percent of cases. Though fusion rates were lower for DDDsp (p .01), clinical outcomes were better than DDDn (p .05). Instrumentation for DDDn resulted in a higher fusion rate but poorer clinical outcome than uninstrumented cases. In contrast, instrumentation for DDDsp resulted in both higher fusion rate and better clinical outcomes. Discussion: The data indicate that clinical outcome and fusion rates differ among the degenerative cascade subgroups. In addition to increasing fusion rates, instrumentation appears to be clinically beneficial for some subgroups, while its routine use should be carefully reconsidered for others.

POSTER NO. P390

Functional and Radiographic Outcome of Sacroiliac Joint Arthrodesis

Jacob Buchowski, MD, *Baltimore, MD (n)*
Khaled M- Kebaish, MD, Baltimore, MD (n)
Vladimir Sinkor, MD, Baltimore, MD (*)
David A Cohen, MD, Baltimore, MD (*)
John P Kostuik, MD, Baltimore, MD (n)

Introduction: The objective of this study was to describe the outcome of sacroiliac joint (SIJ) fusion, with the hypothesis that sacroiliac arthrodesis leads to improved postoperative function. Methods: Patients who underwent SIJ arthrodesis were identified and recruited. Those patients who had other concomitant procedures at the time of surgery were excluded. General health and function was assessed using the SF-36 Health Survey and AAOS Modems Instrument. Results: Twenty consecutive patients with an average age of 45.1 years were recruited. The mean duration of symptoms was 2.6 years, and the mean follow-up period was 4.6 years. The diagnosis was confirmed by pain relief with local injections into the joint under fluoroscopic guidance. Multiple etiologies of sacroiliac symptoms were observed: SIJ dysfunction in 13, osteoarthritis in 5, post-partum SIJ instability in 1, and sacroilitis in 1. 17 of 20 patients went on to a solid fusion. 15 of 20 patients completed pre- and post-operative SF-36 forms. Statistically significant improvement was noted in all SF-36 categories except General Health and Mental Health. Statistically significant improvement was also noted in the Modems Neurogenic Index, Pain/Disability Index, and Satisfaction with Symptoms scale. Discussion and Conclusion: Sacroiliac arthrodesis is a safe and well-tolerated procedure and can be expected to produce a fusion rate of 85 percent. Statistically significant improvement in functional outcome can be expected in multiple categories in carefully selected patients with a documented pain generator at the SIJ. Although the procedure has been used successfully for the treatment sacroiliac joint disorders, to our knowledge, this is the largest series to document the functional and radiographic outcome of sacroiliac joint arthrodesis.

POSTER NO. P391

Osteochondroma of the Spine; Analysis of Twelve Cases and Review of the Literature

Robert Shay Bess, MD, *Cleveland Heights, OH (n)*
Mark R Robbin, MD, Cleveland, OH (n)
Henry H Bohlman, MD, Cleveland, OH (n)
George H Thompson, MD, Cleveland, OH (n)

Objectives: Evaluate the treatment experience of spinal exostoses, and review 165 cases of spinal exostoses reported in the literature. Summary of Background Data: Spinal osteochondromas are uncommon. Most reports consist of one to three cases. Our experience reviews the largest clinical series of spinal exostoses in the English literature. Methods: The complete radiographic and medical records of 12 patients with spinal exostoses treated at our institutions between February 1972 and April 2002 were reviewed. Literature was reviewed using MEDLINE search of English literature. Results: Isolated spinal osteochondromas were more common than those associated with multiple hereditary exostoses (MHE). Spinal exostoses were most common in the upper cervical spine, and originated from the posterior elements. Patients with exostoses associated with MHE were significantly younger and had a higher incidence of symptoms consistent with neurological compression than patients with isolated osteochondromas. Tumor excision resulted in resolution of preoperative symptoms. Intralesional tumor excision resulted in recurrence in all cases. Conclusions: Spinal exostoses are more common than reported in the literature. Physicians evaluating patients with MHE that present with local or neurological symptoms should have a high suspicion for spinal exostoses. Evaluation should include both CT scan and MRI of the spine to define the origin of the tumor and the presence of neurological compression. Surgical excision should be preformed en bloc as intralesional excision results in an unacceptably high recurrence rate.

POSTER NO. P392

Posterior Occipitocervical Fusion with Cotrel-Dubousset and Summit System Instrumentation

George Sotirios Themistocleous, *Athens, Greece (*)*
Georgios Sapkas, MD, Kifisia-Athens, TK Greece (n)
Paul Katonis, Heraklion, Greece (*)
Alecos Hadjipauvlou, Prof, Athens, Greece (*)
Agisilaos Aligizakis, Athens, Greece (*)
Nicolaos Gandaifis, Athens Attiki, Greece (*)

Introduction: The present study was designed to evaluate surgical handling, results, and complications of occipito-cervical fusion. Material-methods: Since January 1995, 22 consecutive patients with craniocervical spine instability and serious neurological deficit were treated with posterior instrumentation and fusion. Ankylosing spondylitis was the cause of instability in 3 cases, tumor in 8, rheumatoid arthritis in 7, trauma in 3 and cervical spondylosis in one .The Cotrel-Dubousset rod-hook system (CD) was used in 16 cases and the Summit System (Depuy-Acromed) in 6 cases, combined with Brooks-Gallie technique in 3 cases and cervical laminectomy in 3 others. Postoperatively the stabilization was secured with a Halo- Jacket for a period of at least 3 months and a Philadelphia collar for additionally 3 months. Results: Patients were followed clinically and radiologically for 1 to 4 years (mean 20 months) using the following parameters: spine anatomy and reconstruction, sagittal profile, neurologic status, functional level, complications and status of arthrodesis.. Assessments were routinely performed at 1 week, 1 month, 3 months, 1/2 year, and every year after surgery. A stable bony fusion was achieved in all cases and there were no instrument-related failures. Good to excellent functional results were seen in 78% of the operated patients and acute,chronic pain was reduced by an average of 2.5 grades, on a scale of 0-3.At final follow-up there was an improvement of the neurologic Frankel status by an average of 1.3 grades. Conclusion: Occipito-cervical fusion with instrumentation is considered an effective and reliable method for the treatment of craniocervical instability.

POSTER NO. P393

Unipedicular Kyphoplasty for Treatment of Vertebral Compression Fractures

Stephen J Timon, MD, *Euless, TX (*)*
Michael J Gardner, MD, New York, NY (n)
Richard Hong, New York, NY (a – Kyphon, Inc)
Joseph M Lane, MD, New York, NY (*)

Introduction: Kyphoplasty effectively achieves pain relief and deformity correction in vertebral compression fractures. The purpose of this study was to evaluate the efficacy of single-balloon unipedicular kyphoplasty in restoration of vertebral height. Methods:One hundred and twenty-one vertebral compression fractures in fifty-two pateints underwent kyphoplasty utilizing a unilateral pedicular approach. One pedicle was perforated posteriorly and the guide wire was inserted across the midline on the anteroposterior view. Each level was measured preoperatively and serially in the postoperative period. Results:Average restoration of anterior height was 21 percent,p less than 0.01, mid-body height increased 40 percent,p less than 0.01, and posterior height increased 5 percent ,p less than 0.01. Forty-eight SF-36 questionnaires were available for analysis. The physical functioning subsection score improved an average of 36 percent ,p less than 0.01, bodily pain improved 68 percent ,p less than 0.01, vitality improved 26 percent ,p less than 0.05, and role emotional improved 56 percent ,p less than 0.01,. Thirty-one Oswestry questionnaires were evaluated and scores improved an average of 30 percent ,p less than 0.01. Conclusions: Single-balloon kyphoplasty allows for excellent correction of deformity and provides the patient with significant pain relief and improved functioning. The correction and patient satisfaction achieved in this series is consistent with previous reports using a standard bipedicular technique. By using a unilateral approach to kyphoplasty, it significantly reduces operative time while maintaining the integrity of the contralateral pedicle.

POSTER NO. P394

◆The Gross and Histologic Behavior of Polymethylmethacrylate During Kyphoplasty versus Vertebroplasty

Jeffrey J Kovacic, MD, *Cleveland, OH*
(a – Synthes, b - Kyphon, Inc)
Isador H Lieberman, MD, Cleveland, OH
(a,b,e – Kyphon, Inc)
Daisuke Togawa, MD, Cleveland, OH (a – Kyphon, Inc)
Thomas W Bauer, MD, PhD, Cleveland, OH (*)
Darrel S Brodke, MD, Salt Lake City, UT (*)
Mary Kay Reinhardt, RN, Cleveland, OH (*)

Introduction:The purpose of this study was to compare the gross and histologic behavior of PMMA during and after both kyphoplasty and vertebroplasty. Materials and Methods:Six elderly, female, osteoporotic baboons were identified. A fluoroscopically-guided, unilateral approach under sterile conditions was used to perform vertebroplasty and kyphoplasty at two levels in

each animal. One level underwent cavity creation only (by inflatable bone tamp expansion). Two levels served as unoperated controls. The seven levels were randomized to the various treatments within each animal. Three animals were sacrificed at 24 hours and three at 26 weeks post-operatively. Immediately after sacrifice, study levels were harvested, labeled, and preserved per protocol. First they were examined macroscopically for evidence of cement migration. Then, both decalcified and undecalcified sections were prepared and examined for evidence of osteonecrosis, foreign body reaction, and cement extravasation. Results:Nine out of twelve vertebroplasty specimens had evidence of intravascular cement extravasation as opposed to two out of twelve kyphoplasty specimens (p=0.002). Histologic analysis revealed cement particles within vascular spaces in multiple specimens. Five vertebrae in each group revealed gross evidence of cement leak into the spinal canal via the foramen for the basivertebral vein. There was evidence for foreign body reaction in some specimens in the 26-week group. No specimen demonstrated evidence of osteonecrosis as a result of the interventions. Discussion/Conclusion:Creating a void in which to place PMMA decreases the likelihood of cement extravasation. Neither intervention causes osteonecrosis. The presence of cement particles induces a local foreign body reaction.

POSTER NO. P395

Lumbar Adjacent Segment Disease: Surgical Outcomes and Complications

Gary Ghiselli, MD, *Cleveland, OH (n)*
Jeffrey C Wang, MD, Los Angeles, CA (n)
Wellington Hsu, MD, Los Angeles, CA (n)
Edgar G Dawson, MD, Santa Monica, CA (*)

STUDY DESIGN: Retrospective investigation of patient outcome and surgical success for patients diagnosed with adjacent segment disease. OBJECTIVE: To determine follow-up data on the surgical success and functional outcome of patients after surgical intervention for adjacent segment disease, specifically evaluating rate of pseudarthroses adjacent to a fusion mass. SUMMARY OF BACKGROUND DATA: There are no studies that look at the long-term follow-up of such patients surgically treated for adjacent segment disease and the influence of demographic and surgical variables on the surgical success and patient outcome. METHODS: Twenty-nine patients (average age 52.2 years; range 21-88), were observed for an average of 5.9 years (range 2.0-11.1 years) following surgery for adjacent segment disease. All patients had documentation of adjacent segment disease that developed after a primary posterior lumbar fusion. Patients were followed to evaluate surgical success and patient outcome. Patient outcome was evaluated with a modified four grade functional outcome scale. Twenty-five of the patients had an adjacent segment fusion while 4 of the patients had an adjacent segment decompression without fusion. All patients had follow-up office visits with examinations and radiographs. Radiographic union, functional outcome and failure, defined as need for further surgery, were evaluated. RESULTS: Pseudarthroses developed in 4/25 (16%) of patients treated with a subsequent fusion. One patient developed new disease adjacent to the fusion mass requiring adjacent segment decompression and fusion. Of the twenty-nine patients followed, 27/29 (87%) had a good or excellent functional outcome at one year following surgery. Functional outcome at last follow-up however, declined to only 12/29 patients (41%) with a good or excellent functional outcome. CONCLUSION: There are few studies which detail the success for the surgical management of adjacent segment disease. Our study shows that there is an increased rate of pseudarthroses after surgical fusion for adjacent segment disease. Although patients improved considerably in the short-term, there was a decrease in long-term functional outcome. DISCUSSION: This is the first study to detail the rate of pseudarthoses and functional patient outcome after a fusion adjacent to a previous fusion mass.

POSTER NO. P396

Histological Evaluation of Human Posterolateral Lumbar Fusion Mass Induced by Osteogenic Protein-1

Daisuke Togawa, MD, *Cleveland, OH (a – Stryker-Biotech)*
Thomas W Bauer, MD, PhD, Cleveland, OH (*)
Masahiro Kanayama, MD, Hakodate, Japan (a,b – Stryker-Biotech)
Tomoyuki Hashimoto, MD, Hakodate, Japan (*)
Keiichi Shigenobu, MD, Sapporo, Japan (*)
Shigeru Yamane, MD, Hakodate, Japan (n)

INTRODUCTION: The purpose of this study is to describe histological findings of biopsies obtained from bone induced by the OP-1 device during human posterolateral spinal fusion. METHODS: Nineteen patients having an L3/4 or L4/5 spondylolisthesis with spinal stenosis were included in this Institutional Review Board approved study. Each patient underwent single level posterolateral fusion using pedicle screw instrumentation and was randomized to receive either Osteogenic Protein-1 putty alone or a combination of autograft with hydroxyapatite/tricalcium phosphate granules. After radiographic confirmation of fusion, the patients underwent removal of pedicle screws and a small biopsy was obtained of the fusion mass for histologic evaluation. RESULTS: A total of 24 specimens from 16 patients were available for evaluation. Of the 13 samples from the OP-1 group, all cases except one showed viable bone. Based on its microscopic appearance, the bone is expected to have normal mechanical properties. In one case, residual OP-1 carrier was recognized associated with a little bone formation. No acute inflammation was present in any biopsies. One of the OP-1 specimens contained evidence of hyaline cartilage surrounded by bone in a pattern that suggested advanced remodeling of bone of endochondral origin. HA/TCP granules were recognized in all 9 control cases; some granules had extensive bone apposition while others were surrounded by fibrous tissue. CONCLUSIONS: This is the first histologic report to show that the OP-1 alone can induce new bone formation in human posterolateral fusion. Modifying technique to maximize retaining OP-1 adjacent to hardware may improve fusion rates.

POSTER NO. P397

A Prospective Randomized Study of Percutaneous Endoscopic and Microscopic Lumbar Discectomy

Jae Yoon Chung, MD, *Gwangju, Korea, Republic of (n)*
Sung Man Rowe, MD, Gwangju, Korea, Republic of (n)
Eun-Sun Moon, Prof, Kwangju-City, Korea, Republic of (n)
Eun Kyoo Song, MD, Kwangju, Korea, Republic of (n)
Keun Bae Lee, Gwangju, Korea, Republic of (n)
Hyoung Yeon Seo, MD, Gwangju, Korea, Republic of (n)

INTRODUCTION : Reported clinical results of percutaneous endoscopic discectomy were variable from 70 percent to 90 percent of success rate and there was only a few reports based on scientific study design. PURPOSE OF STUDY : The authors compared the results of the percutanceous endoscopic discectomy(PES) with microscopic discectomy(MS) only in the

protruded type lumbar disc herniations as a prospective and randomized study. METHODS : Both groups were consisted of 39 patients. Minimum follow up period was two years. Method of operation was selected at random base and was performed under local infiltration anesthesia in all cases. Levels were L4-5 and L5-S1 in 35 and 4, and 31 and 8 in PES and MS, respectively. RESULTS : Average admission periods were 2.8 days in PES and 4.8 days in MS group. Returning to activity level before illness were possible at 42 and 53 days, postoperatively. The over-all objective clinical result was satisfactory in 92 percent and 90 percent. At L4-5 level, it was 97 percent and 87 percent while 50 percent and 100 percent at L5-S1. Disc space height was changed in PES group, from 12.2mm, preoperatively, to 11.2mm (8.3percent) postoperatively, and in MS group, from 12.4mm to 10.9mm(16.9 percent)($p<0.05$). CONCLUSION: Although overall clinical result was similarly satisfactory in both methods. Radiologically, narrowing of disc space height after PES were significantly less than in MS. Regarding the less invasiveness of PES, the authors recommend PES when it is surgically indicated and technically possible.

POSTER NO. P398

Elevation of Concave Thorax Used in Posterior Correction of Scoliosis

Lihua Zhu, MD, *Nanjing, China (n)*
Yong Qiu, NanJing, China (n)

Objective: To investigate the methods and clinical significance of elevation of concave thorax in posterior correction of scoliosis. Methods: All 20 cases were congenital scoliosis in our group, with the mean age of 15.5 years (10-21 years old). 9 cases had the elevation of concave thorax during the second-stage posterior correction, while 11 cases had single posterior correction and elevation of concave thorax. 3 cases received both elevation of concave thorax and convex thoracoplasty (when the razor deformity was above 50 degree). The surgical technique was a modification of Mann¡¯s. These cases were followed 25 months (from 6-46 months). The profile¡¢razor deformity¡¢Cobb angle and X rays were compared before and after surgery, the surgical complication was recorded. Results: The mean number of rib osteotomy was 4.5. All the 20 cases became satisfied (13 cases) and approximately satisfied (7 cases) with their back shape. The mean razor deformity decreased from 37.3 degree to 10.9 degree after surgery. The mean Cobb angle was 82 degree before operation and 37 degree after. Pleural perforation and effusion occurred in 1 case, but recovered quickly after several aspirations. Conclusion: Compared to the traditional convex thoracoplasty, the osteotomy of concave ribs increased the flexibility of the rigid spine, and was helpful to the posterior correction of the lateral curve. The surgery also elevated the depressed thorax in the coronal plane, enlarged the volume of the thorax. This technique was safe, most of the patients did not need to receive another convex osteotomy.

POSTER NO. P399

Minimal Open Anterior Instrumentation for Thoracolumbar Scoliosis without Diaphragm Dissection

Bin Wang, MD, *Nanjing, China (n)*

[Abstract] Objective: To investigate the feasibility and clinical importance of a new surgical approach for anterior instrumentation of thoracolumbar scoliosis without the diaphragm dissection. Methods: From June 2002 to March 2003, 17 AIS patients underwent one-stage anterior instrumentation and spinal fusion. The mean age was 14.6 years (12~19 years). The standing cobb angle was 56 degrees (44¡«76 degree) pre-operatively. Thoracolumbar kyphoses with Cobb angle from 10 to 18 degrees were found in four patients. Patients were positioned on a concave side lateral decubitus position. Two small incisions were made, one below the diaphragm for retroperitoneal and one above the diaphragm for extra/transpleural spinal exposure without diaphragm dissection. The pre-contoured rod was inserted through a hole in diaphragm and derotation and compression maneuver were applied for correction. Results: The initial curve correction was 80 percent. The sagittal alignment restoration was satisfactory. The instrumentation level were from T11 to L3 in 12 cases, T10¡«L3 and T11¡«L2 in two cases respectively, T11¡«L4 in one case. The operation time averaged 240 minutes (210~270 minutes). The blood loss was 400ml (310~600ml). Two patients experienced transient rise of skin temperature and overcorrection. The rehabilitation time was short and the small incision healed very well. No death, no vascular injury or paraplegia occurred in these patients. Conclusion: Minimal open anterior instrumentation for thoracolumbar scoliosis without diaphragm dissection is proved to have the same outcomes as the traditional anterior instrumentation approach without the increase of complication.

POSTER NO. P400

A Prospective Study of De Novo Scoliosis in a Community-Based Cohort

Tetsuya Kobayashi, *Little Rock, AR (n)*
Yuji Atsuta, MD, Asahikawa, Japan (n)
Motoya Ikawa, MD, Asahiksawa, Japan (*)
Hiromi Tsunekawa, MD, Asahikawa, Japan (n)
Takeo Matsuno, MD, Asahikawa, Japan (n)
Naoki Takeda, MD, Asahiksawa, Japan (n)
Masakazu Takemitsu, Wilmington, DE (*)
Tsukasa Onozawa, MD, Asahikawa, Japan (*)

INTRODUCTION: Scoliosis can arise de novo in later life, however, there has been controversy over its etiology. Factors associated with the incidence of degenerative scoliosis have been unclear in previous cross-sectional studies. The purpose of this study was to identify predictors of de novo scoliosis in the elderly in a prospective design. METHODS: Community-based volunteers were recruited, and were examined by an orthopaedic doctor. Their clinical data were recorded, followed by radiological evaluation using standing entire spine radiographs. Radiographic measurements included the angle of scoliosis and sagittal spinal curvatures, degree of bone atrophy, number of degenerated discs and vertebral fractures. We defined radiographic parameters in AP X-ray, the disc index (DI) and the lateral spur index (LSI), in order to evaluate the asymmetrical spinal degeneration. RESULTS: Sixty subjects aged 50-84 years and without scoliosis at baseline were selected and followed for a mean of 12 years. Twenty-two subjects developed de novo scoliosis of more than 10 degrees during observation, and logistic regression analysis revealed that baseline DI and LSI were independent predictors of de novo scoliosis ($P<0.05$). DISCUSSION AND CONCLUSION: Incidence of de novo scoliosis was predictable by assessing unilateral changes of disc degeneration in AP X-ray. More than 20 % decrease in unilateral disc height, or more than 5 mm longer bony spur on one side led to increased incidence of de novo scoliosis, which might also influence long-term results of lumbar surgery. This study provides substantial data to understand the etiology of degenerative scoliosis.

POSTER NO. P401

Treatment Strategy of Scoliosis Associated with Chiari Malformation and/or Syringomyelia

Yong Qiu, *NanJing, China (n)*
Bin Wang, MD, Nanjing, China (*)
Zezhang Zhu, MD, Nanjing, China (*)

Objective: To evaluate the treatment strategy of the scoliosis associated with Chiari malformation and /or syringomyelia. Methods: A total of 52 cases suffered from scoliosis with Chiari ?ntilde;malformation and /or syringomyelia were divided into three groups for surgical treatment. Group 1: 18 cases without obvious neurologic impairment, their scoliosis was corrected with posterior instrumentation if surgically indicated, but their Chiari ?ntilde;malformation and syringomyelia were left untreated surgically. Group 2: 12 patients, their Chiari malformation was associated with syringomyelia, underwent posterior suboccipital craniectomy, C1 posterior arch decompression and dural plasty, no matter whether neurologic deficits were present or not. Group 3: 22 cases, whose scoliosis needed operative treatment and whose Chiari ?ntilde;malformation or syringomyelia caused neurologic deficits, had two-stage surgery: firstly, they underwent the decompression surgery, 6 months later, they underwent the scoliosis correction with instrumentation. Results: In 34 patients who underwent craniovertebral decompression, only 6 of the 24 cases with preoperatively neurologic deficits achieved mild improvement in 6 months postoperatively. In 40 patients who were treated with posterior correction for scoliosis, the average frontal correction was 56 percent, the average sagittal correction was 77 percent. After a mean 19-month follow-up, the average loss of the frontal correction was 6 percent. Conclusion: Scoliosis associated with Chiari malformation and /or syringomyelia can be corrected satisfactorily. Accurate diagnosis and proper treatment for Chiari?ntilde;malformation or syringomyelia before scoliosis surgery will improve the rate of scoliosis correction, decrease the surgical complications in scoliosis and the potiential complications of Chiari ?ntilde;malformation and syringomyelia.

POSTER NO. P402

◆The Effect of rhBMP-2 on Allograft Union and Remodeling in a Corpectomy Model

Klane Keele White, MD, *San Diego, CA (a – Medtronic Sofamor Danek)*
Maneesh Bawa, MD, San Diego, CA (*)
Jae-Sung Ahn, Daejeon, Korea, Republic of (n)
Christine L Farnsworth, San Diego, CA (n)
Frances Faro, MD, San Diego, CA (n)
Andrew Mahar, San Diego, CA (n)
Michelle A Wedemeyer, BS, San Diego, CA (*)
Peter O Newton, MD, San Diego, CA (a – Medtronic Sofamor Danek)
Steven R Garfin, MD, San Diego, CA (n)

Introduction: Healing and incorporation of cortical strut allografts after lumbar corpectomy using rhBMP-2 to augment graft union and remodeling were evaluated. Methods: Calves (age 3-4 weeks) underwent L3 corpectomy with tibial strut allograft reconstruction. rhBMP-2 impregnated collagen sponges filled the empty allograft medullary canals in eight animals (7.0-8.4cc/graft, 0.43mg/cc rhBMP-2); eight animals had allografts filled with autogenous bone from the excised vertebra (control group). Allografts were stabilized with ATL Z-plates between L2 and L4. After four months, lumbar spines were harvested for radiographic, biomechanical and histological evaluation. Results: CT scans and microradiographs revealed allograft incorporation into the vertebral endplates in all specimens except for one pseudoarthrosis (control group). BMP-treated spines had more bone/radiopacity at the ends, while the controls maintained a uniform distribution throughout the strut length. Biomechanical testing suggested greater construct stability in the BMP-treated group compared to the controls, with a trend toward greater stiffness in the BMP-treated group in flexion (p=0.18), extension (p=0.12), lateral bending (p=0.17), and torsion (p=0.10). The BMP-treated group was also stiffer in torsion testing to failure (p=0.08). Histology confirmed allograft incorporation for both treatment groups. Capillary in-growth of the BMP impregnated sponge was identified at the leading edge of bone formation; active allograft and autograft remodeling was identified. Discussion and Conclusion: These results, similar to those previously seen in shorter interdiscal grafts/spacers, suggest the efficacy of BMP in large segment reconstructions after a vertebral corpectomy. This study confirms healing and incorporation of large cortical strut allografts supplemented with rhBMP-2 in a corpectomy model.

POSTER NO. P403

Spinal Fusion in Patients with Severe Spastic Quadriplegic Cerebral Palsy in one Institution

Twee T Do, MD, *Cincinnati, OH (a – University of Cincinnati Orthopeadic Research Education Fund)*
Shital Parikh, MD, Cincinnati, OH (*)
Susan Foad, MS, Cincinnati, OH (*)
G Cox, MD, Cincinnati, OH (*)
L Heper, MD, Cincinnati, OH (*)
R Schmidt, MD, Cincinnati, OH (*)
S Chapman, MD, Cincinnati, OH (*)

PURPOSE: The effects of spinal fusion vs. observation treatment in a group of severely involved adult pts with spastic quadriplegic cerebral palsy (CP) were compared to determine the benefit of early aggressive spinal stabilization for neuromuscular scoliosis. METHODS: All non-ambulatory pts greater than 18 yrs age w/ spastic quadriplegic CP at 1 total care facility were evaluated. All had documented scoliosis (defined by curvature greater than 10 degs). Parameters evaluated included pain medication requirement, oxygen saturation, wheel chair tolerance, mode of feeding, incidence of decubitus ulceration, and ease of daily care. A caregiver satisfaction survey was conducted using a questionnaire. RESULTS: Twenty two pts qualified for inclusion in this study. The social and cognitive functional levels of all pts were w/in 0 to 15 and 0 to 16 months, respectively. The average age of 6 pts treated w/ Luque rods was 24.3 yrs. The avg age at surgery was 10 yrs. The remaining 16 untreated pts had an average age of 25.5 yrs. All pts were permanent residents of the home whose regular nursing staff maintained a ratio of 1:3 pts per nurse or nursing aid. The oxygen saturation determined by pulse oximetry was not significantly different between the two groups; one patient in the untreated group required intermittent oxygen therapy to maintain saturation. The wheelchair tolerance and mode of feeding did not differ significantly between the two groups. There were no incidences of decubiti in any patient. Pain medication was not required by any patient in either group. Nursing time and effort for repositioning and transfers were decreased ($p<0.05$) and facilitated, respectively, in pts w/ spinal fusions. The caregiver's satisfaction was higher in the surgically fused group. DISCUSSION & CONCLUSION: In a skilled nursing care facility where a high ratio of nursing staff to pts is available, the long term effects of neuromuscular scoliosis on quality of life is unaffected. In cases where such constant care is unavailable, however, early spinal fusion may facilitate the daily care of these severely affected pts w/ spastic quadriplegic CP as adults.

COMSS POSTER NO. P404

Scoliosis Research Society

Life Expectancy in Pediatric Patients with Cerebral Palsy and Neuromuscular Scoliosis Who Underwent Spinal Fusion

Athanasios I Tsirikos, MD, *London, United Kingdom (*)*
Freeman Miller, MD, Wilmington, DE (n)
Wei Ning Chang, MD, Wilmington, DE (n)
Kirk W Dabney, MD, Wilmington, DE (n)
Joseph Glutting, PhD, Wilmington, DE (*)

The aim of this study was to document survival rate among 288 severely affected pediatric patients with spasticity and neuromuscular scoliosis who underwent spinal fusion, and to identify exposure variables that could significantly predict survival times. Kaplan-Meier survivorship analysis was performed, demonstrating a mean predicted survival of 11.2 years after spine surgery for this group of globally involved children with cerebral palsy (CP). Cox's proportional hazards model was used to evaluate predictive efficacy of exposure variables such as gender, age at surgery, level of ambulation, mental ability, degree of coronal and sagittal plane spinal deformity, intraoperative blood loss, surgical time, days in the hospital, and days in the intensive care unit (ICU). The number of days in the ICU after surgery and the presence of severe preoperative thoracic hyperkyphosis were the only factors affecting survival rates, demonstrating statistically significant predictability for life expectancy after spine fusion in children with CP.

POSTER NO. P405

Video-Assisted Thoracoscopic Surgery Anterior/Posterior Spinal Fusion in Scheuermannfs Kyphosis

Alvin Howell Crawford, MD, *Cincinnati, OH (n)*
Jose A Herrera-Soto, MD, Hummelstown, PA (*)
Shital Parikh, MD, Cincinnati, OH (*)
Mohammed Sayyadd, MD, Cincinnati, OH

Purpose: Scheuermann's kyphosis is characterized by a sharper, fixed curve that encompasses vertebral wedging, and apophyseal irregularities. This project was undertaken to determine whether anterior release via video-assisted thoracoscopic surgery (VATS) and posterior spinal fusion (PSF) would achieve correction and fusion in adolescent Scheuermann's kyphosis. Methods: 17 consecutive pts with Scheuermann's kyphosis who underwent anterior spinal release and fusion via VATS followed by posterior segmental spinal instrumentation and fusion. The fusion levels are determined by the Cobb angle, usually T2-T3 above and below the first lordotic vertebra below. The 1st lordotic vertebra is the one who's cephalad disc space height is 1.5X greater anteriorly than posterior. Results: 17 Scheuermann's pts. All pts returned to f/u at an avg of 2.75 years. The avg pre-operative Cobb angle was 85.1 degrees. We considered normal kyphosis to be 40 degrees. 100 percent correction was considered when the post-operative Cobb angle was 40 degrees. We obtained an immediate correction of 94 percent. At f/u, the pts demonstrated 92 percent curve correction. This corresponds to a loss of 1.5 degrees of correction. Discussion and conclusion: This is the first series to be reported regarding combined VATS release and fusion followed by PSF for the treatment of Scheuermann's kyphosis. There are several advantages to this procedure. The anterior release increases the flexibility of the spine for a safer and more complete and lasting correction of rigid curves. The use of endoscopy has decreased the blood loss and is less morbid than open thoracotomies. Over-correction of the curve or inappropriate fusion levels may elicit proximal junctional kyphosis. If the end-instrumented vertebra includes the 1st lordotic segment, distal junctional kyphosis and the need for further surgeries, may be prevented.

POSTER NO. P406

Oncologic and Functional Outcome Following Sacrectomy for Sacral Tumors

Christopher A Hulen, MD, *Miami, FL (n)*
Allaaddin Mollabashy, MD, Miami, FL (*)
H Thomas Temple, MD, Miami, FL (n)
Frank J Eismont, MD, Miami, FL (n)

Introduction: A retrospective clinical review was performed to evaluate the oncologic and functional outcomes of patients undergoing sacrectomy for sacral tumors. Materials and Methods: The clinical records of twenty-four patients undergoing sacrectomy were evaluated retrospectively. Variables analyzed included onset, treatment, local and metastatic recurrence rates, length of hospital stay, use of adjuvants, and complications. Results: Twenty-four patients underwent sacrectomy at one institution from 1985 until 2001.Histologic diagnoses included chordoma, colorectal adenocarcinoma, chondrosarcoma, malignant fibrous histiocytoma, teratoma, and ganglioneuroma. Average age at diagnosis was 58.6 years. There were 14 males and 10 females. Mean follow-up was 46.8 months. Overall local recurrence was rate was 58.3 percent. Mean time to first, second, third and fourth recurrence was 26.2 months, 40 months, 51.7 months, and 62.3 months, respectively. Mean time to metastasis was 45 months. Twenty-five percent of patients were clinically disease-free at a mean follow-up of 65.5 months. Seventeen percent of patients had normal bowel and bladder control postoperatively. Thirty-eight percent were able to ambulate without assistive devices. Fifty percent of patients had wound complications and eight percent had a deep vein thrombosis. There was one perioperative death. Discussion and Conclusion: In this series, local recurrence was frequent and metastases occurred late. Most patients with multiple recurrences developed distant disease. Adequate surgery for these tumors results in major functional impairment and significant perioperative complications.

POSTER NO. P407

◆Transfected Fibroblasts Producing BMP-2 Induce Posterolateral Fusion in a Rat

Hyun W Bae, MD, *Santa Monica, CA (n)*
Li Zhao, MD, Shandong, China (*)
Linda E A Kanim, MA, Santa Monica, CA (n)
Pamela Wong, BA, Santa Monica, CA (*)
Edgar G Dawson, MD, Santa Monica, CA
(b – Medtronic Sofamor Danek)
Rick B Delamarter, MD, Santa Monica, CA (n)

Introduction: The purpose of this study was to determine if BMP-2-transduced fibroblasts (mouse, human) via retroviral vector can successfully fuse a rat spine. Methods: 24 female adult (3-4 months) Athymic rats were utilized. Fibroblasts from human (foreskin) and mouse (NIH-3T3) were infected with a retrovirus -BMP-2 or -lacZ(Tissue gene Co, gaithersburg, MD). ELISA was completed to determine concentration of expressed protein. For each species, quantities 5x106, 10x106, 20x106 cells, 0.16-0.18mg/ml rhBMP2(Genetics Institute, Cambridge, MA) were absorbed onto 1cm x 0.5cm collagen hemostatic sponge. A posterior midline approach exposed and decorticated the trans-

verse processes of L4 and L5, Cells/ACS, morselized iliac crest bone were implanted between the L4 and L5 transverse processes bed. Radiographs were performed biweekly until sacrifice. L4-L5 segments were palpated manually. Non-decalcified histology was performed. Results: Mouse derived fibroblasts revealed greater protein expression than did human derived fibroblasts. Bony masses were observed in vivo sites implanted with BMP-2-producing fibroblasts between 4 and 6 weeks with all cell lines and quantities; however, larger bony masses were observed with the mouse fibroblasts. All sites implanted with rhBMP-2 protein were fused at 4 weeks. None of the fibroblasts cells infected with lacZ, decortication alone, collagen carrier alone, or autogenous iliac crest bone graft demonstrated bridging. Discussion: In this study, mouse and human fibroblasts transduced with BMP-2 ex vivo via a retrovirus induced spinal fusion. Fibroblasts are easily harvested from skin and are a vibrant cell source for cell mediated delivery of RhBMP-2.

POSTER NO. P408

Risk Factors for Correction Loss of Kyphosis Following Posterior Fusion for Thoracolumbar Injuries

Hiroshi Taneichi, MD, *Bibai City, Japan (n)*
Kota Suda, MD, Sapporo, Japan (*)
Tomomichi Kajino, MD, Bibai, Japan (*)
Kiyoshi Kaneda, MD, Hokkaido, Japan (*)

Introduction: A purpose of this study was to determine indications for anterior column reconstruction in treatment of unstable thoraco-lumbar spinal injuries. Methods: Forty-five patients who underwent posterior stabilization for thoracic (Th1-Th10: 12 patients) or thoracolumbar/lumbar (Th11-L3: 33 patients) spinal injuries were reviewed with minimum two-year follow-up. Injury types were burst fractures in 16 patients, fracture-dislocations in 28, and seat-belt type injury in 1. Severe vertebral body comminution was associated with translational injury in 12 patients with fracture-dislocations. Risk factors analysis for 10 or more degrees correction loss of kyphosis following posterior reconstruction was conducted by multivariate logistic regression analysis. As possible risk factors, age, gender, grade of vertebral body comminution, magnitude of kyphosis correction, levels of injuries, extent of fusion area, and types of fixation devices was selected. Results: Ten or more degrees_f correction loss of kyphosis occurred in 22 patients (48%). In these 22 patients, an average correction loss was 14 degrees ranging from 10 to 27 degrees. Two important risk factors for correction loss were determined: (1) grade of vertebral body comminution (Odds ratio: 16.9, p=0.0023) and (2) levels of injuries (Odds ratio of thoracolumbar/lumbar injuries: 152.2, p=0.0107). Other factors such as extent of fusion area or types of fixation devices were proved to be insignificant. Discussion: In the thoracolumbar and lumbar spine, anterior column reconstruction was essential for not only burst fractures but fracture-dislocations with moderate to severe vertebral body comminution. Pedicle screw fixation or long fusion was not solution to prevent correction loss in such cases.

POSTER NO. P409

Congenital Variants and Anomalies of the Upper Cervical Spine Associated with the 22q11.2 Deletion Syndrome

Eric T Ricchetti, MD, *Philadelphia, PA (n)*
Harish Sadanand Hosalkar, MS, Bombay, India (*)
Lisa J States, MD, Philadelphia, PA (*)
Junichi Tamai, MD, Cincinnati, OH (*)
Melissa Tonnesen, MS, Philadelphia, PA (n)
Donna M McDonald-McGinn, MS, Philadelphia, PA (*)
Elaine H Zackai, MD, Philadelphia, PA (*)
Denis S Drummond, MD, Philadelphia, PA (*)

Introduction: The 22q11.2 deletion is the most common known interstitial chromosome deletion in humans and encompasses a wide spectrum of congenital anomalies. The purpose of this study is to (1) define the variants and anomalies of the upper cervical spine on plain radiography and advanced imaging (CT/MRI) and (2) postulate their clinical significance. Methods: 79 patients with the 22q11.2 deletion underwent evaluation of the upper cervical spine. All patients underwent plain radiography and 22 underwent advanced imaging (CT and/or MRI). Results: At least one developmental variation was observed in every patient on plain radiographs. These included platybasia (91%), basilar impression (3%), dysmorphic C1 (75%), open posterior arch of C1 (59%), occipitalization of C1 (3%), dysmorphic dens (58%), upswept posterior elements of C2 (59%), and C2-C3 fusion (34%). Increased segmental vertebral motion was observed in 56% of patients, with increased occipitoatlantal motion being the most common (44%). CT and/or MRI verified the presence of every variation detected on plain radiographs with one exception and identified 28 additional pathologies: open posterior (4) and open anterior arch of C1 (11), occipital condyle abnormalities (2), occipitalization of C1 (1), basilar impression (2), spinal canal stenosis (5), and spinal cord impingement (3). Discussion and Conclusion: Variations of the upper cervical spine are common in the 22q11.2 deletion, including increased segmental motion with risks of canal stenosis and spinal cord impingement. Plain radiography is the best initial imaging study, but advanced imaging should be pursued in patients who are at risk of developing myelopathy.

POSTER NO. P410

Comparative Study of Anterior Plate Fixation and Pedicle Screw Fixation of Hangman Fractures

Jae Yoon Chung, MD, *Gwangju, Korea, Republic of (n)*
Sung Man Rowe, MD, Gwangju, Korea, Republic of (n)
Eun Kyoo Song, MD, Kwangju, Korea, Republic of (n)
Sung Taek Jung, MD, Gwangju, Korea, Republic of (n)
Hyoung Yeon Seo, MD, Gwangju, Korea, Republic of (n)
Jong-Keun Seon, MD, Kwangju, Korea, Republic of (n)

INTRODUCTION : Most of hangman fracture can be treated by closed reduction and halo-vest. However in some complicated patients, it needs operative management. PURPOSE OF STUDY : This is to compare the clinical results of two operative methods and to find the surgical indications of the techniques. MATERIAL & METHODS : Total of 26 cases were treated operatively. Anterior plate fixation and fusion of C2-3 in 18 cases, pedicle screws in 8 cases. Surgical indications were Levine type II, IIA, III and type IA with rotational force with displacement more than 3mm, angulation of over 10 drgees and with instability proved by X-ray. Minimum follow up period was over two years. RESULTS : Bony union was obtained in all cases of both groups.

Among the 8 pedicle screw group, neck pain was noted in one, limited neck motion in three and post surgical kyphosis in X-ray in three. However, among 18 anterior plate group, there was no such complications. As the operative complications, malposition of screw was seen in two cases of pedicle screw group and transient swallowing difficulties was noted in two cases of anterior plate group. CONCLUSION : Anterior plate fixation of hangman fracture showed excellent clinical and radiological results and fewer complications, while pedicle screw fixation needed larger operative dissection, more bleeding and more fragment complications. So, in most of the surgically indicated cases, anterior plate fixation is recommended. Pedicle screw fixation is indicated in Type IA with rotational displacement.

POSTER NO. P411

Anterior Cervical Decompression and Fusion for Ossification of the Posterior Longitudinal Ligament

Jeffrey Roh, MD, *Olmsted Falls, OH (n)*
Theodore Andrew Belanger, MD, Charlotte, NC (n)
Steve Hanks, MD, Pittsburgh, PA (*)
James Kang, MD, Pittsburgh, PA (n)
Sanford E. Emery, MD, Morgantown, WV (*)
Henry H Bohlman, MD, Cleveland, OH (n)

INTRODUCTION: This report represents the largest single series of North American patients with OPLL related myelopathy treated with anterior cervical decompression and arthrodesis. METHODS: Sixty-one patients with cervical OPLL and associated neurologic compression treated surgically between 1982 and 2002 are reported. Medical records and radiographic studies were retrospectively reviewed for preoperative extent of disease, perioperative complications, and postoperative improvement of neurologic status. RESULTS: Thirty-eight male and twenty-three female patients with a mean age of 52.8 years were followed for an average of 4.0 years. A continuous pattern of OPLL was seen in 11, with 19 segmental, 24 mixed, and 7 other. Dural defects were encountered intraoperatively in eight patients. Average postoperative improvement of 1.5 Nurick grades was observed. No patients became worse neurologically, while 60 demonstrated neurologic improvement at final follow-up. DISCUSSION: Anterior cervical decompression and arthrodesis is a safe and effective method of treating patients with radiculomyelopathy associated with OPLL.

POSTER NO. P412

Dynamic Anterior Cervical Plates and Why They Fail

Hyun W Bae, MD, *Santa Monica, CA (n)*
Rick B Delamarter, MD, Santa Monica, CA (*)

Introduction: Anterior cervical plates that have dynamic angle screws allowing settling into the plate have become popular over recent years. Increasing, these dynamic plates have been referred to our center for revision surgery. The purpose of this study was to analyze the reasons for failure of these plates. Methods: Over a 2-year period, 18 patients required revision surgery for failed dynamic anterior cervical plate fusions. Original surgery included two 1-level, twelve 2-level and four 3-level fusions. Initial and revision surgery radiographs were digitized and analyzed for plate migration, kyphotic angulation, adjacent segment degeneration, graft collapse and fusion status. Results: Time to revision surgery averaged 16months(range 2-36months). All required removal of dynamic plate, anterior discectomy and fusion at the proximal adjacent level. Additionally, 4 required complete or partial vertebrectomy for kyphotic angulation and graft collapse, 3 required repair of pseudoarthrosis. All plates had migrated upwards, impinging the upper adjacent level. Plates with slotted dynamic screw motion averaged 9.5mm migration while plates with variable angle screw motion averaged 5.5mm. Twelve patients developed kyphotic angulation(4-18degrees). Ten patients had graft collapse greater than 2mm. Discussion: Dynamic anterior cervical plates have become popular primarily due to their ability to allow settling of the fusion construct. Unfortunately, with present plate designs this settling process allows plate migration, with possible adjacent level impingement, kyphotic angulation and graft collapse. Plates that allow unlimited dynamic screw motion appear to have the highest potential for unacceptable plate migration while plates with limited motion from variable angle screws may promote fusion and avoid excessive screw motion.

POSTER NO. P413

Clinical Implication of MRI in Osteoid Osteomas and Osteoblastomas of the Spine

Jeong Hyn Ha, MD, *Seoul, Korea, Republic of (n)*
Jun-Sic Park, MD, Seoul, Korea, Republic of (*)
Jae Hyup Lee, MD, Seoul, Korea, Republic of (*)
Jae Hak Lee, MD, Seoul, Korea, Republic of (*)
Jin-Sup Yeom, MD PhD, Seoul, Korea, Republic of (*)
Bong-Soon Chang, MD, Baltimore, MD (n)
Choon-Ki Lee, Seoul, Korea, Republic of (*)

Introduction: Osteoid osteoma(OO) and osteoblastoma(OB) in the spine have been reported to be easily diagnosed with CT and MRI. However, to the best of our knowledge, there isn¡¯t any report about clinical comparison between them in usefulness. Methods: Since 1985 in our department, twelve patients have been diagnosed as OO/OB of the spine. All of them were pathologically confirmed following wide excision. Average age was 18.7 (6~50) years, and mean preoperative symptom duration was 18 (1~96) months. CT scan was done in all cases, and seven of them were initially studied with CT scan. Five took MRI at first. Results: In six (50%), combined spinal deformities of torticollis and scoliosis were found. Misdiagnosis was more common in MRI. In four of five MRI (80%), abnormal signal-intensity changes were found in anterior part, i.e. vertebral body, even though tumors located in posterior side. Two cases were misdiagnosed as infections and one as malignant tumor by radiologist, and in these cases osteosclerotic lesion wasn¡¯t found in simple radiograph. One OO in lumbar spine misinterpreted as pyogenic infection was operated twice. On the contrary, CT scan was more effective and helpful by showing clear margin between bony component and nidus. Conclusion: With increasing use of MRI as first diagnostic tool, these rare tumors can be masqueraded as malignant tumor or other infectious disease without clinical information. Unusual MRI findings in young patients, who complain of persistent pain, should be verified by meticulous physical examination for spinal deformity and other study including CT scan.

POSTER NO. P414

Surgical Results of Drop Foot Due to Lumbar Degenerative Disease

Hiroyuki Aono, *Sakai City, Japan (n)*
Motoki Iwasaki, MD, San Francisco, CA (*)
Akira Miyauchi, MD, Sakai city Osaka, Japan (*)
Shin'ya Okuda, MD, Sakai city Osaka, Japan (*)
Masahiro Moritani, Tokyo, Japan (*)

[Purpose] We studied recovery from palsy after surgery in patients with drop foot caused by degenerative lumbar disorders. [Methods] This study consisted of 32 patients (21 men and 11 women) presented drop foot preoperatively. The mean age at surgery was 56 years. The mean follow-up period was 33 months. The mean duration of palsy was 70 days. Surgical outcome was evaluated "excellent" when muscular strength of TA recovered to grade 4 or 5, "good" when it reached to grade 3, "fair" when it recovered to less than grade 3, and "poor" when there was no improvement. Preoperative factors we studied were diagnosis, number of compression levels, neurological involvement (nerve root or cauda equina), age at surgery, severity of palsy, presence or absence of leg pain and duration of palsy. [Results]Surgical result was "excellent" in 13 patients, "good" in 8 patients, "fair" in 4 patients and "poor" in 7 patients. Overall, 66% showed excellent or good results after surgery. [Discussion] There are few reports about surgical results on drop foot. This retrospective study showed effectiveness of surgery on drop foot. Severity and duration of palsy were considered to be factors affecting surgical results for drop foot. On the other hand, diagnosis, neurological involvement, number of compression level, age at surgery, and presence or absence of leg pain had no significant effect on surgical outcomes. [Conclusion] Severe palsy had poor results and the shorter duration of palsy had the better results for the surgical treatment of drop foot.

POSTER NO. P415

Ventral or Dorso-Ventral Procedure in the Reconstruction of the Lumbar Spine - A Question of BMD?

Berend Linke, DR, *Davos, Switzerland (n)*
Stefan Knoller, MD, Freiburg, Germany (n)
Georg Meyer, Davos, Switzerland (*)
Christina Eckhardt, Davos, Switzerland (*)
Erich Schneider PhD, Davos Platz, Germany (*)

The optimal instrumentation for reconstruction in the lumbar spine following corpectomy is still controversially discussed. The defect is restored using a placeholder plus either a purely ventral instrumentation or a combined dorso-ventral procedure. Published biomechanical studies investigating such corpectomy models recommend the combined procedure, but none of them investigated the influence of bone mineral density (BMD) on the stability. It is hypotizised that the combined procedure is only necessary in case of poor bone quality. This study investigates the dependency between stability of spinal reconstruction situations and BMD of the specimens to establish a threshold value of BMD above which a single ventral procedure provides sufficient stability. 24 lumbar cadaver spine specimens L1-L3 were used. BMD was determined by quantitative computed tomography. A six-degrees of freedom loading device was used to determine range of motion (ROM, 7.5 Nm) in flexion, extension and torsion. Testing included native specimens and specimens after corpectomy of L2 with restoration of the defect with a titanium cage and two reconstruction situations: single ventral and additional dorsal instrumentation. ROM was correlated to BMD by linear regression models. A significant influence of BMD on ROM was found ($p<0.01$) in all loading directions after instrumentation. Single ventral instrumentation was critical concerning axial rotation. Combined dorso-ventral instrumentation offered sufficient stability even in poor bone quality. A threshold value could be found. Single ventral instrumentation is sufficient in case of a BMD≥0.22g/cm3. Determination of BMD and the use of this guideline provides a valuable tool for surgical planning.

POSTER NO. P416

Effect of Time and Storage Media on Osteoprogenitor Cell Viability when Harvesting Graft in Rabbits

Victor Hayes, MD, *New Hyde Park, NY (n)*
Jeff Scott Silber, MD, Ardsley, NY (n)
Farhan Siddiqi, MD, New Hyde Park, NY (*)
Dimitry Kondrachov, MD, New Hyde Park, NY (*)
Lonner Barron, New Hyde Park, NY (n)
Daniel A Grande, PhD, Manhasset, NY (*)

Purpose:To understand the effect of time on osteoprogenitor cell(OP) viability after harvesting rabbit cancellous iliac crest bone graft.To determine the best storage media for the graft. Methods:10healthy New Zealand white rabbits were anesthetized and cancellous iliac crest bone graft was harvested under sterile technique.The cancellous graft was placed in air or normal saline for 0, 0.5 hrs, 1 hr, and 2 hrs.These samples were morsilized and transferred to petri dishes with the required nutritional media for cell proliferation.Petri dishes were incubated for a total of 14 days;the suspension of cells was diluted, centrifuged and the number of OP cells was counted using standard microscopy and a hemocytometer. Results: OP cell viability decreases as time increases after harvesting of the graft.Storage of the graft in saline increases OP cell viability when compared to graft stored in air. Conclusion:Currently in orthopaedic surgery there is no protocol which dictates the optimal time during a fusion procedure that the iliac crest bone graft should be harvested.Typically surgeons, because of the length and complexity of the procedures,opt for harvesting bone graft early and then leave the graft exposed to air or left in saline for as much as two hours before use.This study provides new information about the viability of the OP cells in air and saline as time increases.This information will influence the way surgeons harvest and store cancellous iliac crest bone graft when performing fusion procedures. Purpose: To understand the effect of time on osteoprogenitor cell(OP) viability after harvesting rabbit cancellous iliac crest bone graft. To determine the best storage media for the graft. Methods:10healthy New Zealand white rabbits were anesthetized and cancellous iliac crest bone graft was harvested under sterile technique.The cancellous graft was placed in air or normal saline for 0, 0.5 hrs, 1 hr, and 2 hrs.These samples were morsilized and transferred to petri dishes with the required nutritional media for cell proliferation.Petri dishes were incubated for a total of 14 days;the suspension of cells was diluted, centrifuged and the number of OP cells was counted using the trypan blue method. Results:OP cell viability decreases as time increases after harvesting of the graft.Storage of the graft in saline increases OP cell viability when compared to graft stored in air. Conclusion: Currently in orthopaedic surgery there is no protocol which dictates the optimal time during a fusion procedure that the iliac crest bone graft should be harvested.Typically surgeons, because of the length and complexity of the procedures,opt for harvesting bone graft early

and then leave the graft exposed to air or left in saline for as much as two hours before use.This study provides new information about the viability of the OP cells in air and saline as time increases.This information will influence the way surgeons harvest and store cancellous iliac crest bone graft when performing fusion procedures.

POSTER NO. P417

Proprioception Recovery after Laminoplasty for the Cervical Myelopathy Patient

Hiroyuki Takayama, MD, *Kakogawa, Japan (n)*
Hirotsugu Muratsu, MD, Kakogawa, Japan (n)
Toshihiko Harada, MD, Kobe, Japan (n)
Shinichi Yoshiya, MD, Kobe, Japan (n)
Masahiro Kurosaka, MD, Kobe, Japan (n)

Introduction:The deep senses including proprioception ascend through the dorsal columns in the spinal cord. When these tracts are compressed in myelopathy, deterioration of proprioception would appear. However, there have been few studies concerning proprioception impairment in myelopathy. We evaluated knee proprioception loss in cervical myelopathy, and analyzed postoperative recovery and correlation to the clinical status. Methods: The patient group included 54 cervical myelopathy patients (group P), including 26 patients who underwent laminoplasty (group S). Fifty-four age-matched healthy volunteers served as the control group (group C). Knee proprioception was assessed by joint position sense, which was evaluated by the error angles during subjects reproduce the predetermined angle. The Japanese Orthopaedic Association (JOA) scores were used for functional evaluation. Results:The average error angles were 2.3 and 3.6 degrees during knee extension and 3.1 and 5.5 degrees during knee flexion, in group C and P each respectively. The error angles in group P were significantly higher than group C. There was significant decrease in error angle two weeks after surgery, and no change later. The functional improvement two years after surgery was significantly associated with the early reduction of error angles. Discussion and Conclusion:This is the first report to assess proprioception quantitatively in cervical myelopathy. We found proprioceptive deficit did exist in cervical myelopathy and its early postoperative recovery also correlated to functional recovery two years later. The joint reposition test in this study would be a useful method for quantitative clinical assessment in cervical myelopathy.

POSTER NO. P418

◆OP-1 Injection Restored Degeneration Following Chemonucleolysis in the Rabbit

Koichi Masuda, MD, *Chicago, IL (a – Stryker Biotech)*
Yoshiyuki Imai, MD, PhD, Chicago, IL (*)
Masahiko Okuma, MD, PhD, Chicago, IL (*)
Koichi Nakagawa, MD, Chicago, IL (*)
Carol Muehleman, PhD, Chicago, IL (n)
Eugene Thonar, PhD, Chicago, IL (*)
Gunnar B J Andersson, MD, Chicago, IL (*)
Howard S An, MD, Chicago, IL (*)

PURPOSE: Chondroitinase-ABC (C-ABC), currently used as a chemonucleolysis agent that has fewer side effects than chymopapain, still causes significant degradation of the matrix in the injected intervertebral disc (IVD). The in vivo administration of the growth factor, osteogenic protein-1 (OP-1), which stimulates IVD matrix synthesis in vitro, has also been shown to increase disc height in the rabbit. Our hypothesis is that the in vivo injection of OP-1 induces will induce the recovery of disc height after the initiation of disc degeneration by chemonucleolysis. METHODS: Forty-eight NZW rabbits (3 kg) were used. First, the C-ABC (10 ul/disc) was injected into 3 levels of IVDs for each rabbit in each group. After four weeks, the same levels were exposed, and the vehicle or OP-1 (100 ug/disc) was injected. Disc height, as Disc Height Index (DHI), and %DHI were monitored radiographically at two-week intervals and statistically analyzed. RESULTS: DHI: Significant disc space narrowing was observed 2 weeks after the injection of C-ABC in both groups. In the C-ABC + vehicle group, this narrowing progressed after the vehicle injection and was sustained for up to 16 weeks. In the C-ABC + OP-1 group, the DHI began to return towards normal 4 weeks after the OP-1injection and gradually approached the control level by 6 weeks after the OP-1 injection (Vehicle vs OP-1, $p<0.01$). This change was sustained up to 16 weeks. DISCUSSION: For the first time, we showed that the injection of rhOP-1 into an IVD dramatically reversed the decrease of disc height induced by C-ABC chemonucleolysis. Our results suggest that OP-1 may be utilized to treat patients with disc height loss following previous chemonucleolysis.

POSTER NO. P419

Local Bone Harvesting Techniques for Avoiding Iliac Crest Autograft

Kris Lewonowski, MD, *Wichita, KS (a – Synthes Spine)*
Kirkham B Wood, MD, Stillwater, MN
(a, b – Synthes Corp, b – AO-ASIF)
Terrence Lee Piper, MD, Saint Charles, MO (*)

Introduction:The use of autologous bone is advantageous in anterior lumbar interbody fusion procedures to increase the rate of fusion. The gold standard and most readily available source is the iliac crest. The vertebral body provides an alternate location for procuring autologous material for fusion without inducing additional trauma and morbidity to the patient. A cortical cancellous implant (Synthes Spine LP) has been designed to fill the vertebral body void created with the trephine technique for autograft harvest and restore the strength of the vertebral body. Methods:Retrospective chart review was done at 3 individual surgeon sites and independent radiographic evaluation. Demographic and operative data was captured, radiographic evaluation of the vertebral body harvest site was used to measure any subsidence or migration of the allograft implant, and the incorporation of implant in the vertebral body. Results:A total of thirty-six vertebral bodies had autograft harvested. Of those 36 levels no vertebral body fractures were reported and one implant had migrated anteriorlateraly within the vertebral body. Of the thirty-six levels assessed, 97% (35) of the implants were evaluated as incorporating after 2 months one implant had delayed incorporation. The mean post operative hospital stay was 4.4 days (range 2 – 7 days), and the mean blood loss was 302 cc range (100 cc – 950 cc). Discussion and Conclusion:Harvesting autograft anteriorly from the vertebral body is a safe, reliable, and time efficient method, which avoids morbidity associated with a second incision over the anterior iliac crest. Cortical cancellous implants incorporate reliably without morbidity to the vertebral body.

POSTER NO. P420

Surgical Management of the Cervical Spine in a Population of Adults with Down Syndrome

Steven M Mardjetko, MD, *Des Plaines, IL (n)*
Leonard Basobas, MS, Des Plaines, IL (*)
Michael F O'Brien, MD, Miami, FL (*)
Brian Chicoine, MD, Des Plaines, IL (n)

STUDY DESIGN: A clinical and radiographic review of 22 adults with Down syndrome (mean age 40, range 30 to 55 yrs; 14 males/4 females) specifically referred for suspected orthopedic/spinal problems. METHODS: Inclusion of 18 patients, who underwent 22 surgical procedures. Indications for surgery included neurologic deficits, an atlantoaxial instability (AAI) of > 5mm in any of the three lateral radiographic positions, and significant degenerative changes resulting in subaxial instability and spinal stenosis. Instability, degenerative changes, and spinal cord compression were classified by location as axial (Occiput-C2), subaxial (C3-C7), or combined (Occiput-C7). RESULTS: Of 18 participants, all possessed AAI (mean distance = 7.2 mm) with associated neurologic deficits. The most common neurologic deficits were spastic quadriparesis and urinary incontinence. All patients possessed moderate to severe cervical degeneration (average number of involved levels = 3.3, range 2 to 6). Cervical stenosis with associated C1-2 instability was noted in 10 (55%) of 18 patients. Cervical myelopathy resulting from degenerative changes in the subaxial cervical spine was noted in 2 subjects. Seventeen (94%) of these patients underwent posterior spinal fusion/instrumentation (average number of levels fused = 5.5, range 1 to 8) which usually involved occipital fixation. The remaining patients underwent trans-articular Magerl screw fixation at C1-2. Preoperative halo-gravity traction was required in 72% of the cases for irreducible C1-2 subluxation. At final follow-up, sixteen (89%) patients improved with regard to ambulatory potential and upper extremity strength and control. Complications were noted in several cases. CONCLUSIONS: AAI combined with subaxial cervical degeneration was the predominant pattern in this population. Longer follow-up is required to determine the fusion rate, outcomes and clinical consequences of these procedures in this population of patients.

POSTER NO. P421

Complications in the Surgical Management of Neuromuscular Spinal Deformity

Steven M Mardjetko, MD, *Des Plaines, IL (n)*
Leonard Basobas, MS, Des Plaines, IL (*)
John Peter Lubicky, MD, Chicago, IL (n)

STUDY DESIGN: A retrospective clinical examination of all children with neuromuscular spinal deformity who underwent an anterior correction and fusion was completed. METHODS: Clinical data of 192 patients with neuromuscular scoliosis who underwent an anterior correction and fusion procedure was reviewed. Anterior procedures were classified as single, combined, or staged. Complications were classified as either major or minor. RESULTS: The overall complication rate for this population was 25% (48 of 192 cases). Wound infections and pseudarthrosis with instrument failure were the predominant complications. Of the 48 complications reported, 50% were classified as major. There were no deaths. Complications were most common in children with cerebral palsy and spina bifida. Twenty-nine patients (15%) had a single anterior fusion/instrumentation procedure. Of these, 24.1% had complications. Twenty-six percent (49 patients) underwent combined procedures. Complications were seen in 9 of the combined procedures. One hundred and thirteen (58.8%) patients underwent staged procedures. Complications were noted in 28% of these patients. CONCLUSION: The overall complication rate in this population is less than that previously reported in patients with neuromuscular scoliosis, with the predominant complications resulting from the posterior procedure.

POSTER NO. P422

◆Biomechanical Evaluation of Kyphoplasty on Treated and Adjacent Vertebral Bodies

Marta Villarraga, PhD, *Philadelphia, PA (a – Kyphon, Inc)*
Anthony Bellezza, New Orleans, LA (a – Kyphon, Inc)
Peter Cripton, PhD, Philadelphia, PA (a – Kyphon, Inc)
Timothy E Harris, MD, Raleigh, NC (*)
Steven M Kurtz, PhD, Philadelphia, PA (a – Kyphon, Inc)
Avram A Edidin, PhD, Portola Valley, CA
(a,d,e – Kyphon, Inc)

Introduction: The objective of this study was to quantify the stress and strain levels in the bone cement, and in the treated and adjacent vertebral bodies, following kyphoplasty. Methods: A 3-D finite element model of T12-L2 with a bone cement cavity in L1 was created. Using a validated model with degenerated discs, we evaluated the sensitivity of stresses and strains in bone and bone cement to variations of vertebral body level, the presence of bone cement, bone cement modulus, and cancellous bone quality. Results: The stress patterns and magnitudes in the adjacent T12 and L2 vertebrae were not substantially affected by the presence of bone cement in L1. The models showed very little sensitivity to changes in bone cement modulus. Changing the cancellous bone quality (normal to osteoporotic) increased the stresses in the cortical bone. We saw only slight differences in the stress levels and patterns in the cancellous bone in the region of the bone cement in the models with a treated L1 vertebral body, as compared to the equivalent region in models with an untreated L1. Discussion and Conclusion: Clinical reports in the literature mention remote and adjacent fractures following both conservative therapy and newer cement augmentation therapies. It is unknown if the incidence of subsequent fractures adjacent to an existing fracture is changed by these therapies, but our models strongly suggest that the stress state of vertebrae adjacent to a treated level remains essentially unchanged following kyphoplasty.

POSTER NO. P423

An Analysis of Risk Factors and Incidence of Postsurgical Spinal Epidural Hematoma

John Awad, MD, *Baltimore, MD (n)*
Khaled M Kebaish, MD, Baltimore, MD (n)
Jonathan Donigan, BA, Baltimore, MD (*)
David A Cohen, MD, Baltimore, MD (*)
John P Kostuik, MD, Baltimore, MD (n)

Hypothesis: Several factors have been implicated in the development of PSEH. These factors include preoperative use of non-steriodal anti-inflammatory medication (NSAIDs), surgical drains, and postoperative use of anticoagulation. However, these factors have not been demonstrated to be significant in a large series. Methods: A case-control retrospective investigation of patients who underwent cervical, thoracic, or lumbar spinal surgery over a 15 year period. Thirty-two patients were identified and compared to one hundred control patients who were matched by surgeon and by time interval. Preoperative, intraoperative, and postoperative factors were compared. Mulitvariant logistic regression was used to analyze the data. Results: Multilevel procedures (greater than 4 levels), preoperative use of NSAIDs, blood loss greater than one liter,

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

subfascial drains, immediate postoperative INR greater than 1.4 were all significant risk factors. Initial versus revision surgery, procedure length, intraoperative laboratory values, and postoperative anticoagulation were not significant risk factors. Discussion/Conclusion: To our knowledge this is the largest series of PSEH that has been invesitigated. In the rare event that a PSEH becomes symptomatic, prompt surgical intervention is warranted; otherwise, the neurologic consequences can be significant and irreversible. Risk factors identified to be associated with a higher incidence of PSEH include, use of NSAIDs preoperatively, multilevel fusions (four levels or greater), use of subfascial drains, and blood loss greater than one liter. Unlike previously reported, the use of postoperative anticoagulation was not associated with a higher risk of PSEH.

POSTER NO. P424

Vertebral Corpectomies Reconstructed with Titanium Mesh Cages

Lawrence G Lenke, MD, *Saint Louis, MO (n)*
Michael Roh, MD, Rockford, IL (n)
Charles Edwards, III, MD, Baltimore, MD (n)
Anthony Rinella, MD, Hinsdale, IL (n)
K Daniel Riew, MD, Saint Louis, MO (n)
Keith H Bridwell, MD, Saint Louis, MO (n)

INTRODUCTION: Vertebral corpectomies are most commonly indicated for vertebral fractures, infections, and tumors. Our purpose was the investigation of using titanium mesh cages, fusion rate, sagittal correction, settling and migration, clinical outcome, and the role of anterior and posterior instrumentation. Methods: Review of 32 corpectomies (31 patients) instrumented with titanium mesh cages and autogenous bone graft, minimum 2-year follow-up was performed. The average patient age was 53 years, with 18 males and 13 females, diagnoses included fracture (21), infection (7), and tumor (4). Lumbar (16), thoracic (14), and cervical (2) cages placed, with anterior (5), posterior (14), or circumferential (13) instrumentation. Results: Anterior cage fusion was successful in 96 percent of cases, however in 5 cases, neither anterior nor posterior fusion could be reliably assessed. Overall, a 100 percent fusion rate (27 of 27) was observed where either anterior or posterior fusion could be confirmed by three independent reviewers. Average sagittal correction was negative 14 degrees early postoperative, and maintained at negative 11 degrees at final follow-up. In 8 of 32 cases (25 percent), settling of greater than 5mm occurred, and was not prevented by a cage ring (p equals .005). There were no cases of revision surgery, vascular or neurological complications. Use of a cage for vertebral osteomyelitis (n equals 7) did not result in recurrent infections. Clinical outcomes showed high patient satisfaction (89 percent). Discussion: Titanium corpectomy cages demonstrated reliable fusion rates and sagittal correction. There were no cage-related complications or failures, and high patient satisfaction was observed.

POSTER NO. P425 - WITHDRAWN

POSTER NO. P426

Progenitor Cell Aspiration from the Vertebral Body: Transpedicular Harvest for Graft Augmentation

James E Fleming, MD, *New York, NY (n)*
Cynthia A Boehm, Cleveland, OH (*)
George F Muschler, MD, Cleveland, OH
(a – Cleveland Clinic Research Program Committee)
Robert F McLain, MD, Cleveland, OH (n)

Introduction: Autograft bone harvest carries significant risks, and complications impair clinical results after fusion. Allograft bone lacks the biological elements needed for consistently successful fusion. Marrow progenitor cells aspirated from the iliac crest and concentrated using composite allograft matrix as an affinity column provides a graft substitute with biological activity comparable to autograft. This study verifies an intravertebral source of autograft progenitor cells, and describes a harvesting technique useful during any spinal instrumentation surgery. Methods: Adult patients undergoing lumbar fusion with pedicle screw instrumentation obtained IRB approval. Osteoprogenitor cells were aspirated from the vertebral body during pedicle screw fixation and quantified relative to matched iliac crest aspirates. 2.0cc aliquots were aspirated from two depths within the vertebral body, through the pilot hole created for screw insertion: at the pedicle body junction (1.5-2.0 cm) and deep vertebral body (3.0cm). Paired samples were harvested percutaneously from the crest. Histological analysis of colony forming units (CFU's) provided quantitative data on the density of marrow progenitor cells relative to depth of aspiration, age and gender, and the iliac crest standard. Results: Aspirates of vertebral marrow demonstrated comparable or greater volumes of CFU's compared to iliac crest. There were no significant differences in marrow progenitor densities relative to side aspirated, depth of aspiration, or gender, but numbers trended lower with age. Aspiration technique was successful in every case, without added risk to the patient. Conclusion: A viable population of autograft progenitors resides within that portion of the vertebral body routinely entered for pedicle screw placement. This alternative procurement source will further reduce the time and morbidity associated with iliac crest harvest.

POSTER NO. P427

Thoracic Pedicle Screw Placement.Analysis Using Anatomic Landmarks Without Image Guidance

Michael Johnathon Elliott, MD, Chesapeake, VA (n)
Joseph B Slakey, MD, Chesapeake, VA (n)

Purpose: To evaluate the safety of placing thoracic pedicle screws using only anatomic landmarks without imagine guidance. Materials & Methods: 80 screws were placed in five fresh cadaver specimens, from T4-T11 along the anatomic axis of the pedicle. No imaging was utilized . The start point is at the lateral edge and perpendicular to the facet in all planes. 5mm screws were used. Pedicles were dissected to determine breakout (medial or Lateral), position of neural structures, and coverage of the pedicle by rib head. Breakout was describe as Grade 1 <1mm penetration, Grade II <2mm, Grade III 2-4mm. Results: 3 screws (3.75percent) perforated the medial cortex: 2 Grade I, 1 Grade II. The grade II medial breakout was in a 4.5mm pedicle. 4 screws (5percent) violated the pedicle directly lateral: 2 grade I, 1 grade II, 1 grade III breakout. All screws laterally were covered by the rib. No pedicle violations superior or inferiorly. The inferior nerve roots contacted the base of the pedicle in all specimens. The distance from the superior aspect of the pedicle to the nerve root varied from 3.3-5.3mm. The amount of the pedicle covered by the rib averaged 80 percent. Conclusions: Placing screws along the anatomic axis of the thoracic pedicle is

safe and accurate using only anatomic landmarks. The nerve roots are most likely to be injured from inferior pedicle wall disruption. Ours results of pedicle screw placement without imaging are comparable to published studies where image guidance was utilized.

POSTER NO. P428

◆Cervical Laminoplasty: The Micro-Plate Open-Door Technique Described and Reviewed

Frank E Fumich, MD, *Morgantown, WV (b – Synthes)*
John C. France, MD, Morgantown, WV (b – Synthes)
Thomas Ducker, MD, Annapolis, MD (*)

Introduction: Our goal was to describe the open-door laminoplasty technique stabilized with a microplate and screws. Methods: A retrospective review of thirty-two patients with cervical spinal stenosis. All were treated with the cervical microplate laminoplasty technique. The raised single unit lamina was maintained in an opened position with a bent 1.5mm micro plate fixed with two 4mm screws in the lamina and two 6mm screws in the lateral mass at each level of decompression. Results: All patients had maintenence of the laminoplasty at follow up. Only one hardware failure was noted as a result of a direct blow to the lower cervical spine. Cervical lordosis was maintained in all but two who developed 4 and 11 degrees of kyphosis. In the younger subgroups of patients (congenital stenosis) all patients improved. The older subgroup (degenerative spondylolytic) likewise made significant mean recovery rate of 58% on JOA scale. Discussion: The neurological recovery using this technique was in line with historical data regarding myelopathy recovery after laminoplasty. This simple technique was effective from a radiological and clinical standpoint in effectively maintaining the open door laminplasty.

COMSS POSTER NO. P429 – AMERICAN SPINAL INJURY ASSOCIATION

Biomechanical Evaluation of the Pull-out Strength of Cervical Screws

Glenn R Rechtine, II MD, *Gainesville, FL(a – Synthes)*
Mary Beth Horodyski, EdD, Gainesville, FL (n)
Bryan P Conrad, Gainesville, FL (a – Synthes)
Andrew Cordista, MD, Baltimore, MD (*)

In the process of anterior cervical fusion, little is known about the biomechanics of anterior cervical screw pullout. In this study, three different aspects of cervical screw fixation were evaluated: self-tapping (ST) vs. self-drilling (SD) screws, the effect of screw geometry (length, diameter, thread pitch), and the use of rescue screws. Nine screws consisting of different diameters, lengths, and thread pitch (cancellous and cortical) were tested in peak pullout force in an artificial bone model using an MTS 858 Mini Bionix test system. Length of screws and thread pitch both had a significant effect on the pullout force. Each 1mm of increased screw length translates to 16 N of increased force to pullout. Pull-out strength did not vary significantly according to screw diameter, nor between SD and ST screws. However, the self-drilling screw has the advantage because it can decrease the length of surgery. The holding power of rescue screws was determined by testing after they had been inserted in the failed holes of previous screws. A decrease in pullout force of between 42.9% and 69.5% was found. In situations in which the use of rescue/salvage screws is required, the surgeon should anticipate that the rescue screw will only have about 50% of the holding force of the original screw. Future directions for research include comparison of pull-out force for different methods of screw use.

POSTER NO. P430 – ORS

The Influence Of Alendronate On Bone Graft And Bcp In Posterior Lateral Spine Fusions

Qingyun Xue, MD, Beijing, China (*)
Haisheng Li, MD, Aarhus, Denmark (*)
Xuenong Zou, MD, Aarhus, Denmark (*)
Mathias Bunger, MD, Aarhus, Denmark (*)
Martin Lind, MD, Aarhus, Denmark (*)
Finn B Christensen, MD, Kolding, Denmark (*)
Cody Bunger, MD, Aarhus, Denmark (*)

Introduction: Treatment with bisphosphonate has been reported to elongate the callus remodeling process during fracture healing. Bisphosphonate treatment may modify bone graft healing and BCP material substitution. The aim of this study is to evaluate the influence of alendronate on bone graft and BCP substitution in posterior lateral spine fusion. Material and method: Twenty-two pigs were included in the study. Eleven pigs in the treatment group received alendronate 10mg/day P.O. postoperatively. Two segmental posterior lateral fusions with CD Horizon system was performed on the lumbar spine using autograft or BCP in all animals. The fusion was evaluated using X-ray, CT and histomorphometry at 3 months after operation. Result: There was no statistical difference in either fusion rate or fusion mass volume between treatment and control groups. The fusion rate was 75% on the 8-gram autograft side and 45% on the 4-gram side ($P<0.05$). The bone graft residual ratio was 0.505 for the treatment group and 0.496 for the control group (NS) and 0.552 for the 4g-autograft sides and 0.412 for the 8g-autograft sides ($P<0.01$). The treatment group have a higher fibrous tissue volume ($P<0.05$), higher proportion of woven bone structure ($P<0.001$) in the fusion mass. Alendronate treatment did not change fusion rate and new bone formation and BCP material substitution. Conclusion: Alendronate 10 mg/daily did not alter the fusion rate or protect bone graft resorption in present study. Alendronate treatment did not influence fusion rate and bone formation in BCP material. ACKNOWLEDGEMENT: Medtronic Sofamor Denek provided CDH and BCP for first 20 pigs.

SCIENTIFIC EXHIBITS

SCIENTIFIC EXHIBIT NO. SE060

Magnetic Resonance Imaging of the Pediatric Spine: Current Techniques and Spectrum of Disease

A. Jay Khanna, MD, *Cleveland, OH (n)*
Bruce A. Wasserman, MD, Johns Hopkins Hospital, MD (*)
Ali Moshirfar, MD, Boston, MA (n)
Paul D. Sponseller, MD, Balitmore, MD (n)

MRI has been shown to be highly successful in imaging pathologic processes involving the pediatric spine. MRI allows for high-resolution, multiplanar imaging of not only the osseous structures of the pediatric spine but also the soft-tissue structures, including the intervertebral discs, spinal cord, and nerve roots. The purposes of this presentation are to: 1) educate and update orthopaedic surgeons on the current state-of-the-art MR imaging techniques, 2) describe the developmental anatomy of the spine as seen by MRI, and 3) illustrate the spectrum of pediatric spinal disease detectable by MRI. This exhibit is divided into three sections. The first describes the essentials and potential applications of multiple MRI techniques, the second reviews the developmental MRI anatomy of the pediatric spine, and the third

illustrates the various infectious, neoplastic, and traumatic processes affecting the pediatric spine and provides recommendations for recognizing their MRI appearance. This exhibit also describes the MRI appearances of spinal dysraphism, one of the major indications for pediatric spine MRI. A discussion of the controversies in pediatric spine MRI is included, with recommendations for resolving these difficult issues. Magnetic resonance imaging is a valuable, noninvasive method of imaging the pediatric spine. This presentation will update orthopaedic surgeons on the various MRI techniques now available and allow him or her to critically and systematically evaluate a pediatric spine MRI and recognize the most commonly seen processes affecting the pediatric spine.

SCIENTIFIC EXHIBIT NO. SE061

Multisurgeon Assessment of Thoracolumbar Fractures: Reproducibility and Repeatability of the AO and Denis Classification Systems

Kirkham B Wood, MD, *Stillwater, MN (n)*
A. R. Vacarro, MD, Minneapolis, MN (*)
D. R. Polly, MD, Minneapolis, MN (n)
Amir A. Mehbod, MD, Minneapolis, MN (n)
G. Khanna, MD, Minneapolis, MN (*)
Jill Wroblewski, MD, Minneapolis, MN (n)

Background: The reproducibility and repeatability of modern classification systems for thoracolumbar trauma have not been sufficiently studied. Methods: AP and Lateral radiographs and complete 2D CT scans of thirty-one acute, traumatic fractures of the thoracolumbar spine were presented to nineteen spine surgeons, who classified the fractures according to both the AO and Denis classification systems. Agreement was measured using Cohen's _ test. Three months later, the thirty-one fractures were scrambled into a different order and fifteen of the observers repeated the classification. Cohen's _ test was used for interobserver and intraobserver agreement. For the AO system, agreement was measured for the basic classification system of A,B,C as well as that of the three subtypes of each ex. A1, A2, A3 etc. For the Denis classification, agreement was measured for the four basic categories (compression, burst, Chance and fracture-dislocation) and then for the 16 subtypes. Results: The type classification of AO (A,B,C) was fairly reproducible with an average kappa of 0.475.(range: 0.389 to 0.598) When the nine subgroups were tested, the kappa was 0.537. The average kappa for the four Denis fracture types was 0.606 (range: 0.325 to 0.702), and 0.173 when divided out into the 16 subtypes. The intraobserver agreement (repeatability) was 81% and 80% for the AO and Denis types respectively. At the subgroup level, the repeatability was 65% and 56%, respectively. Conclusion: Both the Denis and the newer AO classification of spine fractures show only moderate reliability and repeatability. The tendency for well-trained spine surgeons to classify the same fracture differently on repeat testing is of some concern.

PAPERS

PAPER NO. 011

Accuracy of Knee MRI and Unjustified Surgery: A Matter of Twisted Economic Considerations?

Peleg Ben-Galim, *Modiin, Israel (n)*
Ely Steinberg, Tel-Aviv, Israel (*)
Nahman Ash, Tel-Aviv, Israel (*)
Hagai Amir, Tel Aviv, Israel (n)
Ron Arbel, MD, Tel Aviv, Israel (n)

Introduction: Magnetic resonance imaging (MRI) of the knee is reported to have a >90% accuracy rate in detecting intra-articular pathology when it is performed in specialized medical centers and interpreted by specialists in musculo-skeletal MRI radiology. This retrospective study compares the reliability of knee MRIs under conditions of various levels of expertise in a multi-institutional analysis. We also review the factors affecting the accuracy of the results and the interpretations of knee MRI studies. Methods: All knee MRI reports between 1997-8 of soldiers who subsequently underwent primary arthroscopic surgery of the knee within six months were analyzed. MRI results were compared to surgical findings of four structures: medial meniscus, lateral meniscus, anterior cruciate ligament (ACL) and articular cartilage. Results: Of the 633 MRIs of the knee and 1185 arthroscopies that were performed in 14 institutions during the study period, 139 paired MRI-arthroscopic reports fulfilled the study's inclusion criteria. The MRI results showed a false positive rate of 65% for the medial meniscus, 43% for the lateral meniscus, 47.2% for the ACLs, and 41.7% for articular cartilage pathology when compared to surgical findings. The respective accuracy rates were 52%, 82%, 80% and 77%. Discussion and Conclusion: There was a significant discrepancy between MRI diagnosis and surgical findings: 37% of the operations supported by significant MRI pathology were unjustified.These findings emphasize the need to restrict imaging studies as much as possible to ultra-specialist musculo-skeletal radiologists and to encourage qualitative consultations between them and practicing surgeons. Our experience is an example of the negative impact of economic considerations on imaging studies' potentially achievable benefit.

PAPER NO. 012

Neuromuscular Training Improves Performance and Lower Extremity Biomechanics in Female Athletes

Timothy E Hewett, PhD, *Cincinnati, OH (n)*
Gregory Donald Myer, MS, Cincinnati, OH (n)
Kevin Ray Ford, MS, Cincinnati, OH (n)

Introduction: The purpose of this study was to examine the effects of a comprehensive neuromuscular training program on measures of performance and lower extremity biomechanics in female athletes. The hypothesis was that female athletes who received neuromuscular training would get simultaneous improvement in measures of performance and lower extremity biomechanics. METHODS: Forty-one female basketball, soccer, and volleyball players (15.3 ± 0.9 years, 64.8 ± 9.96 kg, 171.2 ± 7.21 cm) underwent six weeks of training that included four main components (plyometric /movement, core strengthening/balance, resistance and speed training). RESULTS: The results revealed increased predicted 1 repetition maximum (RM) squat 92% and bench press 20%. Right and left single leg hop distance increased 10.39 cm and 8.53 cm respectively as vertical jump also increased from 39.9 ± 0.9cm to 43.2 ± 1.1 cm. Speed in the 9.1 m sprint improved from1.80 ± 0.02 seconds to 1.73 ± 0.01 seconds. Pre and post-test 3-D motion analysis demonstrated increased knee flexion-extension range of motion (ROM) during the landing phase of a vertical jump (R- 71.9 ± 1.4° to 76.9 ± 1.4°, L- 71.3 ± 1.5° to 77.3 ± 1.4°). Training also decreased right knee internal valgus 28% and varus 38% moments. Conclusions: The results of this study support the combination of injury prevention training components into a comprehensive program to improve measures of performance and lower extremity biomechanics.

PAPER NO. 013

Gender Differences in Motion Pattern and Risk for ACL Injuries in Stop Jump Task

William E Garrett, Jr, MD, *Durham, NC (*)*
Bing Yu, PhD, Chapel Hill, NC (*)
Donald T Kirkendall, PhD, Durham, NC (n)

Women have significantly higher risk for non-contact ACL injuries than men do. Significant efforts have been made to identify risk factors for non-contact ACL injuries and understand the elevated risk for non-contact ACL injuries in women. We hypothesized that women have different lower extremity motor control strategies that position them closer to injury position than men do and thus have greater risk for non-contact ACL injuries. In previous studies, we found significant differences in lower extremity motion patterns between female and male recreational athletes in selected tasks, especially in stop-jump tasks in which non-contact ACL injuries frequently occur to women. These findings support the first half of our hypothesis. We, however, have not been able to demonstrate that those gender differences in lower extremity motion patterns found in our previous studies are indeed risk factors responsible for the elevated risk for non-contact ACL injuries in women, and provide support to the second half of our hypothesis. The purpose of this study was to compare the probability for non-contact ACL injuries between female and men recreational athletes in stop-jump tasks. Thirty male and thirty female recreational athletes without known lower extremity injuries were recruited as the subjects. Each subject performed 5 trials of vertical stop-jump task with up to 3-4 steps of approach run and maximum jumping effort. Three-dimensional coordinates of critical body landmarks and ground reaction forces were collected. Knee joint resultants were calculated at 1,200 frames/second for each trial. Peak proximal tibia anterior shear force and knee extension, valgus-varus, and internal-external rotation moments and knee flexion angle at the peak proximal tibia anterior shear force were identified for each trial. Data from 3 trials in which the peak proximal tibia anterior shear force had the minimum variation were used to represent the given subject's performance. Independent t-tests were performed to compare selected knee kinetics and kinematics between genders. Monte Carlo simulations were performed to estimate the probability for ACL injuries for each gender. The ACL loading was estimated from the peak proximal tibia anterior shear force and knee valgus-varus and ingternal-external rotation moments at the peak proximal tibia anterior shear force using an equation derived by McLean et al. (2003) based on a study by Kanamori et al.

(2000). ACL injury loading was set at 3 times body weight. Independent t-tests were performed to compare selected knee kinetics in injury events between genders. Female athletes had significantly greater peak proximal tibia anterior shear force, greater knee extension, valgus, and external rotation moments at the peak proximal tibia anterior shear force, and smaller knee flexion angle at the tibia anterior shear force than their male counter part. The probability for non-contact ACL injuries in stop-jump task is 29.1/100,000 for female recreational athletes, and 4.0/100,000 for male recreational athletes. Both female and male athletes had the peak proximal tibia anterior shear force over 1.6 times body weight. Female athletes had greater proximal tibia anterior shear force. All female athletes had excessive knee valgus and external rotation moment in injury events while male subjects had either valgus or varus moment, and either internal-external rotation moment in injury events. The results of this study demonstrated again that women and men have different motion patterns in athletic tasks, and support our hypothesis that lower extremity motion patterns are risk factors for ACL injuries. Peak proximal tibia anterior shear force alone could not create sufficient ACL loading for injury. An excessive knee valgus-varus and/or internal-external rotation moment had to be presented in injury event. Further studies are needed to improve our understanding of non-contact ACL injuries.

PAPER NO. 014

Functional Bracing in Preventing Injury in ACL Reconstructed Professional Skiers

Timothy D Farley, MD, *St. Louis, MO*
(a – Innovation Sports)
William I Sterett, MD, Vail, CO (n)
Chris Dennett, ATC, Vail, CO (*)
Karen K Briggs, Vail, CO (a – Innovation Sports)
J Richard Steadman, MD, Vail, CO
(a, c, d – Innovation Sports)

The protective effect of functional bracing in the ACL reconstructed (ACLr) professional skier was studied utilizing a prospective cohort design. A cohort of 818 professional skiers, at least 2 years post-ACL reconstruction, was identified from a total of 11606 professional skiers that had undergone preseason screening between 1991 and 1997. Allocation of functional bracing during skiing was by a process of shared doctor-patient decision-making. The dependent variable was subsequent knee injury, identified by worker's compensation records. In the cohort, 260 braced skiers were identified compared to 567 non-braced skiers. At preseason screening, braced skiers had significantly higher rates of grade II or higher Lachman and pivot shifts (29 and 22 percent versus 11 and 10 percent, respectively). A total of 61 subsequent injuries were identified, 51 (8.9 percent) in the nonbraced group and 10 (4.0 percent) in the braced group, significantly lower (p=0.009). No difference in Lachman, pivot shift, or age was noted between the injured braced and nonbraced skiers. Non-braced ACLr skiers were 2.74 times more likely to suffer subsequent injury than braced skiers (OR = 2.74 [CI: 1.2 to 4.9]) in this population. Controlling for Lachman, pivot shift, and age, logistic regression modeling identified non-bracing as significant independent, multivariate risk factor for subsequent knee injury in the professional, high demand skier. Whether the protective effect of functional bracing can be extrapolated to other high demand patients is yet to be determined.

PAPER NO. 015

Femoral Notch Width Index Does Not Predict ACL Trauma in Basketball Players: A Prospective Study

Stephen J Lombardo, MD, *Los Angeles, CA (n)*
Paul Sethi, MD, Greenwich, CT (n)
Chad Starkey, PhD ATC, Boston, MA (n)

Background: The predictive value of femoral notch size and notch width index has been debated. This study examined the relationship between the notch width index and anterior cruciate ligament injury in professional basketball players. Hypothesis: We expected that no significant difference exists between the notch width index of professional basketball players who did and who did not suffer ACL trauma.Study Design: Using a notch view x-ray, we prospectively recorded the femoral notch and the condylar widths and calculated the notch width index of all 615 athletes who participated in the National Basketball Association's combine workouts between 1992 and 1999. Methods: After a 4 to 11 year follow up period we queried the National Basketball Association's league-wide injury database to determine the subjects' medical history. These data were then categorized into anterior cruciate ligament injured or noninjured groups. Notch width, condylar width and notch width index were compared between the two groups. Results: A total of 316 players were followed for a period of 4 to 11 years. Anterior cruciate ligament trauma was suffered by 15 (4.8%) of the subjects. The average notch width index was 0.251 ±0.032 for anterior cruciate ligament injured players and 0.241±0.040 for uninjured players (t314 = -1.001, P = .318). This difference was not significantly different. The total condylar width, however, was significantly larger in the injured group. This represented 61,047 game exposures over a 4-11 year follow up period. Conclusions: Based on our findings, we do not recommend the use of a pre participation notch X-ray view in professional basketball players as a method of identifying individuals who are predisposed to ACL injury. The NWI of players who injured their ACL as compared to players without ACL injury were not different. We were unable to identify a level of critical notch stenosis or a critical value for intercondylar notch stenosis. We also did not find an association of the absolute measurement of the femoral intercondylar notch that was predictive of, or correlated with, ACL injury. We do not believe that the information obtained from the notch view offers predictive information in identifying the professional basketball player at risk, nor do we believe that this information should be used to counsel patients, or offer prophylactic treatments in this population.

PAPER NO. 016

Normal Clinical Findings During Successful ACL Reconstruction and Rehabilitation

Melissa A Yadao, MD, *Alexandria, VA (n)*
Gene R Barrett, MD, Jackson, MS (n)

Purpose: Little date exists regarding the normal clinical course of a successful ACL reconstruction and rehab. This study attempts to define "normal" subjective and objective parameters that occur in the postoperative and rehabilitation period after a successful ACL reconstruction. Materials and Methods: 372 ACL reconstructions (214 males and 158 females) were identified from our relational database. These patients underwent primary intra-articular ACL reconstruction with at least two-year follow-up and a Lysholm score of greater than 84. The average age was 27.3 years. 247 patients had patella tendon reconstruction, 75 patients underwent hamstring reconstruction and 50 patients had allograft reconstruction. Subjective data included a 15-point

visual analog scale and objective data included effusion, Lachman, pivot shift and KT-1000 difference. Results: The average follow-up postoperatively was 41.2 months. The average postoperative Lysholm score was 95. Over 90% of the patients felt they had swelling up to six months after surgery (range 0 to 6, mean 1.6). Over 90% of the patients had an effusion at three months, but by 6 months greater than 95% of the patients were without an effusion. Mild pain symptoms persisted up to final follow-up. Most patients felt their knee was stable at 9 months. At three months, 90% of the patients showed a 0 to 1+ Lachman and greater than 90% of the patients had a negative pivot shift. These percentages remained to final follow-up. However KT-1000 differences did not stabilize until the 12-month follow-up. Conclusions: In a successful ACL reconstruction it is "normal" to experience some swelling up to six months after surgery, and always have mild pain symptoms. Although subjective instability may persist up to nine months postoperatively, objective tests such as pivot shift and Lachman demonstrate stability as early as three months after surgery. KT-1000 difference, however, may not be reliable until one year post-op.

PAPER NO. 017

The Posterolateral Corner of the Knee: Repair Versus Reconstruction

Stephen L Brown, MD, *Birmingham, AL (n)*
James P Stannard, MD, Birmingham, AL (n)
James T Robinson, Birmingham, AL (n)
Robert Baird, MD, Birmingham, AL (*)
Gerald McGwin, Jr, PhD, Birmingham, AL (n)
David A Volgas, MD, Birmingham, AL (n)

PURPOSE: To compare the results of repair of posterolateral corner (PLC) tears with reconstruction in a non-randomized, prospectively obtained patient population. MATERIALS AND METHODS: 63 patients with 64 tears of the PLC have been treated, with 39 repairs and 25 reconstructions using a modified two-tailed technique. Follow-up was a mean of 28 months (range 24 – 50). There were 50 multi-ligament knee injuries and 14 isolated or ACL/PLC injuries. Lysholm knee scores have been obtained on all patients, and we are currently obtaining IKDC scores. RESULTS: 39 patients with repairs had 13 (33%) failures that required revision reconstruction. 25 patients with primary reconstruction had 2 (8%) failures. The difference is significant with a p value < .05. Lysholm knee scores were obtained with a mean of 86.4 for repairs and 90 for reconstructions at final follow-up. All 15 patients that had a failed PLC have undergone successful revision using the two-tailed technique. DISCUSSION / CONCLUSIONS: Posterolateral corner tears are a common injury with knee dislocation, and occasionally occur as either an isolated injury or associated with an ACL tear. Many authors have recommended repair if the injury is treated in the acute phase and the FCL and popliteus both have been avulsed and appear to have good tissue. Our results with repair followed by early range of motion have been significantly inferior when compared to reconstruction utilizing the modified two-tailed technique. Based on our results, we now utilize reconstruction rather than repair in the majority of patients who have sustained tears of the PLC following high energy injuries.

PAPER NO. 018

The Use of MRI to Assess Knee Cartilage Repair Tissue after Microfracture of Chondral Defects

Arun J Ramappa, MD, *Vail, CO (n)*
Thomas James Gill, MD, Boston, MA (n)
Karen K Briggs, Vail, CO (n)
Kathleen Buckley, Boston, MA (*)
Charles Ho, MD, Vail, CO (*)
J Richard Steadman, MD, Vail, CO (c – Linvatec)

Objective: A noninvasive method to assess the repair tissue produced by techniques that treat chondral defects has not been established. The objective of this study was to evaluate the ability of specialized MRI sequences to predict the amount and quality of repair tissue of knee articular cartilage defects treated by microfracture. Methods: Nineteen recreational or high-functioning athletes were prospectively entered into our IRB-approved study. They underwent standard microfracture technique for twenty-three full-thickness chondral defects (average surface area 166 mm2). The patients subsequently underwent repeat arthroscopy an average of 25.4 months post-microfracture. MRI studies using fast-spin echo and STIR sequences were obtained an average of 1.1 months prior to the second-look arthroscopies. Blinded readers evaluated the MR images for the presence of full-thickness articular cartilage defects and for the quality of the repair tissue. At arthroscopy, the quality and quantity of the repair tissue was assessed and used as the standard. Results: MRI had a sensitivity of 86%, specificity of 94%, positive predictive value (PPV) of 86%, negative predictive value (NPV) of 94%, and accuracy of 91% in predicting the presence or absence of a full-thickness lesion in a previously microfractured area. A sensitivity of 79%, specificity of 78%, PPV of 85%, NPV of 70%, and accuracy of 78% was found for the ability of MR imaging to determine whether the repair tissue was of good or poor quality. Conclusions: MRI using fast-spin echo and STIR sequences is a promising technique for evaluating repair tissue in full-thickness defects treated by microfracture.

PAPER NO. 019

Antegrade Drilling for Osteochondritis Dessicans of the Knee in Adolescents

Sumeet Garg, *Brookline, MA (n)*
Theodore J Ganley, MD, Philadelphia, PA (*)
John M Flynn, MD, Philadelphia, PA (*)
Rena R Amro, MD, Wellington, FL (n)
John R Gregg, MD, Valley Forge, PA (*)

Introduction: At our institution, antegrade drilling is performed for intact osteochondritis dessicans (OCD) lesions of the knee that fail to heal after a course of non-operative therapy. We hypothesized that skeletally immature adolescents have better functional outcomes than skeletally mature adolescents. Methods: 44 adolescents with 47 affected knees who failed a course of non-operative treatment for OCD had antegrade drilling performed between 1995 and 2000. 32 adolescents (34 knees) have follow-up greater than two years. IKDC evaluation form was used in follow-up to quantify recovery of knee function. Results: Physeal status at time of surgery was open in 23 knees (average age 13.0 years) and closed in 11 knees (average age 17.5 years). Average follow-up was 3.7 years (range 2.6-5.2) in the closed physis group and 4.5 years (range 2.2-9.9) in the open physis group. At last follow-up, there was a significant difference in functional status using the IKDC subjective assessment (maximum score 100). Average score was 73.3 in the closed physis group and 92.4 in the open physis group (p<.001).

At last follow-up, there was also a significant difference based on physical examination. Only 5 of 11 knees drilled with closed physes were judged to be normal while 19 of 24 knees with open physes were judged to normal ($p<0.05$). Conclusions: After failure of non-operative treatment, antegrade drilling is an effective treatment for OCD of the knee in skeletally immature patients but does not always lead to excellent recovery in patients who are skeletally mature at the time of surgery. The goal of treatment is to have the lesion resolved prior to growth plate closure.

PAPER NO. 020

Arthroscopic Peripatellar Synovectomy for Treatment of Chronic Anterior Knee Pain

Scott F Dye, MD, *San Francisco, CA (n)*

Introduction: New theories on the etiology of anterior knee pain emphasize the loss of tissue homeostasis (e.g. peripatellar synovitis) over the presence of structural / biomechanical characteristics (e.g. patellofemoral malalignment). This study tracts the results of adults with chronic anterior knee pain treated by the means of an arthroscopic peripatellar synovectomy followed for a minimum of two years (average 3.7 years). Methods: 37 patients, 23 females, 14 males (average age 35.3 years) with 44 symptomatic knees were included in this study. All patients failed a conservative program for patellofemoral pain including load restriction and physical therapy. At surgery all patients had a gentle peripatellar synovectomy and minimal cartilage debridement if chondromalacia was present. Patients reported anterior knee pain on a ten point visual analog scale (VAS). Results: At surgery all 44 knees manifested peripatellar synovitis with patellofemoral chondromalacia being present in 23 knees. 42 of 44 knees improved, 20 knees resolved (+6.2 VAS) with 22 reporting partial improvement (+3.6 VAS). The pathology in all cases was chronic non-specific hypertrophic proliferative synovitis. Discussion: Symptomatic peripatellar synovitis can be likened to biting the inside of one's cheek repetetively, leading to the hypertrophy of inflamed innervated tissues. In this study it has been shown that a careful synovectomy can substantially diminish anterior knee pain in the majority of patients, safely and predictably. When properly performed this technique results in minimal surgical perturbation of the knee and in addition, does not preclude further patellofemoral surgery. Therefore an arthroscopic peripatellar synovectomy can be an effective and safe method of treatment for a substantial source of chronic anterior knee pain in adults.

PAPER NO. 101

The Condylar Cut-Off Sign - A New Radiographic Sign in Knees with Discoid Lateral Meniscus

Chul Won Ha, MD, *Brookline, MA (n)*

This is to report the 'condylar cut-off sign' , a new radiographic sign in knees with discoid lateral meniscus, and to report the sensitivity, specificity, positive and negative predictive value of the sign for the diagnosis of discoid meniscus by simple radiography. Fifty knees with complete discoid lateral meniscus and fifty normal knees formed the basis of this study. All of them were arthroscopically confirmed for the discoid or normal lateral meniscus. The authors developed a method to measure the length of the medial and lateral condylar prominence on tunnel view radiography of knee. The ratio of the length of the medial and lateral condylar prominence were compared and analyzed.The average ratio was 0.716 in the discoid meniscus group, and 0.902 in the normal group, which showed statistically significance by t-test(p less than 0.0001, t-value ?1.13). Chi-square test using cut point 0.8 also showed significant difference between the two groups, with 76 percent sensitivity, 100 percent specificity, 100 percent positive predictive value and 81 percent negative predictive value. The 'condylar cut-off sign?was readily detectable in all cases of discoid lateral meniscus. The condylar cut-off sign on the tunnel view of simple radiography of the knee will serve as serve as a simple and reliable radiographic sign for the diagnosis of discoid lateral meniscus, with 100 percent specificity and 100 percent positive predictive value.

PAPER NO. 102

Isolated Type II SLAP Lesions Treated with a Bioabsorbable Tack - The Impact of Portal Placement

David B Cohen, MD, *Hamden, CT (n)*
Struan H Coleman, MD, New York, NY (n)
Mark Drakos, MD, New York, NY (*)
Answorth Anthony Allen, MD, New York, NY (n)
Stephen J O'Brien, MD PLLC, New York, NY (n)
David W Altchek, MD, New York, NY (n)
Russell F Warren, MD, New York, NY (c – Smith & Nephew)

Introduction: Previous labral studies include patients with mixed pathology and multiple concomitant procedures. This study evaluates outcomes of superior labral repair in a truly isolated group and determines the significance of surgical approach. Methods: Charts of 860 patients treated for labral pathology were retrospectively reviewed. Forty-one "isolated" type II SLAP lesions treated with tack fixation were identified after excluding patients with prior ipsilateral shoulder surgery, concomitant rotator cuff repair, stabilization, or subacromial decompression. Follow-up was obtained on 39 of the 41 patients using the L'Insalata questionnaire. 33 also underwent a physical exam and completed ASES questionnaires. One patient died; one was lost to follow-up. Mean age at surgery was 34 years; mean follow-up 44 months (r, 25-97mos). Eight were throwing, 21 were non-throwing athletes. Tack placement was performed using a rotator-interval portal in 16, and a rotator cuff-penetrating portal in 23 patients. Results L'Insalata: The mean L'Insalata Score was 86.7 points; yet, only 69% rated overall satisfaction as "good" or "excellent". Among the 29 athletes, only 14 (48%) were able to return to their pre-injury level; 13 (45%) returned in a limited capacity. The mean L'Insalata score for non-throwing athletes was 90.8 with a good-excellent satisfaction rating of 71% compared to 75.9 and 38% for throwers ($p<0.04$). Of the 8 throwing athletes, 3 returned to pre-injury levels while 5 returned in a limited capacity. Night pain was present in 16 of 39 patients (41%). The mean L'Insalata score for the groups with and without night pain were 73.9 and 95.6.ASES: Mean ASES score was 86.8 points. Pain rated absent or mild in 28 patients (85%), moderate in 4 (12%). 10 patients (30%) continued to experience pain at night. Twenty of 33 (61%) lost minimum one vertebral level internal rotation (mean 1.7 levels). Interval vs. Rotator Cuff-Penetrating Portal: The average ASES scores in the rotator-interval portal group compared to the cuff-penetrated group was 95 versus 83.3 ($p<0.05$). In the interval-portal group 9 of 11 patients (82%) rated satisfaction as good-excellent; in the cuff-penetrated group only 12 of the 22 patients (55%) rated satisfaction as good-excellent. All 10 (100%) with night pain according to ASES questionnaire, and 13 of 16 patients noting night pain in the L'Insalata questionnaire had undergone a cuff-penetrating approach. Reasons for Failure: 7 patients demonstrated impingement (L'Insalata score 77 vs 86.7 overall) and good-excellent satisfaction rating of 43% (vs. 69% overall). 2 patients demonstrated instability, both rating satisfaction as

poor. One patient re-tore his labrum after not complying with post-op restrictions. Only 40% returned to pre-injury levels of athletic activity. Finally, the cuff-penetrating surgical approach yielded significantly lower scores, satisfaction, and accounted for the vast majority of patients with night pain. Discussion and Conclusion: Although mean L'Insalata and ASES scores were high (86 points), overall patient satisfaction was less impressive (64% G-E). Only 40% returned to pre-injury levels of performance. SLAP repairs in which the rotator cuff was not penetrated yielded significantly higher functional scores, satisfaction, and lower rates of night pain. Failure to recognize and address impingement and instability may compromise successful results.

PAPER NO. 103

◆Collagen Matrices and Chondrocytes Increased Cartilage Repair After Microfracture in a Sheep Model

Stefan Nehrer, MD, *A-1090 Wien, Austria*
(a, b, e – Geistlich Biomaterials)
Ronald Dorotka, MD, Vienna, Austria
(b – Geistlich Biomaterials)
Ullreich Bindreiter, Vienna, Austria (*)
Cyril D Toma, MD, Vienna, Austria (n)
Udo Losert, MD, Vienna, Austria (*)

Introduction: The technique of microfracture in the treatment of articular cartilage defects has been shown to result in fibrocartilagenous tissue partially filling the defect. This study evaluates the repair tissue after microfracture and implantation of a trilayer collagen matrix with and without cell-augmentation in an ovine model. Methods: 32 adult sheep were used in the study following a protocol accepted by the Animal Care Comittee. Two chondral defects with a diameter of 4,5 cm were produced in the medial condyle of the right knee witout penetrating the subchondral bone. In 24 animals microfracture was performed with a curved pick, of which eight received no further treatment. In eight sheep defects were covered with collagen implants without cells and in eight chondrocyte-augmented collagen matrices were implanted. Eight knees served as controls. After 4 and 12 months the knees were histologically analyzed (H&E, Saf-O, Kollagen I, II) and graded according to Pineda and O'Driscoll Scores. Results: All treatment groups showed a statistically significant better filling of the defects than the untreated defects. Histological analysis showed that hyaline-like tissue was predominately formed in the cell-augmented treatment group and fibrocartilagenous tissue in the other groups. Conclusion: Collagen implants are not able to increase the repair of chondral defects compared to microfracture treatment alone. However, cell-augmentation with cultured autologous chondrocytes improved the results and facilitated cartilage-like tissue formation.

PAPER NO. 104

Immunohistological Analysis of Arthrofibrotic Tissue in Knee Joints

Johannes Zeichen, *Hannover, Germany*
(a – The German Association of Trauma Surgery)
Michael Skutek, Hannover, Germany (n)
Martijn Van Griensven, PhD, Hanover, Germany (n)
Andreas Weiler, MD, Berlin, Germany (n)
Christian Krettek, MD, Hanover, Germany (n)
Ulrich Bosch, Hannover, Germany (*)

Introduction: arthrofibrosis represents a severe complication in joints after trauma and surgery, with loss of motion due to an excessive fibrotic response in the repair process. A chronic inflammatory process may play a crucial role in the mechanism. Purpose of our immunohistological study was to determine the cellular patterns of arthrofibrotic tissue. Materials and methods: from 18 patients (10 woman, 8 men; mean age 32,5 years) undergoing knee arthrolysis tissue samples were taken from the anterior and intercondylar knee compartment. Average time between surgery and arthrolysis was 16 months. Sections were stained with hematoxylin and eosin to study the overall histopathological changes. Major histocompatibility complex (MHC) class II expressing cells as well as CD3, CD4, CD25, CD28, CD45, CD68, CD80 and CD83 positive cells were localized immunohistologically. Tissue samples from five knee joints without any macroscopic pathology of the synovial tissue served as zero controls. Results: the results demonstrated synovial hyperplasia with fibrotic enlargement of the subintima and infiltration of inflammatory cells in arthrofibrotic tissue. MHC class II expressing cells was increased. In the subintima moderate infiltration of T cells including activated T cells (CD 25), CD 4 (T-helper) cells was detected. Positive immunostaining for CD80/CD28 indicated the costimulatory signal for T cell activation and clonal expansion. Discussion: these findings strongly support an immune response as the cause of capsulitis leading to formation of diffuse scar tissue within the knee joint. We conclude that a T cell mediated immune response plays a crucial role in the mechanism of arthrofibrosis.

PAPER NO. 105

Mechanical Injury Activates Genes Involved in Matrix Degradation

Darryl D D'Lima, MD, *La Jolla, CA*
(a – ALSAM Foundation, Skaggs Institute)
Shantanu Patil, MS, La Jolla, CA
(a – ALSAM Foundation, Skaggs Institute)
Clifford W Colwell Jr, MD, La Jolla, CA
(a – ALSAM Foundation, Skaggs Institute)
Martin Lotz, MD, La Jolla, CA
(a – ALSAM Foundation, Skaggs Institute)
Arnie Bergula, BS, La Jolla, CA
(a – ALSAM Foundation, Skaggs Institute)

Introduction: Joint trauma is a major predisposing factor to secondary osteoarthritis. Treatment of established osteoarthritis has limited success. The molecular and biochemical events following cartilage injury are very significant in predicting clinical outcomes and developing novel therapeutic approaches. Methods: Chondrocytes were isolated from normal cartilage obtained from fresh donor human knees. Chondrocytes were embedded in agarose gel in a three-dimensional culture system. Cylindrical chondrocyte-gel constructs, 5 mm in diameter, were subjected to mechanical injury that produced 30% strain. RNA was extracted at 3, 6, and 12 hours after injury and was analyzed

for the activation of specific genes. Uninjured chondrocyte-gel constructs were used as negative controls. Constructs stimulated with IL-1 were used as positive controls. Results: Type II collagen and aggrecan expression decreased in injured constructs at 3 hours after injury. Matrix metalloproteinase expression (MMP-1, MMP-3) was higher in injured constructs and IL-1 stimulated constructs. MMP-13 and iNOS (inducible nitric oxide synthase) expression was seen in IL-1 stimulated constructs but not in injured constructs. Discussion: Cartilage matrix turnover is regulated by the balance between matrix synthesis and degradation. After cartilage injury, genes responsible for matrix degradation (MMPs) were activated while genes responsible for matrix synthesis (type II collagen and aggrecan) were suppressed. The similarities seen in gene expression between injured constructs and those exposed to IL-1 suggest shared pathways for degradation. Injury causes immediate structural damage to the matrix. However, the cellular response can result in further degradation. Chondroprotective agents that specifically target these degradative pathways may prevent progression of cartilage lesions.

PAPER NO. 106

Pathogen Inactivation of Soft Tissue Allografts Using High Dose Gamma Irradiation with Early Clinical Results

Warren D King, MD, *Palo Alto, CA (a, b, e – Clearant, Inc)*
Teri A. Grieb, PhD, Gaithersburg, MD (d, e – Clearant, Inc)
Ren-Yo Forng, PhD, Gaithersburg, MD (d, e – Clearant, Inc)
Jack Lin, Gaithersburg, MD (d, e – Clearant, Inc)
Lloyd Wolfinbarger, Virginia Beach, VA (n)
Chris Sharp, Gaithersburg, MD (e – Clearant, Inc)
William N. Drohan, PhD, Gaithersburg, MD (d, e – Clearant, Inc)
Wilson H Burgess, Gaithersburg, MD (d, e – Clearant, Inc)

INTRODUCTION: Recent CDC reports of allograft-associated bacterial and viral infections in recipients of human tissue reiterate a need for improved pathogen inactivation and terminal sterilization. We hypothesize that optimized gamma irradiation of plasma-derived therapeutic proteins can be applied to complex biologics like human allografts. METHODS: Tibialis tendons were treated as follows: no irradiation; 18kGy conventional irradiation; 50kGy controlled irradiation; or 50kGy controlled irradiation with radioprotectant. Samples were tested for tensile strength and elasticity. Biochemical analysis of collagen degradation was also performed. RESULTS: There was no significant difference in the tensile strength of non-irradiated tendons compared to those irradiated to 50kGy under controlled conditions with radioprotectants. Similarly, there was no change in Young's moduli between groups. Biochemical analysis indicated no collagen degradation following 50kGy in the presence of radioprotectants. Significant degradation occurs in tissue subjected to 50kGy without radioprotectants. Robust inactivation of bacteria (spore and vegetative), enveloped virus, non-enveloped virus, and fungi was achieved with 50kGy controlled irradiation. DISCUSSION/CONCLUSION: A new method of gamma irradiation can be used to significantly increase the safety of human allograft tissue. Inactivation of pathogens can be achieved without losing mechanical or biochemical integrity associated with existing irradiation protocols. Preservation of the structural integrity of Achilles tendons following 50kGy of gamma irradiation using the optimized process was confirmed by an orthopedic clinic. This result led to the initiation of a clinical evaluation of these allografts. The status of this evaluation will be presented.

PAPER NO. 107

Meniscus Transplantation: MRI Analysis Under Loaded Conditions and Clinical Results

Marc E Rankin, MD, *Cincinnati, OH (a – CryoLife, Inc)*
Frank R Noyes, MD, Cincinnati, OH (a – CryoLife, Inc)
Sue Barber-Westin, BS, Cincinnati, OH (a – CryoLife, Inc)

Introduction: We prospectively evaluated 40 consecutive meniscus transplants using MRI under unique loading conditions and a rigorous clinical rating system. Methods: 40 cryopreserved meniscus transplants were done in 38 patients. Thirty-six transplants were evaluated a mean of 40 months (range, 24 to 69) clinically and 29 were evaluated a mean of 36 months with MRI under loaded weight-bearing conditions. Four transplants failed early. We combined subjective, clinical, and MRI factors to determine meniscus allograft characteristics. Osteochondral autograft transfers were also done in 13 knees and knee ligament reconstructions, in 8 knees. Results: 94% rated their knee condition as improved. Preoperatively, 77% had pain with daily activities but at follow-up, only 6% had pain with daily activities. Twenty-seven patients (77%) returned to light sports without problems. Associated OAT and knee ligament reconstructions improved knee function and did not increase the rate of complications.The mean displacement of the meniscus allografts in the coronal plane was 2.2 + 1.5 mm (range, 0 to 5 mm). The mean displacement of the posterior horn of the allografts in the sagittal plane was 1.1 + 2.0 mm (range, 0 to 9 mm). Seventeen (42.5%) allografts had normal characteristics, 12 (30%) had altered characteristics, and 11 (27.5%) failed. Discussion/Conclusions: Meniscus transplantation is an acceptable procedure for younger patients and may be worthwhile at least as a temporizing operation. This study did not determine if meniscus transplantation provides a chondroprotective effect in meniscectomized tibiofemoral compartments.

PAPER NO. 108

Fresh Osteochondral Allografting in the Treatment of Osteonecrosis of the Knee

William Bugbee, MD, *La Jolla, CA (n)*
Bahram Khadivi, MS, La Jolla, CA (*)

INTRODUCTION: Osteonecrosis of the knee is a difficult clinical problem. We report on our experience with reconstruction using fresh osteochondral allografts. METHODS: 22 knees in 18 patients with osteonecrosis of the knee were treated with fresh osteochondral allografts after failure of other treatment. Evaluation was via 18-point modified D'Aubigne and Postel scale and patient questionnaire. RESULTS: 2 patients were lost to followup; 1 was revised to TKA and considered a failure. The remaining 19 knees in 15 patients were evaluated. Mean followup time was 5.1 years (range 1-16). 4 were male, 11 were female; average age was 30 years (range 15-68). Corticosteroid-induced osteonecrosis was the underlying etiology in 95% (18/19). 5 grafts involved the medial femoral condyle (MFC), 10 involved the lateral femoral (LFC), 4 involved both MFC and LFC, and 1 involved the patella. 1 patient had successful revision osteochondral allograft. 95% (18/19) had improved clinical scores (53% rated good/excellent, 42% rated fair, 5% rated poor). Mean scores improved from 11.3-15.0 ($p<0.001$). 100% reported satisfaction with treatment; 93% had subjective knee function improvement from 3.9-6.8 on a 10-point scale ($p< 0.001$). DISCUSSION: Fresh osteochondral allograft treatment of osteonecrosis of the knee resulted in pain relief, improved function, and high patient satisfaction. We conclude that fresh osteochondral allografts are effective alternative treatment for osteonecrosis of the knee.

PAPER NO. 109

Fresh Stored Osteochondral Allograft Transplantation: An Analysis of Material Properties

Riley Joseph Williams, MD, *New York, NY*
(a – Institute for Sports Medicine Research & Arthrex Inc)
Timothy S Johnson, MD, Baltimore, MD (n)
Stephanie Cho, BS, New York, NY (n)
Chih-Tung Chen, New York, NY (*)
Armando F Vidal, MD, New York, NY (*)

Fresh osteochondral allograft transplantation is an effective method of treating cartilage defects. Successful transplantation has been described with grafts implanted within 7 days post-retrieval. Fresh commercial allografts are currently available up to 42 days post-harvest. We hypothesize that the material properties of allograft tissue will significantly decrease over a 42-day storage interval compared to specimens stored 1 and 17 days. Whole ovine femoral condyles were cold-stored (4C) in nutrient medium for 1, 17 or 42-days. Osteochondral plugs were harvested from stored specimens and implanted into the distal femur of eighteen adult sheep. Host sheep were sacrificed at 4 and 16 weeks following allograft placement. Chondrocyte viability, matrix proteoglycan, and the modulus of elasticity were analyzed (donor and host knees).Donor specimen chondrocyte viability decreased 26 percent (Day 17) and 48 percent (Day 42) compared to Day 1 ($p<0.001$). Following implantation, chondrocyte viability continued to significantly decrease for all stored specimens at both 4 and 16 weeks ($p<0.001$). At 4 and 16 weeks post-implantation, the decrease in viability, noted in Day 42 specimens (80%), was significantly greater than the decreases noted in Day 1 (57%) and Day 17 (71%) specimens ($p<0.01$). Proteoglycan content, and the modulus of elasticity were significantly less in Day 42 specimens compared to Day 1 and 17 specimens, following initial condyle storage, 4 and 16 weeks post-implantation ($p<0.01$). Allograft specimens, stored for 42 days, exhibited material properties that compared poorly to 1 and 17 day storage. The compromise in material properties did not improve following graft implantation.

PAPER NO. 110

The Effect of ABO Blood Type on Outcome of Fresh Osteochondral Allograft Transplantation

William Bugbee, MD, *La Jolla, CA (n)*
Christine Kwak, MS, La Jolla, CA (*)
Lauralynn Lebeck, PhD, La Jolla, CA (n)
Michael E. Brage, MD, San Diego, CA (n)

INTRODUCTION: Fresh osteochondral allografting (OCA) is an established treatment for chondral and osteochondral injuries. Current clinical practice does not include donor recipient blood match. We sought to determine the effect of ABO blood type match /mismatch on clinical outcome. METHODS: ABO blood type of 55 patients undergoing fresh OCA and their respective graft donors was determined from serum samples. Clinical outcome was determined at minimum 2-year followup. Failure was defined as graft collapse, revision or removal. Success was defined as improved 18-point clinical score. RESULTS: 16 patients and donors had identical blood types. 14/16 had successful allograft procedures (88%). 39 patients/donors had mismatched blood types. 28/39 were successful (72%). The difference was significant ($p<.05$). CONCLUSION: ABO blood type matching has significant impact on the outcome of fresh osteochondral allograft transplantation. Matching donor and recipient blood types should be considered when performing fresh OCA.

PAPER NO. 231

Kinematic Consequences of Chronic ACL Injury

Paul N Smith, MD, *Canberra, Australia (a – National Health and Medical Research Counsil Project Center)*
Jennifer Mary Scarvell, Woden, Australia (*)
Kathryn Margaret Refshauge, Lidcombe, Australia (n)
Howard Galloway, MD, Woden, Australia (n)
Kevin R Woods, FRACS, Forrest, Australia (n)

Late degeneration of the ACL injured knee may be in part due to repeat injury, but also due to aberrant kinematics altering the wear pattern at the chondral surface. The aim of this study was to use tibiofemoral contact mapping by MRI to examine kinematic changes due to chronic ACL deficiency.23 subjects with a history of chronic ACL deficiency (mean 18 years since injury) performed a closed chain leg press, relaxed and against a 15 kg weight. MRI recorded the tibiofemoral contact position at 15-degree intervals from 0 to 90 degrees of knee flexion. Intra-articular pathology was assessed for all subjects by MRI, and at arthroscopy for 10 subjects. The tibiofemoral contact pattern of the ACL injured knee differed from the healthy contralateral knee (p equals 0.003). This difference was greatest in the medial compartment, particularly at 0 and 15 degrees of knee flexion (p less than 0.01), with the femur 2mm (mean, SD 3.2mm) posterior on the tibial plateau. Damage to the chondral surface was seen in the medial compartment in 16 subjects and lateral compartment in 12; medial meniscus damage was present in 16 subjects and lateral meniscus in 15. Chondral surface damage correlated with the difference in the tibiofemoral contact pattern between the healthy and injured knee in the medial compartment of the knee. Joint damage was not related significantly to time since injury, or Cincinnati knee score. Joint damage was related to level of sports participation, but probably indicates that as the joint failed, subjects curtailed their activity.The kinematic consequences of chronic ACL injury may in part be responsible for the pattern of degenerative change, especially in the medial compartment of the knee.

PAPER NO. 232

MRI Analysis of Kinematics of the ACL Injured Knee

Jennifer Mary Scarvell, *Woden, Australia*
(a – National Health and Medical Research Counsil Project Center, Stryker Howmedica Osteonics)
Paul N Smith, MD, Canberra ACT, Australia
(a – National Health and Medical Research Counsil Project Center)
Kathryn Margaret Refshauge, Lidcombe, Australia (n)
Howard Galloway, MD, Woden, Australia (n)
Kevin R Woods, FRACS, Forrest, ACT Australia (*)

Degenerative change in the anterior cruciate ligament (ACL) injured knee is due in part to instability, which generates shearing at the knee. Magnetic Resonance Imaging (MRI) records the position of the knee with precision, and can accurately describe the tibiofemoral contact pathway. The aim of this research is to quantify the kinematic changes due to ACL injury. 20 subjects with a unilateral ACL injury were recruited (12 female, age 19 to 52 years, time since injury 3 weeks to four years). Passive ligament laxity was quantified using a KT1000 device. MRI scans were performed of both knees at 15 degree intervals from 0 to 90 degrees of knee flexion, unloaded, and in a closed chain leg-press against a 15 kg weight. Tibiofemoral contact points were measured at each position. Passive laxity

demonstrated side-to-side difference of 5.8mm (SD 2.4mm). MRI of injured knees demonstrated anterior displacement of the tibia compared to the intact knees, (p equals 0.043), which was more evident in the lateral compartment of the knee; the femoral contact more posterior on the tibial plateau (mean 1.7mm). The mediolateral contact pattern was preserved in the injured knees, indicating the preservation of the longitudinal rotation. But the medial contact points were more disturbed than the lateral contact points, suggesting the axis of rotation had shifted medially. The tibiofemoral contact path of the loaded knees did not differ from the unloaded knees.Anterior tibial displacement of the contact points was demonstrated by MRI in ACL injured knees through the range of knee flexion. Degenerative change in the ACL injured knee may be in part to aberrant knee kinematics generating shearing at the articular surface.

PAPER NO. 233

Natural History of Associated Injuries in Chronic ACL Tears

Steven Yin Wei, MD, *East Lyme, CT (n)*
Michael A Eslava, MD, APO, AE (*)

Introduction: To determine the natural history of cartilage and meniscus injuries associated with anterior cruciate ligament (ACL) tears in a population of American military personnel stationed in Germany, where ACL reconstructions are often delayed because of referral patterns and geographic distance. Methods: Retrospective review of all ACL reconstructions performed by two orthopedic surgeons at a single United States Army hospital in Germany over a two-year period. A review of the intra-operative records and arthroscopy photographs were used to determine the incidence of associated cartilage and meniscus injuries. Results: Sixty ACL reconstructions were performed during the study period, with Surgeon A performing 32 cases and Surgeon B performing 28. Statistical analysis revealed no significant difference between the two surgeons' practice patterns. The average age of the patients was 27.0 years (range 13-45). The average time from the date of injury to the first appointment with a primary healthcare provider was 30.0 days (range 0-313), and the average time from the first appointment with a primary care provider to the first appointment with an orthopedic surgeon was 151.2 days (range 1-1597). The average time from the first appointment with an orthopedist to the date of surgery was 75.2 days (range 2-256). The average time from the date of injury to the date of surgery was 259.7 days (range 12-1622). Intra-operative findings reveal a 33.3% incidence of lateral compartment damage, including a 20.0% incidence of lateral meniscus tears and a 26.7% incidence of lateral cartilage damage. Surgical findings also reveal a 50.0% incidence of medial compartment damage, including a 43.3% incidence of medial meniscus tears and a 30.0% incidence of medial cartilage damage. Conclusion: This study reveals the natural history of cartilage and meniscus injuries associated with ACL tears in a young, active population undergoing delayed ACL reconstruction. The high incidence of medial compartment damage in this patient population emphasizes the need for prompt referral of patients with ACL tears to an orthopedic surgeon.

PAPER NO. 234

A Comparison of BTB and Bone-Hamstring Tendon-Bone Autografts for ACL Reconstruction

Akio Matsumoto, MD, *Kobe, Japan (n)*
Shinichi Yoshiya, MD, Kobe, Japan (n)
Nobuzo Matsui, MD, Kobe,Hyogo, Japan (n)
Yasunobu Iwasaki, Kobe, Japan (n)
Masayoshi Yagi, MD, Kobe, Japan (n)
Ryosuke Kuroda, MD, Kobe, Japan (n)
Masahiro Kurosaka, MD, Kobe, Japan (n)

There have been a number of studies comparing patellar tendon versus hamstring tendon autografts for anterior cruciate ligament (ACL) reconstruction. However, in most of the previous studies, these two grafts were used to reconstruct the ACL with different fixation technique and level. In order to make a fair comparison between the two graft materials, in this study, clinical results of bone-patellar tendon-bone (BTB) autograft and bone-hamstring-bone (BHB) autograft were examined and compared. Seventy consecutive patients who underwent ACL reconstruction were included in this prospective study. Use of the two graft materials were randomized according to their birth year. Both BTB and BHB autografts were fixed with the same metal interference screw. Sixty-three out of 70 patients (BTB: 34/39, BHB: 29/31) were tracked for a minimum of 5 years with a mean follow-up period of 85.9 months. Follow-up evaluation was performed using IKDC criteria and scores. There was no significant difference between the groups in IKDC subjective and standard evaluations. KT-1000 evaluation showed no significant intergroup difference at manual maximum stress. Donor site morbidity in the BHB group was less common than that in the BTB group. With respect to kneeling, moderate or extreme difficulty was experienced in 5 of 34 patients in the BTB group and only 1 of 29 patients in the BHB group. No difference was found between the two groups with respect to IKDC scores and anterior knee laxity, however donor site morbidity was clearly less in the BHB group than in the BTB group.

PAPER NO. 235

Anatomic Anterior Cruciate Ligament Reconstruction: A Comparison of Two Endoscopic Techniques

David J Chao, MD, *San Diego, CA (n)*
David Hoang, DO, Sturbridge, MA (*)
Tal S David, MD, San Diego, CA (*)
Jonathan Jaseniuk, ATC, San Diego, CA (n)
Sean Young, ATC, OPA-C, San Diego, CA (*)
Patrick Cawley, PhD, Carlsbad, CA (*)

Introduction: The normal ACL has a defined sagittal orientation. ACL reconstruction should seek to reproduce the native ligament's anatomic sagittal angle. The authors hypothesize that drilling the femoral tunnel via the medial portal more closely mimics the anatomic sagittal ACL angle when compared to drilling the femoral tunnel transtibially. Methods: A single surgeon perfomed ACL reconstruction utilizing two endoscopic techniques (transtibial vs medial portal drilling of the femoral tunnel). The sagittal orientation of the ACL grafts were compared to that of the native ACL using two established MRI measurement techniques. ACL angles were measured in reference to the medial and lateral tibial plateau. Two separate evaluators recorded the reconstructed sagittal ACL angles independently. These values for the two techniques (transtibial vs medial portal) were then compared to that of the normal ACL. Results: There

was a statistically significant difference (p<0.001) between the mean sagittal ACL angle of the transtibial ACL graft (74.7 sd 8.0) compared to that of the normal ACL (56.9 sd 6.0). No statistical significance (p<0.8) was noted when comparing the mean sagittal angle of the medial portal ACL graft (57.5 sd 8.7) to that of the normal ACL. There was also a statistically significant difference (p<0.001) between the mean sagittal angle of the transtibial ACL graft and the medial portal ACL graft. The two evaluators and the two measurement techniques yielded similar results. Conclusions and Discussions: Based on MRI measurements of sagittal orientation, the authors conclude that the medial portal technique for drilling the femoral tunnel produces a more anatomic ACL reconstruction.

PAPER NO. 236

Hamstring vs. Patellar Tendon ACL Reconstruction: Experience from an Academic Medical Center

Derrick Fluhme, MD, *Pittsburgh, PA (n)*
Suzanne Miller, MD, Newton, MA (n)
Kenneth Westerheide, MD, Columbus, OH (*)
Kimberly A Francis, MS, Pittsburgh, PA (*)
James J Irrgang, PhD PT, Pittsburgh, PA (n)
Freddie H Fu, MD, Pittsburgh, PA (n)
Christopher D Harner, MD, Pittsburgh, PA (n)

Introduction: In 1994 we began using hamstring grafts (HS) as an alternative to patellar tendon (PT) autograft for ACL reconstruction. The purpose of this study was to compare the clinical outcome of these two grafts. We hypothesized that there would be no difference in clinical outcome and return to sports. Methods: From 1994 to 2000 815 patients underwent ACL reconstruction, of which 394 met the criteria for inclusion. 152 underwent PT reconstruction and 154 with HS. Outcomes included the IKDC Subjective Score, physical exam, instrumented measurement of laxity and return to sport. Results: 120 patients (65 PT, 55 HS) were evaluated at 4.1 years (range 2.1-5.9). There was no difference in IKDC Subjective Scores between groups (88 PT vs. 90 HS p=.19). There were no differences in Lachman (91% PT, 97% HS normal/nearly normal p=.20) or pivot shift (74% PT, 77% HS equal side-to-side p=.69). The average 30lb. KT side-to-side difference was 1.7 mm for each group, however only 2% of the PT compared to 13% of the HS had greater than a 5 mm side-to-side difference KT (p=.06). There was no difference between groups in patellofemoral crepitus with pain, however 16% of the HS & 44% of the PT avoided kneeling (p=.01). 78% of the PT and 69% of the HS returned to the same or more strenuous level of sports. Discussion & Conclusion: In our experience clinical outcome and return to play are similar for both grafts. HS appears to be an acceptable graft choice for ACL reconstruction.

PAPER NO. 237

ACL Reconstruction in Patients Over 40 years Old: Allograft Versus Autograft Patellar Tendon

David A Stokes, MD, *Atlanta, GA (*)*
Gene R Barrett, MD, Jackson, MS (n)
Miranda White, Research, Jackson, MS (n)

Objective: The purpose of this study is to compare the clinical results of ACL reconstruction using autograft and allografts BPTB grafts in patients over the age of forty years old. Methods: Sixty-three patients were identified from our knee database that met the criteria for this study; 38 in the allograft group (A), and 25 patients in the autograft group (B). All patients were over 40 years old and had at least 24 months follow-up. Objective parameters included pre-injury and postoperative Tegner and Lysholm scores, range of motion, thigh circumference differences, side-to-side KT-1000 differences, and clinical examination for Lachman and pivot shift tests. Subjective evaluations were performed using a 15-point Visual Analog Scale. Results: Group A showed a quicker return of the Lysholm score to the 90-level at 6 months. Tegner activity scores returned to pre-operative levels in both groups. Visual analog scales and range of motion data were similar between the two groups. KT-1000 data showed an average maximum difference of 1.46mm for group A and 0.10mm for group B. Three knees showed > 5 mm difference in Group A compared to none in Group B. There was one clinical failure in Group A. In Group A, 57% of patients had returned to sport by 6 months versus only 25% of patients in group B (p = 0.006). At final follow-up, Group A had increased to 71% back to sports, while Group B stayed at 44%(p =0.004). Thigh circumference differences also decreased quicker in Group A, but were not of statistical significance. Conclusions: In this older age group, our data support the use of allograft BPTB for ACL reconstruction as our patients had quicker return of satisfaction (Lysholm) and return to sporting activities when compared to autograft BPTB.

PAPER NO. 238

The Effect of ACL Reconstruction on the Risk of Knee Re-injury

Warren Dunn, MD, *New York, NY (a – AAOS / OREF)*

Introduction: While there is evidence that very active, young patients are better served with ACL reconstruction, there is a lack of objective data demonstrating that future knee injury is prevented by these procedures. Methods: We identified a cohort of 6,576 active-duty Army personnel who had been hospitalized for ACL injury from 1990 to 1996. Using the Total Army Injury and Health Outcomes Database, we retrospectively followed these individuals for up to 9 years and collected clinical, demographic, and occupational data. These data were evaluated with bivariate and multivariable analyses to determine the effect of ACL reconstruction on the rate of knee re-injury requiring operation. Results: Of the 6,576 study subjects 3,795 subjects (58%) underwent ACL reconstruction, and 2,781 (42%) did not. The rate of re-operation was significantly lower among the ACL reconstruction group (4.90 per 100 person-years) compared to those treated conservatively (13.86 per 100 person-years (p<0.0001). Proportional hazard regression analyses adjusted for age, race, sex, marital status, education, and physical activity level confirmed that ACL reconstruction was protective against meniscal and cartilage re-injury (p<0.0001). Secondary medial meniscal injury was more common than secondary lateral meniscal injury (p<0.003). Younger age was the strongest predictor of failure of conservative management leading to late ACL reconstruction (p<0.0001). Conclusions: ACL reconstruction protected against re-operation in this young, active population; younger subjects treated conservatively were more likely to require late ACL reconstruction.

PAPER NO. 239

Subjective Results of Nonoperatively Treated, Acute, Isolated Posterior Cruciate Ligament Injuries

Yegappan A L Muthukaruppan, MD, *Singapore, Singapore (n)*
K Donald Shelbourne, MD, Indianapolis, IN (n)

A previous natural history study of acute posterior cruciate ligament (PCL) injuries showed that subjective and objective results were not statistically significantly different based on the degree of PCL laxity and that the scores did not significantly decrease with time from injury. This current study is a continuation of the previously reported natural history study. Our purpose was to continually evaluate subjective scores that were obtained yearly from patients. Between 1983 and 2001, 271 patients who were seen for an acute, isolated posterior cruciate ligament injury were asked to enroll in a long-term study (Grade 1, N=100; Grade 1.5, N=43; Grade 2, N=128). A modified Noyes subjective knee survey was mailed to patients on a yearly basis. Since 2000, an International Knee Documentation Committee Subjective Knee Survey has been mailed on a yearly basis. The most recent modified Noyes survey was obtained from 215 patients at a mean time of 7.8 years after injury (range 1 to 18), and the mean total score was 85.6 +/- 15.0 points. IKDC subjective scores were obtained from 85 patients at a mean time of 8.8 years after injury, and the mean score was 82.7 +/- 16.0 points. There was a statistically significant correlation between the IKDC subjective score and the modified Noyes total score (R2., 0.56426; P<0.0001). Patients with greater PCL laxity did not have statistically significant lower subjective scores than patients with lesser PCL laxity. There were 146 patients who had at least 4 modified Noyes subjective surveys that could be evaluated for their consistency of total scores through time after injury. Total scores were consistently excellent for 40 percent, consistently good for 10 percent, consistently fair for 6 percent, consistently poor for 2 percent, consistently improving scores for 16 percent, decreasing scores for 12 percent, and inconsistent scores for 14 percent. Of 67 patients who scored less than 85 points in the first 2 years after injury, only 34 had a score less than 85 points at their most recent survey. The results of this study show that the subjective scores of patients with acute, isolated PCL injuries were independent of grade of PCL laxity and mean scores did not decrease with time from injury.

PAPER NO. 240

Ten to Twenty-Year Results After Anterior Cruciate Ligament Reconstruction

K Donald Shelbourne, MD, *Indianapolis, IN (n)*
Tinker Gray, MA, ELS, Indianapolis, IN (n)

We sought to determine what factors adversely affected the results at 10 to 20 years after ACL reconstruction. Factors considered included the status of the menisci and the articular cartilage, age, sex, acute or chronic injury, and return of normal knee extension and flexion after surgery. Subjective follow-up was obtained on 815 patients at a mean of 13.5 +/- 2.5 years postoperatively. Objective follow-up according to IKDC criteria was obtained on 345 patients at a mean of 12.8 +/- 2.4 years postoperatively. The mean KT-1000 arthrometer manual maximum difference was 2.0 +/- 1.7 mm. Stepwise regression analyses determined, in order of importance, that any lack of knee extension compared with the normal knee, a medial meniscectomy, damaged articular cartilage surface, and lateral meniscectomy were statistically significantly associated with lower subjective total scores (P<0.01). The mean total score was 91.0 for patients who had normal extension and flexion, 88.1 for patients who had normal extension but lacked flexion, 82.6 for patients who lacked extension but had normal fleixon, and 78.1 for patients who lacked both extension and flexion . Subjective scores, obtained yearly, remained consistently above 92 points for patients who had intact menisci. Most notably, patients with medial meniscectomy had a sharp decline from 88 points at 12 years, to 84 points at 15 years and 79 points at 18 years after surgery. Abnormal IKDC radiographic ratings were associated with meniscal removal. We recommend that patients who wish to remain active in twisting and pivoting activities after an ACL injury should undergo an ACL reconstruction before they suffer additional giving-way episodes. Furthermore, obtaining full symmetrical knee motion, especially extension, is critical for obtaining an optimum result.

POSTERS

POSTER NO. P304

A Long-Term Serial Histologic Evaluation of the Patellar Tendon After Harvestings its Central Third

Juri Kartus, MD, *Trollhattan, Sweden (n)*
Michael Svensson, MD, Trollhattan, Sweden (n)
Lars Rostgard Christensen, MD, Lidkoping, Sweden (n)
Tomas Movin, MD, Huddinge, Stockholm, Sweden (n)
Nikos Papadogiannakis, MD, PhD, Stockholm, Sweden (*)
Jon Karlsson, MD, Gothenburg, Sweden (n)

Introduction: The aim of the study was to obtain serial biopsies from the central and peripheral parts of the patellar tendon, at approximately two and 6 years after harvesting its central third. Methods: Seventeen consecutive patients (7 female and 10 male), who had undergone anterior cruciate ligament (ACL) reconstruction using patellar tendon autograft were included in the study. Biopsies from all patients were obtained under ultrasound guidance using a 1.2 mm needle at median 27 and 71 months after the index procedure. The sections were stained with hematoxylin and eosin for the evaluation of the fibre structure, cellularity and vascularity. The Alcian Blue (pH 2.5)/Periodic Acid-Schiff method was used to detect glycosaminoglycans (GAGs). The biopsies were evaluated with the light microscope using a semi-quantitative scoring system. Results: At both occasions the fibre structure was significantly (p<0.001) deteriorated and the vascularity and cellularity were significantly (p<0.001) increased compered with normal tendon. This was seen both in the central and peripheral part of the tendon. At both occasions no increase of GAGs was found in either part of the tendon. Discussion and Conclusion: At nearly 6 years after harvesting its central third the patellar tendon still revealed a deteriorated fibre structure and an increase of cellularity and vascularity both in the central and peripheral parts of the tendon. This means that re-harvesting of the patellar tendon cannot be recommended when autograft tissue is required e.g. for revision ACL surgery.

POSTER NO. P305

Analysis of Knee Kinematics Following Successful ACL Reconstruction using Dynamic MRI

Martin Charles Logan, MBChB, MRCS, London, United Kingdom (n)
Andrew Williams, MBBS, FRCS, London, United Kingdom (*)
Wady Gedroyc, MBBS, FRCR, London, United Kingdom (*)
Michael A R Freeman, MD, London, United Kingdom (*)

Introduction: The aim of reconstruction of the ACL is to reduce excess joint laxity, hoping to restore normal tibiofemoral kinematics and therefore improve joint stability. It is unclear if current methods of ACL reconstruction restore normal kinematics and whether it is this which is associated with a good surgical result. This study employs open access MRI to assess the kinematics of the ACL reconstructed knee. Methods: Ten patients who had successful isolated ACL reconstruction with hamstring autograft (Lysholm score average 98/100) and who had returned to normal daily and sporting activities were scanned using open access MRI allowing both sagittal laxity (assessed by Lachman's test) and weightbearing tibiofemoral motion through the arc of flexion 0-90 to be assessed. Contralateral normal knees were used as the control. Results: Sagittal laxity was similar between the ACL reconstructed and the contralateral normal knees. The amount of excursion between the tibial and femoral joint surfaces was similar through the arc of flexion but the relationship of tibia to femur was always different with persistent anterior subluxation of the lateral tibial plateau in all positions of flexion in the ACL reconstructed group($p<0.003$). Conclusion: Successful ACL reconstruction using four-strand hamstring autograft reduces excess joint laxity but does not restore normal tibiofemoral kinematics. This may help explain, at least in part, the observation that the incidence of osteoarthritis does not reduce after ACL reconstruction.

POSTER NO. P306

The Effect of ACL Surgery on Bone Mineral in the Calcaneus

***Lars Ejerhed, MD,** Trollhattan, Sweden (n)*
Juri Kartus, MD, Trollhattan, Sweden (n)
Ulf Nilsson, PhD, Kristianstad, Sweden (*)
Ragnar Kullberg, PhD, Halmstad, Sweden (n)
Jon Karlsson, MD, Gothenburg, Sweden (n)

INTRODUCTION Could modern anterior cruciate ligament (ACL) reconstruction technique, followed by an early and aggressive rehabilitation programme prevent previously described local bone loss? The aim of the study was to evaluate the effect of ACL reconstruction on the bone mineral areal mass (BMA) in the calcaneus on the injured and non-injured side. METHODS Thirty-four consecutive patients with a unilateral ACL rupture underwent arthroscopic reconstruction using patellar tendon autografts. The BMA was assessed bilaterally in the calcaneus using a g-camera according to the Dual-energy Photon Absorptiometry technique, before the operation and after six and 26 months. RESULTS Thirty-one of thirty-four patients (20 men and 11 women) underwent all the BMA measurements. The median age at the index operation was 27 (16-50) years and the reconstruction was performed 12 (2-192) months after the injury. The median preoperative Tegner activity level increased from 3 (2-8) to 7 (2-9) at 26 months ($p<0.0001$). The BMA in the calcaneus on both the injured and non-injured side decreased by 16% and 17% respectively from the preoperative measurement to the 26-month control ($p=0.0014$, $p=0.0006$). On all occasions, the BMA was lower on the injured side than on the non-injured side ($p=0.012$). CONCLUSIONS Patients with a unilateral ACL rupture had a lower BMA in the calcaneus on the injured side compared with the non-injured side. Although the patients increased their activity level after the reconstruction, the BMA in the calcaneus decreased on both the injured and the non-injured side up to two years after the operation.

POSTER NO. P307

Surgical Results of Tibial Inlay Method with Quadriceps Tendon-Bone Autograft for PCL Reconstruction

***Tai-Yuan Chuang, MD,** Taoyuan, Taiwan (n)*
Chen Chih-Hwa, Prof, Taoyuan, Taiwan (n)
Wen-Jer Chen, MD, Kweishan Taoyuan, Taiwan (n)

INTRODUCTION: Surgical reconstruction of the posterior cruciate ligament (PCL) is indicated in a PCL-deficient knee with symptomatic instability and injury to other ligaments. The tibial inlay method with bone patellar tendon-bone generally has been used. In the present study, we describe the tibial inlay method with an alternative graft, the quadriceps tendon-patellar bone autograft, by using posterior arthrotomy and arthroscopy-assisted PCL reconstruction. METHODS: From September of 2000 through March of 2001, a quadriceps tendon-patellar bone autograft for tibial inlay technique was used in 13 patients with PCL injuries. RESULTS: After 24-30 months of follow-up, the clinical outcomes for those patients with this graft in tibial inlay technique have been encouraging. Eleven patients could return to the same of pre-injury daily activity and sports activity. According the International Knee Documentation Committee rating System, 11 of the 12 patients had normal or nearly normal ratings. Recovery of quadriceps muscle strength to 80% of normal knee was achieved in 11 patients in 1 year. DISCUSSION: Clinically the long-term result of the transtibial reconstruction of PCL is not quite satisfactory. This traditionally method of posterior cruciate reconstruction utilizes a transtibial tunnel in which the graft must pass around an acute angle at the posterior aspect of the tibia. This type of configuration will generate the high local tissue stresses theoretically. The tibial inlay method for PCL reconstruction has the benefit of preventing the acute turn associated with transtibial reconstruction and permitting accurate anatomic placement of the graft. The previous choice of the graft in the inlay technique was patellar tendon autograft. The patellar tendon autograft was not only difficult to pass through the tunnel due to its orientation, it was also associated with donor site morbidity including severe permanently anterior knee pain and patellar fractures. Additionally, patellar tendon autograft had inherent defect of length problems, especially too long for the fixation on the femoral site. The advantages of the quadriceps tendon graft include the following: the graft is larger and stronger than the patellar tendon; morbidity of harvest technique and donor site is less than that of patellar tendon graft; there is little quadriceps inhibition after quadriceps harvest; there is quicker return to sports activities with aggressive rehabilitation. CONCLUSION: This inlay technique with quadriceps tendon-patellar bone autograft is a reasonable alternative to PCL reconstruction in patients for PCL reconstruction.

POSTER NO. P308

Quantitative Comparison of Bone-Patellar Tendon-Bone and Tibialis Tendon Allografts

Gregory P DeConciliis, PA, *Boston, MA*
(a – Regeneration Technologies, Inc)
Kellen Choi, MD, Cambridge, MA (n)
Chris Balint, DO, Roxbury Crossing, MA
(a – Regeneration Technologies, Inc)
Glen Ross, MD, Wayland, MA
(a – Regeneration Technologies, Inc)
Arnold D Scheller, MD, Brookline, MA (n)

Introduction: Several biologic graft substitutes are available for ACL reconstruction. While bone-patellar tendon-bone (BTB) grafts have been commonly employed, soft tissue grafts such as quadrupled hamstring , and doubled tibialis tendon, have been increasingly utilized. There are few quantitative studies available to compare the diameter and mass of tendon tissue of equally sized BTB and soft tissue grafts. The objective of this study is to quantify and compare BTB and soft tissue grafts, as are typically employed in clinical ACL reconstruction. Methods: A controlled laboratory format was selected. Ten fresh frozen BTB, and nine doubled tibialis tendon allograft specimens were prepared. BTB grafts were created as 9, 10, and 11 mm. bone blocks with a leader suture placed through a drill hole. Tibialis tendons were whipstitched on both ends and doubled over a suture. Standardized graft sizing was performed using a closed sizing block, with a pull-through force of 2.5 kg. measured on a tensiometer. The bone blocks were then removed from the BTB specimens, and the intervening tendon tissue was re-sized. Tendon diameter and mass were measured and compared for a standardized length. Results: The average diameter of the tendon component of the BTB grafts was 64% of the corresponding average bone plug . A typical 10 mm. BTB construct had a sized tendon diameter of 6.5 mm. For a standardized construct length, the average mass of the tibialis tendon graft was 65% greater ($p < .01$) than the mass of a comparable BTB after bone plug removal. Conclusion: The patellar tendon component of bone-patellar tendon-bone grafts may be less than two-thirds the diameter of the attached bone plugs. The average tendon mass available for ACL reconstruction is approximately 65% more using a doubled tibialis tendon in comparison to a BTB with standard clinical constructs and sizes. Grafts with smaller bone tunnels, and larger mass, may be advantageous in minimizing morbidity, while still providing greater available collagen for ulitmate "ligamentization."

POSTER NO. P309

Arthroscopic Sliding Knot: How Many Additional Half Hitches Are Really Needed?

Seung-Ho Kim, MD, *Seoul, Korea, Republic of*
(d – Linvatec)
Jae-Chul Yoo, MD, Seoul, Korea, Republic of (n)
Joon Ho Wang, MD, Seoul, Korea, Republic of (n)
Kuiwon Choi, Seoul, Korea, Republic of (*)
Tae Soo Bae, Seoul, Korea, Republic of (*)
Chang Yang Lee, MS, Seoul, Korea, Republic of (*)

Introduction: To evaluate the optimal number of additional half hitches for achieving an optimal knot-holding capacity of lockable sliding knots. Methods: Four configurations of arthroscopic knots (Duncan loop, Field knot, Giant knot, and SMC knot) were tested for their knot-holding capacity. For each knot configuration, 6 sequential knots were made including the initial sliding knot and additional 5 knots by incrementing one half hitches at a time. For each sequential knot configuration, 12 knots were made by No. 2 braided sutures. On the servo-hydraulic material testing system (Instron 8511, MTS, Minneapolis, MN), cyclic loading, load to clinical failure (3-mm displacement), load to ultimate failure, and mode of failure were measured. Results: Most of the initial loop without additional half-hitch showed dynamic failure with cyclic loading. However, after one additional half hitch, all three (SMC, Field, and Giant) knots showed resistance to dynamic cyclic load. After 2 additional half hitches, Duncan loop was secured without slippage from the cyclic loading test. The mean displacement after the end of cyclic loading decreased with each additional half-hitches. Especially, SMC and Giant knot showed plateau of less than 0.1 mm displacement after one additional half hitch, whereas Field and Duncan loop needed 3 additional half hitches. The SMC and Duncan knots needed 1 additional half hitch to reach greater than 80N at clinical failure, whereas the other 2 knots needed 2 additional half hitches. For the load exceeding 100N for clinical failure, the SMC knot required 3 additional half hitches and the other three knots needed 4 additional half hitches. Addition of more than 3 half hitches did not increase the load to clinical failure in the SMC knot. However, load to clinical failure increased up to 4 additional half hitches in the other 3 knots ($p<0.05$). The load to ultimate failure reached plateau when 3 or more additional half hitches were made for all knot configurations. As the number of additional half hitches incremented, the mode of failure switched from pure loop failure (slippage) to material failure (breakage). Duncan loop showed poor loop security in that even with 5 additional half hitches, some failed by slippage (17%). On the other hand, after 3 additional half hitches, the 3 other knots showed greater than 75% of failure by material breakage mode (SMC and Field 92%, Giant 75%). Discussion and Conclusion: Even with its own locking mechanism, lockable sliding knot alone does not withstand the initial dynamic cyclic load. For all tested variables, SMC knot requires a minimum of 2 additional half hitches. All knots showed a near plateau in knot security with 3 or more additional half hitches. Duncan knot may need more than 3 additional half hitches for optimal security.

POSTER NO. P310

Reconstruction of the Ulnar Collateral Ligament of the Elbow Utilizing a Gracilis Allograft

Mark S Fitzgerald, MD, *Boston, MA (n)*
Craig D Morgan, MD, Wilmington, DE (*)
Anthony Alberto Schepsis, MD, Boston, MA (n)

Introduction: Reconstruction of the ulnar collateral ligament has been shown to be a very gratifying procedure in throwing athletes as well as athletes where repetitive valgus stresses are placed on the elbow. The traditional graft source has been the palmaris longus, however in many people it is absent or diminutive. Furthermore, it, as well as other potential autogenous sources, carries potential complications and morbidity. We report a series of athletes where reconstruction was carried out with a fresh frozen gracilis allograft. Methods: Between 1998 and 2001, 29 patients underwent UCL reconstruction using a fresh frozen gracilis allograft. Two primary surgeons from separate centers contributed. The average length of follow-up was 3.3 years, range: 2 to 7 years. There were 27 males and 2 females with a mean age of 21, range: 17-30. Eleven (38%) were professional baseball players, 10 (34%) were collegiate baseball players, and 4 (14%) were high school players. Twenty-one of these baseball players were pitchers. Also included were 2 football players, one

martial artist, and one hockey player. Reconstruction was performed via modified Jobe technique, the flexor pronator mass was not detached. The gracilis was sized to the appropriate diameter. Three (10%) patients had ulnar nerve transposition, and 2 (7%) underwent removal of olecranon osteophytes. Results: Results were classified according to the Conway-Jobe (ref.) criteria based on return to competitive sport and related symptoms. At two year follow up 24 (82%) patients met the criteria of "excellent". Five (18%) patients had "good" results. No patients demonstrated "fair/poor" results. Seven (24%) had ulnar nerve symptoms preoperatively. Two of these patients underwent ulnar transpostition. All 7 reported complete resolution of symptoms postoperatively. Two patients underwent a second procedure for osteophyte excision at 3 months and 2.5 yrs respectively following index procedure with excellent results within 4 months. There was no incidence of late instability, recurrent laxity, rejection, infection, or any complications related to the allograft. Conclusions: The gracillis tendon allograft has excellent biomechanical and size characteristics for reconstruction of the UCL. The allograft performs well in this richly vascular environment.

POSTER NO. P311

The Molecular Weight Dependent Influence of Hyaluronic Acid on Human Chondrocytes

David Wohlrab, MD, *Saale, Germany (n)*
Werner Hein, MD, Saale, Germany (*)

Introduction: Osteoarthritis occurs as a consequence of pathological changes of synovial hyaluronic acid (HA). The impact of cell biological features by HA has only been partially investigated . In this study, the concentration-dependent influence of five HA with different molecular weight (0.5-6.0 million Dalton) on chondrocytes has been investigated. Methods: The investigations were performed on human chondrocytes. Cells were cultivated for 14 or 28 days. Three different concentrations of each HA were applied. Cells were counted in a counting chamber. Flow cytometry was used to determine the DNA synthesis capacity and the cell cycle distribution. Results: Under the influence of HA, a considerable increase in the cell number and of the DNA synthesis capacity together with a displacement of the cell cycle phases, occur in human chondrocytes. Particularly, the DNA synthesis capacity increased with high molecular weight HA (6.0 million Dalton) by up to 70%. In chondrocytes cultivated with another HA preparation the increase of the DNA synthesis capacity was only up to 35%. Conclusion: HA leads to a modulation of the proliferation of human chondrocytes. The increase of chondrocytes proliferation depends on the HA molecular weight and is most distinct under the influence high molecular weight HA (6.0 million Dalton).

POSTER NO. P312

Anterior Capsularraphy: An In Vitro Comparison of Volume Reduction - Arthroscopic Plication versus Open Capsular Shift

Steven B Cohen, MD, *Charlottesville, VA (n)*
Vipool K Goradia, MD, Richmond, VA (*)
Mark D Miller, MD, Charlottesville, VA (n)

Introduction: Shoulder instability is a result of several pathologic processes including capsular laxity, labral detachment, and a rotator interval defect. The anterior capsular shift has become a well-established procedure for the treatment of the unstable shoulder. Multiple techniques have been used to reduce capsular volume from both open and arthroscopic approaches. The purpose of this study was to objectively compare volume reduction following arthroscopic plication and open lateral capsular shift. We hypothesized that capsular volume reduction would be achieved to a greater degree using an open capsular shift when compared to arthroscopic capsular plication. Methods: Fifteen fresh frozen human cadaver shoulders were assigned to one of two groups: arthroscopic plication (N=7), or open lateral capsular shift (N=8). A power analysis performed prior to the study revealed 90% power with the minimum use of seven shoulders per group. Initial capsular volume was measured by repeated injection of a viscous fatty acid sulfate solution and recorded for each specimen. Repeated measurements were taken post-procedure to determine volume reduction. Results: Both procedures resulted in reduction of capsular volume. The arthroscopic plication resulted in a 22.8% volume reduction and the open lateral capsular shift resulted in a 49.9% volume reduction. Comparison of the two procedures revealed significant volume reduction following open lateral capsular shift to arthroscopic plication (p=0.00001). Repeated measurements confirmed that the injection technique was valid and reproducible. Discussion / Conclusion: The lateral capsular shift resulted in significantly greater volume reduction when compared to arthroscopic plication. Based on these results we recommend an open lateral based capsular shift for patients with instability and a large patulous shoulder capsule. The amount of volume reduction required to eliminate instability still remains unknown for patients with shoulder instability due to capsular laxity.

POSTER NO. P313

MRI of Medial Patellofemoral Ligament in Recurrent Patellar Dislocation

Yoshiki Shiozaki, MD, *Osaka, Japan (n)*
Shuji Horibe, MD, Osaka, Japan (*)
Norimasa Nakamura, MD, Sakai, Osaka, Japan (n)
Tomoki Mitsuoka, MD, Sakai, Osaka, Japan (*)
Yukiyoshi Toritsuka, MD, Osaka, Japan (*)
Konsei Shino, MD, Habikino Osaka, Japan (*)

PURPOSE: Although the usefulness of MR imaging for acutely injured medial patellofemoral ligament (MPFL) has been reported, no study on MR appearance in patients with recurrent patellar dislocation has been conducted. The purpose of this study was to correlate MR findings of MPFL with macroscopic findings in patients with recurrent patellar dislocation, and clarify its usefulness. METHODS: Seventeen knees with recurrent patellar dislocation underwent preoperative MR evaluation and subsequent surgery. There were 4 males and 12 females with a mean age of 22 years. With an axial T2-weighted fast spin-echo MR imaging, MR findings of MPFL were graded as normal (intact fibers with no adjacent edema), stretched (wavy continuous fibers with adjacent edema), deficient at the femoral attachment site, or absent (no intact fibers noted), according to Sanders TG et al (JCAT, 2001). RESULTS: MR findings were classified into normal in 0, stretched in 1, disrupted (at the femoral attachment site) in 14, or absent in 2. At the time of surgical exploration, the MPFL was ligament-like tissue in one, scar-like tissue in 3, deficient at the femoral attachment site in 4 and absent in 9. The MR findings were especially well correlated with the operative ones in stretched, absent cases.CONCLSION: Since MRI accurately depicts of the injured MPFL in patients with recurrent patellar dislocation, it plays a significant role in selecting surgical procedures.

POSTER NO. P314

Retroversion of Chondrolabral Glenoid in Atraumatic Posteroinferior Multidirectional Instability

Seung-Ho Kim, MD, *Seoul, Korea, Republic of (d – Linvatec)*
Kyu-Cheol Noh, MD, Seoul, Korea, Republic of (*)
Jun-Sic Park, MD, Seoul, Korea, Republic of (n)
Byung Dam Ryu, MD, Seoul, Korea, Republic of (n)
Irvin Oh, MD, Seoul, Korea, Republic of (n)

Introduction: Conformity of the glenohumeral joint is an integral function of articular cartilage and labrum. Although retroversion of the bony glenoid has been controversial with respect to the potential cause of the posteroinferior instability, the measurement of the glenoid version can be more logical when chondrolabral structures are included. The purpose of this study was to evaluate the containment of the chondro-labral glenohumeral joint in patients with atraumatic posteroinferior multidirectional instability of the shoulder. Methods: We evaluated three measurements representing glenohumeral containment (bony and chondrolabral glenoid version, labral height, and glenoid depth) on T2 axial images of the magnetic resonance imaging-arthrogram of 33 shoulders with atraumatic posteroinferior type of multidirectional instability. The shoulder with a documented labral tear was excluded. The measurements were compared with 33 age-matched control patients without glenohumeral pathology. The angle of version of the chondro-labral glenoid was measured in three consecutive plains (upper 25%, middle 50%, and lower 75% from upper limb of the glenoid) perpendicular to the long axis of the glenoid. Results: Bony and chondrolabral glenoid have more retroversion in the posteroinferior instability group than the control group in the middle and lower plains. In upper plain, there was no difference in the version between two groups. The chondrolabral glenoid version (retroversion 7.0 degree) was more retroversed than bony glenoid version (retroversion 4.6 degree) in the lower plain ($p=0.008$). Glenoid depth of the lower plain of the instability group was significantly shallower than those of control group and middle and upper plains of the instability group ($p<0.001$). The height of the posterior labrum in the lower plain of the instability group decreased than that of control group and other plains of the same group. Discussion and Conclusion: Chondrolabral retroversion of the middle and lower parts of the glenoid is a consistent finding and is due to the loss of posterior labral height. Although it is unclear whether the retroversion of the posteroinferior labrum is a cause or consequence, the correction of the chondrolabral retroversion should be considered in surgical intervention.

POSTER NO. P315

BMP-Signalling Plays a Role in Tendon-to-Bone Healing: A Study of rhBMP-2 and Noggin

C Benjamin Ma, MD, *San Francisco, CA (n)*
Sumito Kawamura, MD, New York, NY (n)
Lilly Ying, MD, New York, NY (*)
Xiang-Hua Deng, MD, New York, NY (*)
Scott Alan Rodeo, MD, New York, NY (n)

Background: Since healing of a soft tissue graft in a bone tunnel requires osteointegration, it is likely that BMPs play an important role in regulation of healing. This study tests the hypothesis that rhBMP-2 stimulates and noggin (a BMP inhibitor) inhibits healing of a tendon graft in a bone tunnel. Methods: 21 mature New Zealand rabbits underwent bilateral ACL reconstruction with an autologous tendon graft. Three rabbits each received rhBMP-2 (11.5, 50 or 115mg) or noggin (10, 15, 30 and 100ng), applied to the tendon-bone interface using a calcium phosphate carrier. Controls received only the calcium phosphate vehicle. Animals were sacrificed at 2 weeks and the tissues were analyzed using high resolution radiographs and histomorphometric analysis of tendon diameter, width of new bone formation (NBF) and width of the tendon-bone interface (IF) using computerized image analysis. Results: rhBMP-2 treatment led to a significant increase in new bone formation around the graft in a dose-dependent fashion (0.24-0.35mm vs 0.13-0.16mm for control). rhBMP-2 treatment also decreased the width of the fibrous tendon-bone interface. All dosages of noggin inhibited NBF from 38-60% (0.06-0.1mm vs 0.15-0.16mm for control), with a concomitant 14-60% increase in the width of the fibrous tendon-bone interface. High resolution radiographs demonstrated increased radiodensity and a decrease in tunnel diameter in the rhBMP-2 group, while the noggin group was not significantly different than control. Conclusion: rhBMP-2 demonstrated a strong, positive dose-dependent effect on osteointegration at the tendon-bone junction, while noggin, a potent BMP inhibitor, decreased osteoblastic activity. These findings indicate that BMPs play an important role in tendon healing to bone.

POSTER NO. P316

ACL Impingement Against the PCL: Imaging using MRI with Three Dimensional Reconstruction Software

Eisaku Fujimoto, MD, PhD, *Kure, Japan (n)*
Yoshio Sumen, MD, Hiroshima, Japan (*)
Masataka Deie, MD, Hiroshima, Japan (n)
Kenji Kobayash, MD, PhD, Hiroshima, Japan (n)
Mitsuo Ochi, MD, Hiroshima, Japan (n)

Introduction: Arthroscopy during the operation cannot assess ACL impingement against the PCL in the extended position. The purpose of this study was to evaluate ACL impingement against the PCL. Methods: Ten normal knees and 30 ACL reconstructed knees were assessed using MR axial proton density images against the ACL. The three-dimensional reconstruction of the ACL, PCL, femur and tibia were carried out using commercially available software. The ACL impingement against the PCL was graded into 3 categories. Grade 1: some space between the ACL and PCL; Grade 2: no space between the ACL and PCL, and the reconstructed ACL ran straight; and Grade 3: the reconstructed ACL did not run straight. The angle of the reconstructed ACL against tibial plateau was also measured. Results: All normal knees were graded as Grade 1 (negative impingement). Reconstructed 30 knees were classified as follows: Grade 1; 12 cases, Grade 2; 7 cases, and Grade 3; 11 cases. The mean angle of the Grade 3 (positive impingement) reconstructed ACL was significantly vertical against the tibia compared with Grade 1 ($p<0.05$). The postoperative KT-2000 side-to-side difference of the Grade 1 is smaller than that of the Grade 2 and 3, but quite significant difference could not be detected between the 3 groups in the postoperative KT-2000 data. Discussion and Conclusion: This method is useful to evaluate ACL impingement against PCL, which could not be detected by arthroscopy during the operation. The surgeon should pay careful attention to the coronal angle of the reconstructed ACL.

POSTER NO. P317

Enhanced Tendon to Bone Healing: A Pilot Study Comparing PLLA vs. TCP Interference Screws

Beth E Shubin Stein, MD, *New York, NY*
(a,b – Bionx, Institute for Sports Medicine Research)
Frank A Cordasco, MD, New York, NY
(a – Bionx, Institute for Sports Medicine Research)
Scott Alan Rodeo, MD, New York, NY
(a – Bionx, Institute for Sports Medicine Research)
Jo A Hannafin, MD, PhD, New York, NY
(a – Bionx, Institute for Sports Medicine Research)
Hollis Potter, MD, New York, NY (n)
Peter Torzilli, PhD, New York, NY (n)
Russell F Warren, MD, New York, NY
(a – Bionx, Institute for Sports Medicine Research)

Introduction:Since tendon-to-bone healing involves bone ingrowth into a tendon graft, we hypothesized that tricalcium phosphate (TCP) impregnated screws could accelerate healing of soft tissue within a bone tunnel. Methods:ACL reconstruction was performed in 32 sheep using long digital extensor tendon autografts. The graft was secured with PLLA screws in 16 animals and with TCP impregnated screws in 16 animals. Four sheep from each group were sacrificed at 3,6,9 and 12 weeks and evaluated with MRI and histology. MR evaluation included graft signal at the tunnel, bone-screw interface (including edema pattern, fibrous tissue, fluid, alteration in trabecular pattern and bone resorption) graft-bone interface, graft integrity and tunnel diameter. Results:MR imaging demonstrated greater bone ingrowth and less bone resorbtion in the TCP-treated animals. In the TCP group 71% of the bone tunnels showed good to excellent bone ingrowth vs. 19% in the PLLA group. Twenty-nine percent of TCP-treated specimens showed bone resorption around the screw compared to 81% in the PLLA group. Seven percent of the specimens showed greater than 2mm of edema surrounding the TCP screw vs. 50% in the PLLA group. There was a higher prevalence of fraying of the graft at the femoral aperture in the TCP group (5/7 vs. 2/8).Histologic examination demonstrated that the PLA-treated specimens had a highly cellular, fibrous tissue interface along the bone tunnel. There were osteoclasts along the margin of the bone tunnel. A loosely-organized, wide fibrous interface was still present at 12 weeks. In contrast, the interface tissue generally appeared more dense in the TCP-treated specimens. There were newly-formed bone trabeculae along the tunnel margin in the TCP specimens. Conclusion:TCP impregnated screws demonstrated improved healing over PLLA screws, based on histologic and MR analysis of regional tissue reaction. TCP impregnated interference screws have enhanced biologic characteristics, but may require refinements in design and structural properties to avoid graft damage.

POSTER NO. P318

Enveloping of Periosteum on Tendon to Enhance Healing in Bone Tunnel: Histology in Three Models

Chih-Hwa Chen, MD, *Taoyuan, Taiwan*
(a – National Council Institute)
Tai-Yuan Chuang, MD, Taoyuan, Taiwan (n)
Wen-Jer Chen, MD, Kweishan Taoyuan, Taiwan (n)
Chun-Hsiung Shih, MD, Taipei, Taiwan
(a – National Council Institute)

Purpose: Successful ligament reconstruction with tendon graft requires solid healing of the tendon graft in the bone tunnels. Periosteum contains multipotent mesodermal cells and has the capacity to form osteogenic tissue. In this study, we will present the effect of periosteum-enveloping tendon on the tendon-bone healing in 3 different experimental models in rabbits: 1) wrapping on a tendon surface; 2) inserted within an extraarticular tibial bone tunnel, and 3) reconstructed in the intra-articular femoral and tibial bone tunnels. Materials and methods: In each experimental model, 10 adult New Zealand white rabbits were used. For the tendon surface model, a periosteum was sutured on the long digitorum extensor tendon. For the extra-articular model, the long digitorum extensor tendon was transplanted into a bone tunnel of the proximal tibia with periosteum suturing on the surface of tendon. For the intra-articular model, anterior cruciate ligament reconstruction was done with periosteum-enveloping rabbit hamstring tendon autograft. Histology for the tendon-periosteum and tendon-bone interfaces were evaluated at 4, 8, 12 weeks after operation. Results: In tendon surface groups, new bone formation was found on the tendon surface by passing through a cartilage state from transplanted periosteum. In extra-articular groups, an interface fibrous layer formed by periosteum between the tendon and the bone became progressive integrated during the healing process. The cancellous bone lining in the bone tunnel had been interdigitated with the fibrous interface tissue. Collagen fiber-bone anchorage and organization with fibrocartilage formation developed between tendon and bone. In intra-articular groups, a fibrovascular interface tissue formed by periosteum tissue between the tendon and bone with progressive mineralization and maturation. The interface fibrous layer became integrated and mixed together with tendon and bone lining and unable to identify the margin. Progressive collagen fiber growing into bone with fibrocartilage formation appeared at later period. Discussion: Periosteum can induce differentiation of the mononuclear cells into osteoblastic cells with following direction into fibrocartilage or osteoid production. Our results showed that where the cambium layer of periosteum was present, there was a definite tendency towards the neoformation of bone. When the periosteum was sutured on the tendon that was transplanted within a bone tunnel, a superior tendon-bone healing process appeared. Conclusions: Periosteum had the ability to augment bone ingrowth into tendon and to induce ossification and bone formation not only in the free tendon but also in the extra-articular and intra-articular bone tunnels.

POSTER NO. P319

Anatomical Medial Collateral Ligament Reconstruction Using The Autogenous Hamstring Tendons

Shinichi Yoshiya, MD, *Kobe, Japan (n)*
Nobuzo Matsui, MD, Kobe, Hyogo, Japan (n)
Masahiro Kurosaka, MD, Kobe, Japan (n)
Kiyonori Mizuno, MD, Kobe City, Japan (n)
Hirotsugu Muratsu, MD, Kakogawa, Japan (n)
Ryosuke Kuroda, MD, Kobe, Japan (n)

Introduction: We have been performing reconstruction of the medial collateral ligament using the hamstring tendon graft. The objective of this study was to review our experience with this procedure. Methods: From 1995 through 2000, 26 patients underwent this procedure. Twenty-three of those patients were evaluated after a minimum period of 2 years. In the procedure, the autogenous semitendinosus and gracilis tendons were used to anatomically reconstruct the anterior longitudinal component of the superficial medial collateral ligament. The distal attachment site was selected at the center of the insertion of the remaining ligament, while the location of the femoral bone

tunnel was determined after assessing the length change of the graft though the range of motion intraoperatively. Fixation was achieved with the EndoButton (or an interference screw) distally and an interference screw proximally. Results: Of the 23 patients, combined cruciate ligament injuries were observed in 21 cases. In principal, we attempted to surgically reconstruct all the deficient ligaments simultaneously. Postoperative range of motion was graded as normal or nearly normal (IKDC evaluation system) in all of the patients. With respect to the ligament function, excellent medial stability (side-to-side difference in medial joint opening of 2 mm or less) was achieved in 21 of the 23 knees. Discussion and Conclusion: Although this report represents a short-term follow-up study, it is considered that the operative results of this procedure are superior to those of previous procedures.

POSTER NO. P320

Healing Articular Surface Defects with Adipose Derived Stem Cells

Jason L Dragoo, MD, *Marina Del Rey, CA (n)*
Grace A Carlson, MS, Los Angeles, CA (*)
Min Zhu, MD, Los Angeles, CA (*)
Prosper Benhaim, MD, Los Angeles, CA (n)

The purpose of this study was to assess whether adipose derived stem cells, ADSC, can be induced into cartilage and heal critical sized articular surface defects. Adipose tissue was harvested from 36 New Zealand rabbits. ADSC were isolated, transduced with lac Z adenovirus, seeded into fibrin glue and cultured in chondrogenic media for 7 days. Defects were made in rabbit knees and nodules were implanted. The contralateral defect was left empty as a control. The rabbits were sacrificed after 8 weeks. All 36 treated articular surface defects completely healed with hyaline like cartilage. All grafts integrated with subchondral bone, but 2 knees incompletely healed to surrounding cartilage. Average Moran scores for treated knees was 18 compared to 10 (p equals .001) in controls. All healed specimens stained positive for alcian blue, type II collagen and Lac Z. Stem cells derived from human fat can be used to heal articular surface defects. Cell labeling demonstrates regenerate cartilage is composed of induced ADSC. This tissue engineering strategy may prove to be clinically useful to heal articular surface defects.

POSTER NO. P321

The Prevalence of ACL Tears With Tibial Eminence Fractures in Skeletally Immature Patients

William L Hennrikus Jr, MD, *Madera, CA (n)*
Mark L. Holman, MD, Madera, CA (*)
Daniel R Oberto, BS, Madera, CA (*)

Introduction: ACL tears in skeletally immature patients are considered rare; instead, these patients avulse the ACL from the tibial eminence because the ligament is stronger than the epiphyseal cartilage. The purpose of this paper is to determine the prevalence of ACL tears compared with Tibial Eminence (TE) fractures in immature patients. Methods: The records and radiographs of 118 patients age less than 18 with ACL tears or TE fractures were reviewed. Age at injury, mechanism of injury, and gender were recorded. Diagnosis of TE fracture was made by knee radiographs. Diagnosis of ACL tear was made by physical exam and confirmed by MRI, arthroscopy, or KT-1000. Radiographs were graded for skeletal maturity as: physis open, physis closing, or physis closed. Bone age was determined by the Pyle Hoerr method. Results: 16 TE fractures and 102 ACL tears were studied. 11 males and 5 females had fractures while 57 males and 45 females had ACL tears. The ave age of the TE patients was 11.4 years; the average bone age was 10.8 years. The ave age of the ACL patients was 15.3 years; the ave bone age was 15.3 years. 38 patients had open physes, 25 closing physes, and 55 had closed physes. 14 TE fractures occurred in patients with open physes, 2 in closing physes, and none in closed physes. 24 ACL tears occurred in open physes, 23 in closing physes, and 55 in closed physes. Conclusion: ACL tears are more common than TE fractures in skeletally immature patients. 24 of 38 (63%) of patients with open physes sustained ACL tears while 14 of 38 patients (37%) had TE fractures.

POSTER NO. P322

The Effects of Medial Meniscal Transplantation Techniques on Intra-Articular Contact Pressures

Eric Matthew Berkson, MD, *Chicago, IL (*)*
Edward H Kolb, MD, Bloomington, IL (n)
Brian J Cole, MD, MBA, Chicago, IL (n)
Ralph B Garretson, MD, Warrenton, VA (n)
Jack Farr II, MD, Indianapolis, IN (*)
Benjamin Fregley, PhD, Chicago, IL (*)

The meniscus serves an important role by increasing contact area across the knee joint thereby decreasing average and peak contact pressures across the knee joint. To assess the biomechanical implications of different fixation techniques, contact pressures across the knee joint were measured.Tekscan pressure sensors were implanted into nine cadavaric knees. Peak pressure, average pressure, and contact area of the medial and lateral compartments were determined in each specimen at 0 and 30 degrees of flexion under a 1000N load. Contact mechanics were measured for the intact knee, after meniscectomy, after meniscal transplant with the bone plug technique, and after meniscal transplantation with the bone trough technique.Total medial meniscectomy resulted in a 46 percent(95 percent confidence interval[CI] 39-53) decrease in contact area, a 43(CI, 35-51) percent increase in medial contact pressure, and a 33(CI, 20-46) percent increase in medial peak contact pressure. Average medial contact area improved from 295(CI, 253-337) square millimeters in full extension in the meniscectomized knee to 494(CI, 386-602) square millimeters with a medial bone plug and 471(CI, 405-537) square millimeters with a medial bone trough technique. Similar improvements were noted in medial contact pressure and medial peak contact pressure. When comparing meniscal transplant techniques at both 0 degrees and 30 degrees, no significant difference ($p > 0.05$) was noted in regards to contact mechanics. The bone trough technique shows similar contact mechanics to the double bone plug technique and maintains the natural hoop stress of the meniscus during medial meniscal transplantation.

POSTER NO. P323

Randomized Double Blind Comparisson of Femoral Fixation Methods in ACL Reconstruction

Ari Pressman, MD, *Pittsburgh, PA (n)*
Donald Hugh Johnson, MD, Ottawa, ON Canada (*)
Benoit J Bessette, MD, Gatineau, QB Canada (n)
Franklin Tran, MD, Ottawa, ON Canada (n)

Introduction: ACL reconstruction grafts are fixed in tunnels drilled into the lateral femur in the intercondylar notch. EndobuttonsTM (Smith and Nephew, Memphis, TN) placed on the outside of the femoral cortex and interference screws with bioabsorbable EndopearlsTM (Linvatec, Largo, FL) represent two methods of femoral graft fixation. Methods: A prospective

randomized double blind study, with sample size derived to detect a 1mm KT-1000 difference between groups with a power of 90%(alpha =0.05), was approved by the institutional ethics board. Randomization by computer-generated table was completed for 92 patients after ACL deficiency was confirmed intraoperatively. Post-operative KT-1000, IKDC and radiographs were completed for 2 years by Board Certified Orthopedic Surgeons who were not aware of femoral fixation type. Grafts were harvested with the same incisions; however additional incisions were used for meniscal repairs when warranted. Results: Demographics and preoperative IKDC results were similar noting a male preponderance in the button fixation group. In 2 of 46 cases technical difficulty led to accessory fixation of EndbuttonsTM with interference screws. One of 45 patients randomized to EndopearlTM required button fixation because of posterior wall insufficiency. One patient with screw fixation re-ruptured his ACL at sixteen months. The mean side-to-side difference for KT-1000 results was 1.8+/-2.3mm for interference screws and 2.2+/-1.6mm for the button. IKDC scores were 85+/-10 and 87+/-12 for these groups respectively. Conclusion: Using a double-blinded randomized design with adequate power, no significant differences between groups were detected at two years. The authors found crossover between techniques useful in 3 of 92 cases.

POSTER NO. P324

Prospective Analysis of an Arthroscopic Repair Technique Using Two Rows of Fixation

Kyle Anderson, MD, *Birmingham, MI (e – Mitek)*
Daniel Aschenbrener DO, Farmington Hills, MI (*)

INTRODUCTION: The transition to an all-arthroscopic repair of the rotator cuff is resisted by some orthopaedic surgeons because they prefer the security and healing surface area of a two-row fixation technique that has thus far been described only with open and mini-open techniques. The objective of this study was to prospectively evaluate the outcome of a technique for arthroscopic rotator cuff repair that utilizes two rows of fixation. METHODS: 55 patients with a rotator cuff tear who met the inclusion criteria were treated with an arthroscopic rotator cuff repair using a medial and lateral row of suture anchors. Minimum follow-up was 12 months. Patients were evaluated prospectively by examination, the L'Insalata shoulder rating questionnaire, and a general health assessment (SF-36). RESULTS: The average L'Insalata functional score improved from 37 pre-operatively to 87.2 at most recent follow-up (p=0.02). 53 patients (96 percent) reported satisfaction with the procedure. Average active elevation increased significantly from 135 to 173 degrees (p=.02); internal rotation at ninety degrees of abduction improved from 47 to 66 (p=.01). Strength of the elevation was symmetric with the contralateral, asymptomatic shoulder in 86 percent of patients. CONCLUSION: This study presents evidence that arthroscopic rotator cuff repairs can be performed with dual rows of fixation similar to open and mini-open repairs with an excellent short-term outcome. Mechanical studies in a healing model will be needed to determine the relative strengths of this repair technique.

POSTER NO. P325

The Accuracy of MRI in the Evaluation of Articular Cartilage

Sharon Lee Hame, MD, *Los Angeles, CA (n)*
Andrew B Weiss, MD, Torrance, CA (n)
Carol Andrews, Los Angeles, CA (n)
David R McAllister, MD, Los Angeles, CA (n)
Amy Stauff, BS, Los Angeles, CA (n)
Kambiz Motamedi, MD, Los Angeles, CA (n)

Introduction: The purpose of this study was to determine the accuracy of magnetic resonance imaging of the knee in evaluating the articular cartilage in a cohort of patients undergoing knee arthroscopy. Methods: Fifty-eight patients (59 knees) underwent knee MRI and knee arthroscopy at our institution from 2000 to 2002. There were 25 females and 35 males. The average age of the subjects was 29.5 years (range: 15-54). Articular cartilage damage on MRI was documented by a musculoskeletal radiologist. Articular cartilage damage at arthroscopy was recorded by a Sports Medicine fellowship trained orthopaedic surgeon. Each articular surface (patellar, trochlea, medial and lateral femoral condyle, and medial and lateral tibial plateau) was graded using a modified Outerbridge classification. MRI and arthroscopic data were then compared and statistical analysis performed. Results: 354 articular surfaces were examined. A total of 37 lesions were identified at arthroscopy. Sixteen were identified on the MRI (43%). Seven of 23 grade II articular defects, 6 of 11 grade III lesions and 3 of 3 grade IV defects were identified on the MRI. Three of 10 lesions were identified on the patella, 3 of 4 lesions were identified on the femoral trochlea, 3 of 10 lesions were identified on the medial femoral condyle, 0 of 2 lesions were identified on the medial tibial plateau, 3 of 8 lesions were identified on the lateral femoral condyle, and 1 of 3 lesions were identified on the lateral tibial plateau. The overall sensitivity for MRI detection of articular cartilage defects was 45%, and the specificity was 80%. Conclusions: MRI is a useful tool for evaluating high grade lesions of the articular cartilage. It does not appear to be helpful in other types of lesions. Special MRI sequencing for articular cartilage will likely increase the accuracy of MRI.

POSTER NO. P326

Effect of Wedged Insoles on the Lateral Thrust of ACL-Insufficient Knees

Ichiro Yoshimura, MD, *Fukooka, Japan (n)*
Jing Fan Zhang, MD, Saint Louis, MO (*)
Kazuhiko Saeki, MD, Saint Louis, MO (*)
Michiya Hara, Fukuoka, Japan (n)
Masatoshi Naito, MD, Fukuoka, Japan (n)

ACL-insufficiency is cited as a cause of OA in the knee, and lateral thrust increases significantly with ACL insufficiency. The purpose of this study was examined the effect of insoles on the lateral thrust in knees with ACL-insufficiency. Sixty participants with normal healthy knees and hip joints were recruited to serve as controls. 35 patients scheduled to undergo ACL reconstruction indicated due to be with physical activity or feel giving-way frequently in patients were examined. Unidirectional accelerometers were used to record the medial-lateral and perpendicular components of acceleration while walking. The peek value of lateral thrust was compared between normal and ACL-insufficient knees, ACL-insufficient knees and ACL-insufficient knees with insoles. The peak value of the lateral acceleration immediately after heel strike was significantly larger in the ACL-insufficient knees compared to normal knees. The peak value of the

lateral acceleration immediately after heel strike was significantly smaller in the ACL-insufficient knees compared to that in healthy knees. The expected course of an untreated ACL rupture is often one of progressive deterioration of knee function resulting in a meniscal tear and degeneration of the articular cartilage. If left untreated the case gradually transforms to OA In this study, the ACL-insufficient knees using an accelerometer, and found that the lateral acceleration peak value immediately after heel contact was significantly larger in ACL-insufficient knees than in normal knees. However, the value of the lateral acceleration peak was seen to decrease significantly when valgus insoles were used. This results in a decrease of adduction moment and a subsequent decrease in compression force applied on the medial compartment. Thus, use of an insole is one possible prophylaxis for OA with an ACL-insufficient knee which does not require surgery.

POSTER NO. P327

Neuromuscular and Biomechanical Adaptations in Patients with Isolated PCL Deficiency

Timothy C Sell, *Pittsburgh, PA (n)*
Scott M Lephardt, PhD, Pittsburgh, PA (*)
Christian A Fontbote, MD, Pittsburgh, PA (n)
Kevin G Laudner, MS, Pittsburgh, PA (n)
Marcus Haemmerle, MPT, Pittsburgh, PA (n)
Christina Allen, MD, Burlingame, CA (n)
Fabrizio Margheritini, MD, Rome, Italy (*)
Christopher D Harner, MD, Pittsburgh, PA (n)

INTRODUCTION Functional adaptations of PCL deficient (PCL-d) patients are largely unknown. The purpose of this study was to examine the neuromuscular and biomechanical adaptations of PCL-d patients during gait and landing. METHODSTen physically active patients (avg. years since injury: 4.0 yrs; avg. age: 28.4 yrs) with unilateral, asymptomatic, GRII PCL deficiency underwent clinical, biomechanical, and neuromuscular testing and were compared to 10 matched controls (avg. age: 30.0 yrs). RESULTSInstrumented laxity exam and radiographic stress test revealed significantly greater posterior tibial displacement in the PCL-d knee compared to the uninvolved knee (p equals 0.001). There were no differences in strength present in the PCL-d group. For gait, the PCL-d group had less knee flexion at initial contact (p equals 0.049) and greater vertical ground reaction force at midstance (p equals 0.013). The PCL-d group also demonstrated a decrease in maximum knee valgus moment during the stance phase (p equals 0.027). PCL-d individuals demonstrated greater plantar flexion at initial contact (p equals 0.014) and decreased loading rate (p equals 0.020) during the vertical drop landing. EMG analysis revealed no differences during gait or vertical drop landings. DISCUSSION AND CONCLUSIONPCL-d individuals make kinematic and kinetic adaptations in order to perform these two functional tasks. Increased knee extension at initial contact may provide greater stability during gait but results in increased ground reaction forces. By plantar flexing more at the ankle, these patients decrease the loading rate and attenuate the impact forces during the vertical drop landing.

POSTER NO. P328

Residual Pivot Shift After ACL Reconstruction using Quadriceps Tendon

Sang-Hoon Lee, MD, *Seoul, Korea, Republic of (n)*
Yoon Keun Park, MD, Seoul, Korea, Republic of (n)
Sang Cheol Seong, MD, Seoul, Korea, Republic of (n)
Myung Chul Lee, MD, Seoul, Korea, Republic of (n)
Hyunchul Jo, MD, Seoul, Korea, Republic of (n)

Introduction: This retrospective study was performed to determine the clinical significance and the causes of residual pivot shift after ACL reconstruction. Methods: 93 knees of 92 patients who underwent an arthroscopic ACL reconstruction using quadriceps tendon were reviewed. A minimum of follow-up was two years. Clinical results were evaluated by Lysholm score and Cybex dynamometer. Laxity was assessed using KT-2000 and patients were classified into three groups by postoperative Pivot shift and Lachman test; Group 1 (all negative), Group 2 (positive in Lachman), Group 3 (all positive). The radiographic analysis was performed by angles between tibial and femoral tunnel on A-P images, angles between tibial tunnel and ant. tibial cortex on lateral images, femoral and tibial tunnel location using Aglietti method. Postoperative MRIs were obtained with the patient's permission, and angles between joint line and the graft, angles between Leo's line and femoral tunnel were measured. Results: The numbers of each group were 75, 8, 10 respectively. Patients in group 1 showed greater improvement in Lysholm score, and patients in group 3 experienced greater maximum Arthrometer differences by KT-2000. There was difference in the radiological results between three groups in terms of angles between Leo's line and femoral tunnel and angles between joint line and the graft on oblique coronal view, which were higher in group 3. Conclusion: This suggests that the postoperative symtoms are related to Pivot shift rather than Lachman, and residual Pivot shift is related to the vertical placement of the reconstructed ligament in coronal plane.

POSTER NO. P329

Sensitivity of Saline Arthrogram in Detection of Intraarticular Knee Wounds

Matthew Boes, MD, *Natick, MA (n)*
Paul Tornetta III, MD, Boston, MA (n)
Anthony Alberto Schepsis, MD, Boston, MA (n)
Timothy E Foster, MD, Boston, MA (*)
Mohit Bhandari, MD, Hamilton, ON Canada (n)

Purpose: The purpose of this study was to determine the sensitivity of the saline arthrogram in known small intra-articular wounds around the knee. Methods: Fifty patients undergoing elective arthroscopic knee surgery and with no history of prior knee surgery gave informed consent to study participation. Following standard preparation for the arthroscopic knee operation, a single incision was made in the knee to begin the procedure. Average length of the incision was 6.9 mm (4-10). Intra-articular position was confirmed by the attending surgeon using a blunt probe, and then a saline arthrogram was performed using 60 cc of normal saline. The known arthrotomy (operative wound) was observed during the injection for evidence of saline leakage indicating a positive test. The knee was then brought through a range of motion to determine if this led to a positive test. Results: Thirteen of fifty patients had a positive test without passive range of motion of the knee (static sensitivity = 26%, 95% CI = 15.9-39.6%). Three additional patients had a positive test with subsequent passive motion (dynamic sensitivity = 32%,

95% CI 20.8-45.8%). Of the sixteen true positive tests, thirteen were obtained from infrapatellar incisions and three were from suprapatellar incisions. Conclusion/Significance: Our data indicates that the saline arthrogram has a poor sensitivity in detecting small traumatic arthrotomy wounds of the knee. These results suggest that other factors beside the result of the saline arthrogram should be considered in deciding which patients with periarticular knee lacerations require emergent irrigation and debridement.

POSTER NO. P330

Will Early Extension, After an ACL Reconstruction, Damage the ACL Graft?

Jonas L Isberg, MD, *Goteborg, Sweden (n)*
Eva C Faxen, RPT, Goteborg, Sweden (n)
Sveinbjorn Brandsson, Reykjavik, Iceland (*)
Bengt I Eriksson, MD, Goteborg, Sweden (n)
Johan Nils Karrholm, MD, Gothenburg, Sweden (n)
Jon Karlsson, MD, Gothenburg, Sweden (n)

INTRODUCTION: The aim of this study was to investigate whether permitting full extension immediately following an ACL reconstruction would increase the postoperative anterior-posterior (AP) laxity.PATIENTS AND METHOD: Twenty-two consecutive patients (13 men, 9 women, median age: 24 years were included. All patients had an unilateral ACL injury. The patients were randomly allocated to postoperative rehabilitation programs either allowing (Group A, n=11) or not allowing (Group B, n=11) full extension (0-30 degrees) immediately after the operation.The patients were evaluated with Radiostereometric analysis RSA and KT-1000 preoperatively, 6 months, 1 and 2 years after the reconstruction. RESULTS: Median, (range) Preoperatively, the RSA showed a side-to-side difference, in Group A of 7.0 mm (2.2-17.5), and in Group B 7.4 mm (2.3-15.4). KT-1000 in group A of, 3.8 mm (0-10), and in group B, 2.0 mm (0-8.0). At the 6 months follow-up, the RSA showed a side-to-side differences in Group A of 3.4 mm (-1.3-17.4), and in Group B of 3.4 mm (-0.6-11.5). The corresponding KT-1000 values were, for Group A, 1.2 mm (-1.0-4.5), and for Group B, 0.0 mm (-3.0-1.5). At 12 months, the RSA showed a side-to-side differences in Group A of 4.0 mm (-5.0-7.8), and in Group B of 4.2 mm (-1.2-7.1). The corresponding KT-1000 values were, for Group A, 0.5 mm (0.0-5.0), and for Group B 0.5 mm (-0.5-2.5). At two years, the difference between the two groups (A:B) were minimal regardless of method used (RSA Groups A:B, 3.0 mm (-1.8-9.6) : 2.7 mm (-0.1-10.7), KT-1000 A:B: 0.5 mm (-1.0-4.0) : 1.0 mm (-2.0-3.5)) without any difference. CONCLUSION: Early active full extension training (0-30 degrees) immediately after an ACL reconstruction did not increase the knee laxity postoperatively. This rehabilitation protocol appears to be safe as judged by knee laxity and function up to 2 years after the operation.

POSTER NO. P331

◆Treatment of Isolated Knee Cartilage Lesions with MACI versus Microfracture

Erhan Basad, MD, *Giessen, Germany (b – Verigen AG)*
Georg Bachmann, Bad Nauheim, Germany (n)
Henning Stuerz, PhD, Giessen, Germany (*)
Juergen Steinmeyer, Giessen, Germany (b – Verigen AG)

INTRODUCTION: The Matrix-guided-Autologous-Chondrocyte-Implantation (MACI) offers a simplified surgical technique to treat isolated cartilage defects. The MACI procedure uses a collagen type I/III membrane, which is loaded with autologous chondrocytes multiplied in vitro and subsequently implanted into the defect via miniarthrotomy. The goal of this prospective study was to compare the clinical outcomes of MACI-treated versus microfracture (MFX)-treated patients. METHODS: 46 patients with posttraumatic, single, symptomatic and isolated chondral defects (2-10 cm2) of the femoral condyle or patella were included and randomized. A cartilage biopsy was obtained during an initial arthroscopy from patients subjected to receive MACI during a second surgical intervention. After multiplying the chondrocytes in vitro, a collagen type I/III membrane was loaded with the cells 3 to 4 days prior to implantation. This membrane was subsequently fixed into the chondral defect using fibrin glue. Another randomized group of patients was treated with MFX during a single arthroscopic procedure. The clinical outcomes were evaluated during a two-year period using the Meyers score, Tegner-Lysholm score, Lysholm-Gillquist score and the ICRS-classification. In addition, MRI-images were taken after 1 week, 3, 6, 12 and 24 months postsurgically using T1 and T2 weighted TSE sequences with a 512 matrix and fatsuppressed 3D flash sequence in coronal and sagital orientation with effective slice thicknesses of 1.5 mm. MRI-images were evaluated for signal intensity and graft thickness compared to the surrounding healthy cartilage. RESULTS: Between July 2000 and March 2003, 46 patients (33 MACI/ 13 MFX) were treated. The average age of patients was 33 years in both groups. By March 2003 results covering a period of at least 2 resp. 1 year were availablefor 5 (4 MACI / 1 MFX) resp. 19 (10 MACI / 9 MFX) patients. The clinical outcomes of both surgical procedures, as determined before and one year after surgery using different evaluation scores, changed as follows: A) Meyers score (MACI: from 11.2 to 17.7; MFX: from 11.1 to 13.0) B) Lysholm-Gillquist score (MACI: from 49.3 to 76.7; MFX: from 47.5 to 51.6) C) Tegner-Lysholm score (MACI: from 49.3 to 81.9; MFX: from 47.5 to 62.8) D) The changes in the ICRS-classification between MACI- and the MFX-group were statistically not significant, but improved within each group. These data seem to be confirmed by our preliminary 2year results, which will be completely obtained and presented. During the first 12 months no complete equalization of MRI signal intensity to the surrounding cartilage was observed; however, this occurred after 24 months. The thickness of regenerated tissue reached between 1 and 1.8 mm; the original thickness of the MACI graft during implantation was 0.5 mm. All MFX-induced cartilage regenerates displayed partially different signal intensities compared to the normal surrounding cartilage. DISCUSSION AND CONCLUSION: Technically demanding and expensive cell-based techniques should prove superiority against MFX in order to receive reimbursements by health insurance companies. Compared to ACT using a periosteal flap, MACI represents a simplified surgical technique through which the joint surface can successfully be remodeled. Our clinical results with MACI show a better improvement compared to patients treated with MFX. However, these results can only be considered as a temporary assessment at this point in time; our study with additional patients and longer follow-ups is in progress. Our MRI- results demonstrate increasing thickness and conversion of the regenerating tissue for at least two years. With MACI a new cell and matrix based procedure for the repair of cartilage damage is available.

POSTER NO. P332

The Anatomical Reconstruction for Lateral Ankle Ligaments using Hamstrings Tendon

Satoru Ozeki, MD, *Koshigaya, Japan (n)*
Kou Suzuki, MD, Koshigaya, Japan (*)
Takaoki Negishi, MD, Koshigaya, Japan (*)
Kenske Yasumura, MD, Koshigaya Saitama, Japan (*)
Yutaka Nohara, MD, Koshigaya, Japan (n)
Kazunori Yasuda, MD, Sapporo, Japan (n)

High quality performance of sport activities requires the complete function of the ankle. To preserve it, we reconstructed both the anterior talofibular (ATF) and calcaneofibular (CF) ligaments with a free semitendinosus or gracilis tendon from one hole at the anterior site of the lateral malleolus. Materials and Methods: From 1991 to 2001, one hundred and four ankles in 94 patients were treated; 93 ankles in 83 patients were followed over 2 years. The average follow up period was 4.6 years. The average age at surgery was 26.7 years old. Results: The average Seligson's functional scale improved from 3.8 to 9.4, and the average American Orthopaedic Foot and Ankle Society Score improved from 65 to 95 at the latest follow up. The average talar tilt improved from 13.5 degrees to 5.2 degrees. The most obvious improvements were instability and joint pain; the most frequent residual symptom, however, was pain. Discussion and Conclusion: The origin sites of the ATF and CF ligament are anatomically very close to each other. Our procedures reconstructing two ligaments from one hole restored ankle stability and preserved physiological joint motion. High quality performance of sport activities requires the complete function of the ankle. To preserve it, we reconstructed both the anterior talofibular (ATF) and calcaneofibular (CF) ligaments with a free semitendinosus or gracilis tendon from one hole at the anterior site of the lateral malleolus. Materials and Methods: From 1991 to 2001, one hundred and four ankles in 94 patients were treated; 93 ankles in 83 patients were followed over 2 years. The average follow up period was 4.6 years. The average age at surgery was 26.7 years old. Results: The average Seligson's functional scale improved from 3.8 to 9.4, and the average American Orthopaedic Foot and Ankle Society Score improved from 65 to 95 at the latest follow up. The average talar tilt improved from 13.5 degrees to 5.2 degrees. The most obvious improvements were instability and joint pain; the most frequent residual symptom, however, was pain. Discussion and Conclusion: The origin sites of the ATF and CF ligament are anatomically very close to each other. Our procedures reconstructing two ligaments from one hole restored ankle stability and preserved physiological joint motion.

POSTER NO. P333

Bone Mineral Density and Bone Metabolism Markers of Female Long-Distance Runners

Keishoku Sakuraba, MD, *Tokyo, Japan (n)*
Hisashi Kurosawa, chief professor, Tokyo, Japan (*)
Keisuke Sawaki, Prof, Chiba, Japan (*)
Takuji Ishikawa, Kobe, Japan (*)
Natue Koikawa, Chiba, Japan (*)

[Introduction] Female long-distance runners sometimes suffer from stress fractures with low bone mineral density. In this study we investigated the bone mineral density(BMD), menstruation cycle and bone metabolism markers prospectively, with special reference to stress fractures.[Subjects and methods] The subjects were 14 female long distance runners (mean 20 years). They were checked BMD(by DEXA) and bone metabolism markers(bone ALP, PICP, osteocalcin, DPD, NTx), at normal period and special training period during two years. [Results] The BMD of abnormal menstruation group was significantly lower than normal menstruation group at the lumber and femoral neck region, and the bone absorption markers (NTx, DPD)were significantly higher. The BMD of the subject suffered from stress fractures were significantly lower than normal group .Although, the bone absorption markers were significantly high,no significant difference was noted in any osteogenic markers.[Discussion] This is the first report on the realtionship between sequential changes in bone metabolism markers, BMD, and stress fractures. Among markers for bone absorption, NTx showed most sensitive and found to be rise when a stress fractures occurred or conditioning was poor.

POSTER NO. P334

◆Time Release Delivery of a Recombinant BMP to Repair Cartilage Defects in the Dog Knee

Laura P Patron, BS, *New Orleans, LA*
(a – Stryker Biotech)
John T Davis, MD, New Orleans, LA (n)
Stephen D Cook, PH D, New Orleans, LA
(a,e – Stryker Biotech)
David C Rueger, PhD, Hopkinton, MA
(d,e – Stryker Biotech)

INTRODUCTION: Osteogenic protein-1 (rhOP-1) has improved the repair of articular cartilage defects. Little information exists on the optimal rhOP-1 delivery rate to elicit cartilage repair. This study examined the effect of time-release delivery of rhOP-1 on articular cartilage repair. METHODS: Bilateral chondral or osteochondral 5mm diameter defects were created in the medial femoral condyle in 10 dogs. Mini-osmotic pumps, positioned extra-articularly on the femur, delivered 200Fl recombinant protein (170Fg rhOP-1) or control solutions at 0.5 Fl/hour via catheter tubing through a distal femur bone canal into the knee joints for 14 days postoperative. Defect healing at 16 weeks was evaluated by gross and histologic grading methods. RESULTS: Four of five rhOP-1 treated chondral defects had improved gross appearance scores compared with paired controls, although differences were not significant. The mean gross score of control osteochondral defects was significantly higher than that of rhOP-1 treated defects. The histology score of all five rhOP-1 treated chondral defects was significantly higher than paired controls. The nature of the repair tissue, structural characteristics, and degenerative changes were improved for rhOP-1 treated chondral defects. Histologic appearance of rhOP-1 treated osteochondral defects was improved in 3 of 5 comparisons. DISCUSSION AND CONCLUSION: Rate-controlled delivery of rhOP-1 into the canine knee joint induced the formation of reparative tissue in chondral and osteochondral defects. Improvements in the histologic appearance of chondral defect repair were more marked. The time-release delivery of a recombinant OP to a synovial joint has a potential role in the treatment of articular cartilage damage.

POSTER NO. P335

Subscapularis Tendon Tears: Arthroscopic Evaluation and Repair

Eric S Millstein, MD, *Van Nuys, CA (n)*
Stephen J Snyder, MD, Van Nuys, CA (a,c,e – Linvatec, a,c - S&N Endoscopy, a - Mitek Pacific Research, Don Joy, c – Arthrex, DJOrtho, e – Wright Medical)

Recent advancements in technology and methodology have allowed for improved accuracy in addressing subscapularis tears with arthroscopic techniques. This study presents the technique and results of arthroscopic subscapularis repair by a single surgeon. The study cohort represents the first 28 patients treated by the senior author with an arthroscopic repair of the subscapularis tendon. The average age was 56 years old (range 30-78) and the average follow-up was 66 months (range 3-100 months). Tears ranging in size from superior corner lesions to complete avulsions were repaired with a reproducible technique utilizing SuperRevo® suture anchors, Spectrum® suture hooks, and suture shuttle relays®. The UCLA score, Constant-Murley score and Simple Shoulder Test were completed by all patients and compared to pre-operative scores based on chart review. Twenty-three of the patients returned to the clinic for physical exam. The average UCLA score improved from 18.0 pre-operatively to 31.9 following repair (P<0.001). Similarly, the Constant-Murley score increased from 69.6 to 89.1 (P<0.001) and the Simple Shoulder Score increased from 5.1 to 10.8 (P<0.001). Only two patients required an unplanned return to the operating room. There were no additional post-operative complications. All patients indicated that they were satisfied with the outcome and would repeat the procedure. With the exception of two worker's compensation patients, all of the patients returned to their pre-injury occupation or activity level. Proficiency in shoulder arthroscopy allows for improved recognition of subscapularis pathology. This series demonstrates clinical success with a reproducible technique for arthroscopic subscapularis repair.

POSTER NO. P336

Assessment of Gait Patterns in ACL Deficient Patients using the Non Linear Dynamics Theory

Anastasios Georgoulis, MD, *Ioannina, Greece (n)*
Tina Moraiti, MD, Ioannina, Greece (n)
Nick Stergiou, MD, Omaha, NE (n)
Giannis Giakas, MD, Ioannina, Greece (n)
Stavros Ristanis, MD, Ioannina, Greece (n)
Panayotis N Soucacos, MD, Athens, Greece (*)

INTRODUCTION When the behavior of a system exhibits chaotic properties, it is characterized with great complexity, adaptability and ability to operate under various conditions. It has been demonstrated that healthy human gait exhibits such chaotic properties, which seem to break down with pathology. The purpose of this study was to investigate the behavior of the ACL deficient knee. We hypothesized that the behavior of the ACL deficient knee during walking will be more regular and less complex than a healthy knee. METHODS Ten ACL deficient subjects and ten healthy controls walked on a treadmill at their self-selected speed. Two minutes (approximately 120 footfalls) of continuous data were collected with a 6-cameras Peak Performance System (50 Hz). Nonlinear analysis consisted of the calculation of the Approximate Entropy (ApEn), the Lyapunov Exponent (LyE) and Surrogation for the knee flexion-extension time series. Statistical analysis was performed using Student t-tests (a = 0.05). RESULTS The ACL deficient knee flexion-extension time series exhibited significantly smaller ApEn values and significantly larger LyE values than the contralateral intact knee time series. There were no significant differences between the intact knee and the control knee. Significant differences between the LyE values before and after surrogation were found in all comparisons indicating that the deterministic behavior of the flexing-extending knee during walking are not affected by the absence of the ACL. DISCUSSION AND CONCLUSION Our results indicate that the ACL deficient knee seems to be less periodic, but most importantly more regular than the contralateral intact knee. Thus, ACL deficiency may render the knee less flexible and less adaptable to the changing environmental demands. This may, in turn, increase susceptibility to injury and osteoarthritis.

POSTER NO. P337

A Comparative Study: Adverse Reactions to Synvisc(r) but not Hyalgan(r)

Barry Garcia, DO, *Sebastian, FL (b – Wyeth & Sarofi)*

Synvisc (hylan G-F 20), SYNV, and Hyalgan (sodium hyaluronate, 500-730 kDa), HYAL, have been approved for treatment of knee osteoarthritis pain since 1997. Several studies have demonstrated that they are safe and effective for their intended use. However, prospective, controlled clinical studies comparing their efficacy and safety have not been published. A prospective, randomized, clinical practice study was conducted using a 10cm Visual Analog Scale for pain, and the Knee Injury and Osteoarthritis Outcome Score (KOOS) as outcome measures at Baseline and at week 5. Patients were randomly assigned sequentially to receive either 3 weekly injections of SYNV or 5 weekly injections of HYAL. Twenty-six and 25 patients were initially treated, as well as 3 and 2 of these patients retreated with HYAL or SYNV respectively. At Baseline, evaluated patients treated with HYAL tended to have more severe pain at Baseline, 46.9mm±6.0SEM, compared to 32.1mm±4.4SEM. Both treatments demonstrated significant improvement of 20.9mm, HYAL, and 24.0mm, SYNV, from Baseline, although these improvements were not statistically different from each other. There were statistically more early terminations with SYNV, and 12% of the SYNV patients reported pseudoseptic reactions. One patient with SYNV pseudosepsis was retreated with HYAL with good clinical response and without further sequelae. Literature reports have documented these pseudoseptic reactions to SYNV, but no published reports using HYAL. Full disclosure of these distinctions should be made when counseling patients on their appropriate hyaluronan therapy selection.

POSTER NO. P338

Open Versus Arthroscopic Bankart Repair for Recurrent Anterior Shoulder Instability

Kevin Blake Freedman, MD, *Maywood, IL (n)*
Adam Smith, BA, Chicago, IL (*)
Brian J Cole, MD, MBA, Chicago, IL (n)
Anthony A Romeo, MD, Chicago, IL (*)
Bernard R Bach Jr, MD, River Forest, IL (n)

Introduction: The purpose of this study was to compare the results of open and arthroscopic Bankart repair for traumatic, unilateral, recurrent anterior shoulder instability using a meta-analysis of the published literature. Methods: A Medline search identified all randomized control trials or cohort studies which directly compared open versus arthroscopic techniques of Bankart repair for traumatic, unilateral, recurrent anterior instability. Included studies required all patients to have an arthro-

scopically documented Bankart lesion. Data collected from each study included patient demographics, surgical technique, rehabilitation, outcome, and complications. Tests of heterogeneity were performed to determine if the studies were combinable. A pooled analysis was performed for all comparisons, with chi-square testing for all proportions. Results: Six studies met all inclusion criteria. There were 172 patients in the arthroscopic group (transglenoid sutures = 90 patients; arthroscopic tacks = 77 patients, suture anchors = 5 patients), and 156 patients in the open group. The groups were similar in demographic characteristics. When comparing the arthroscopic to the open group, there was a significantly higher rate of recurrent dislocation [12.6% vs. 3.4%; p=0.01] and total recurrence (recurrent dislocation or subluxation) [20.3% vs. 10.3%; p=0.01]. In addition, there was a higher proportion of patients with an excellent or good post-operative Rowe score in the open group (88%) than in the arthroscopic group (71%) [p=0.01]. Conclusions: Arthroscopic Bankart repair using bioabsorbable tacks or transglenoid sutures results in a higher rate of recurrent instability compared to open techniques. Studies directly comparing open repair to newer arthroscopic techniques using suture anchor fixation and capsular plication are necessary.

POSTER NO. P339

Biomechanical Comparison of Repair Techniques for Rupture of the Distal Tendon of Biceps Brachii

William Michael Mihalko, MD, *Clarence Center, NY (n)*
Timothy V McGrath, MD, Amherst, NY (n)
Vijay K Bansal, Buffalo, NY (n)
Paul J Favorito, MD, Cincinnati, OH
(a – Smith&Nephew Endoscopy)
Marc S Fineberg, MD, Buffalo, NY (n)

Introduction: This study compares pullout strengths of five different repair techniques available for biceps tendon ruptures. Methods: Twenty fresh frozen specimens were utilized for comparison of biceps repair to the normal tendon. Pullout strengths were measured at 90 degrees flexion using a servohydraulic testing machine. The five techniques included: Bone-tunnel repair with number 2 Ethibond; two Mitek GII anchors; Endobutton repair with two number 2 Ethibonds, Endobutton repair with one number 2 Fiberwire; and a distal biceps tenodesis screw with number 2 Fiberwire. Each utilized a running-locking suture. Normal strengths were measured at 45 and 90 degrees with ten paired specimens for comparison. Results: The average normal pullout strength at 90 degrees was 459 + 142.2 N and 312 + 89.1 N at 45 degrees (p less than 0.05). The average strength for the bone tunnel repair was 127 + 64.1 N, and 172 + 40.1 N for the Mitek anchors. The Endobutton with two ethibonds resulted in 258 + 39.2 N and with Fiberwire 269 + 52.9 N. The tenodesis screw resulted in an average of 197 + 80.4 N. Each were significantly less than the normal pullout (p less than 0.05), but the Endobutton techniques were stronger than the tenodesis screw, Mitek, and bone tunnel techniques (p less than 0.05). The normal tendon strength at 90 degrees was 458.9 + 142.2 N and 312 + 129.1 N at 45 degrees (p equal to 0.016). Discussion and Conclusion: Based on the results, the less invasive techniques with stronger suture may provide a repair which could possibly lead to earlier mobilization and quicker return to function.

POSTER NO. P340

Determining Composite Likelihood Ratios in the Prediction of Meniscal Tears Based on Patient Exam

Timothy D Farley, MD, *St. Louis, MO (n)*
David W. Wing, BA, Vail, CO (n)
William I Sterett, MD, Vail, CO (n)
J Richard Steadman, MD, Vail, CO (n)

An evaluation of a composite examination in the prediction of meniscal tears was prospectively performed. Patients were evaluated for the presence or absence of the following findings: 1) patient history of "catching" or "locking," 2) pain with forced hyperextension, 3) pain with forced flexion, 4) McMurray's sign, and 5) joint line tenderness. These signs and symptoms were correlated to arthroscopic findings. The average age of the patients was 34 years. A total of 131 (133 knees) patients were followed, 77 males and 54 females. At the time of arthroscopy, 61 meniscal tears were identified. Other associated pathologies included 30 ACL tears, 2 ACL/MCL tears, 2 PCL tears, 1 ACL/PCL/MCL tear, 35 with DJD, and 30 with chondral lesions. The data found that the presence of a McMurray's sign or pain with passive hyperextension demonstrates specificity values of 94% and 90% and positive likelihood ratios of 3.8 and 4.4, respectively. More notably, the composite exam findings become more predictive of meniscal pathology as the number of positive signs increase. While the specificity of 2 or more findings is 71%, this number increases to 90% with 3 or more and approaches certainty with 5 out of 5 positive findings. Additionally, a positive likelihood ratio of 3.9 for 3 or more findings was noted which increased to 5.5 and 9.4 for 4 and 5 out of 5 positive findings, respectively. This study demonstrates that utilizing a composite examination is an effective means of predicting meniscal tears.

POSTER NO. P341 - WITHDRAWN

POSTER NO. P342

ACL Reconstruction: Comparison of Bone Patellar Tendon Bone Graft with Central Quadriceps Tendon

Yoon Keun Park, MD, *Seoul, Korea, Republic of (n)*
Sang Cheol Seong, MD, Seoul, Korea, Republic of (n)
Myung Chul Lee, MD, Seoul, Korea, Republic of (n)
Sang-Hoon Lee, MD, Seoul, Korea, Republic of (n)
Hyunchul Jo, MD, Seoul, Korea, Republic of (n)

Introduction: The purpose of this investigation is to compare the outcome of ACL reconstruction using patellar tendon(BPTB) to that using central quadriceps tendon autograft. Methods: 162 patients who received ACL reconstruction from 1994 to 2001 were reviewed in a retrospective manner. 72 underwent reconstruction with BPTB autograft, and 90 were treated with quadriceps tendon. Patients were followed for an average 39months (range, 20-69 months). Each group were evaluated in terms of clinical test, Lysholm score, IKDC(patients satisfaction, activity level), KT-2000 laxity measurement and isokinetic quadriceps strength using Cybex II. Results: A mean age at operation, delayed time from injury to operation, concomitant injury was similar between the two groups. The two treatment methods produced similar outcomes in terms of patient satisfaction, activity level, range of motion and knee function (Lysholm score improved from 71 to 92 in BPTB group and from 71 to 91 in quadriceps group). 69, 85 patients were found to be grade 0 or 1 in Lachman test and pivot shift each group. At follow-up, no statistical difference was found between the groups in side to side difference evaluated by KT Arthrometer. Quadriceps strength

measured by cybex II recovered to 82 % of contralateral side at 1 year and 89% at 2 years in quadriceps group, and 72%, 76% in BPTB groups. Conclusion: ACL reconstruction using quadriceps tendon showed similar satisfactory results when compared with that using BPTB. In terms of quadriceps strength recovery, quadriceps tendon could be an alternative graft choice.

POSTER NO. P343

The Healing Response Technique to Treat Proximal ACL Injuries in the Skelatally Immature Patient

J Richard Steadman, MD, *Vail, CO (c – Linvatec)*
Michelle L Cameron, MD, Livingston, MT (n)
Karen K Briggs, Vail, CO (n)
William G Rodkey, DVM, Vail, CO (n)

The purpose of this study is to document the outcomes of skeletally immature patients with proximal ACL tears treated with the healing response technique to promote healing in proximal ACL tears. Thirteen skeletally immature patients with a proximally torn ACL underwent a healing response (HR) procedure (Microfracture holes made into the cortical bone at the origin of the disrupted ligament). Exclusion criteria included previous ACL surgery, other concurrent ligament pathology, and mid-substance ACL tears. Average pre-operative KT-1000 manual maximum difference(MMD) was 4.8 mm (range 3-10 mm). Pre-operatively, all patients had a 1+ or 2+ pivot shift and all patients reported that their knee function was abnormal to severely abnormal. Three(23%) patients had a reinjury and underwent an ACL reconstruction at an average of 36 months post-HR(range 24 to 55). Subjective follow-up on the remaining 10 patients(average=69 months post-HR;range 26 to 113) indicated no patients experienced pain or giving way, all considered their knee function normal, average Lysholm score was 96, average Tegner was 8.5 (range 7 to 10), and average patient satisfaction at follow-up was 9.9 (1=very dissatisfied; 10=very satisfied). Clinical exam on 7 of 10 patients(average=35 months post-HR, range 12 to 63) showed 5 patients with a negative pivot shift and 2 with a 1+ pivot shift and. KT-1000MMD improved to 1.7 mm (range 0 to 3 mm) post-HR. In the active skeletally immature patient, the healing response procedure restored stability and knee function. Patients were very satisfied with the procedure and returned to a high level of sports and activities

POSTER NO. P344

Femoral Rollback in a PCL Reconstructed Knee, an In-Vivo Study

Timothy C Wilson, MD, *Lexington, KY (n)*
Markus Holzhauser, Lexington, KY (n)
Timothy L Uhl, PhD, Lexington, KY (n)
Darren L Johnson, MD, Lexington, KY (n)

Introduction: Femoral rollback is a measurement that examines the effectiveness of restoring normal arthrokinematics in total knee arthroplasty, but has not been evaluated in a PCL reconstructed population. Methods: Femoral rollback was measured in patients who had previously undergone PCL reconstruction (single bundle/tibial tunnel/allograft). 9 subjects 22 + 13 months following reconstruction were radiographically studied. A series of 4 fluoroscopic views at 0degrees, 45degrees, 90degrees, and maximal flexion 120degrees in a functional closed chain position were taken of both the reconstructed and the normal non-operative knee to determine femoral rollback. A Wilcoxon-signed rank test for paired observations was performed to evaluate femoral rollback on the operated knee compared to the control, non-operated knee. Results: The average range of motion of the PCL reconstructed group was 2-130degrees. No significant differences in the amount of femoral rollback were found between the operated and control knee at each specified angle, using a Wilcoxon-Rank paired test ($p<0.05$). The total femoral rollback average was seven millimeters less than the uninjured side. Discussion and Conclusion: This is the first study to attempt to measure arthrokinematics (femoral rollback) in-vivo in a PCL reconstructed knee in an active population. Cadaveric studies and human in-vivo studies have shown abnormal kinematics in PCL deficient knees up to 70degrees of flexion. This study measured rollback in a functional position up to a minimum of 120degrees of flexion. PCL reconstruction appears to restore normal kinematics in our patient population. This may delay future degenerative changes that develop in chronic PCL deficiency.

POSTER NO. P345

Hamstring Grafts Should be Kept at Body Temperature During ACL Reconstruction

William J Ciccone, II MD, *Colorado Springs, CO (a – Stryker Endoscopy)*
Jennifer A Cech, BS, Colorado Springs, CO (n)
David Weinstein, MD, Colorado Springs, CO (a – Stryker Endoscopy)
Mary Bucholz, BS, Colorado Springs, CO (n)
John J Elias, PhD, Colorado Springs, CO (a – Stryker Endoscopy)

Introduction: Hamstring tendons used for ACL reconstruction are typically harvested during surgery and cool to ambient temperature prior to reimplantation. Following femoral fixation, the grafts are tensioned and subsequently warm to body temperature within the knee. Graft stiffness may decrease with increasing temperature, which may contribute to graft laxity after surgery. Methods: The stiffness of six gracilis and six semitendinosus grafts was measured at 37 degrees C and 19 degrees C. Each tendon was individually tested in a saline bath, with sutures stitched into the tendon to serve as displacement markers. Each graft was preconditioned by cycling between two set positions, initially corresponding to 20 N and 80 N of applied load. After preconditioning, the grafts were loaded in tension to 100 N at 10 mm/min, and a digital video camera was used to determine the graft elongation between the sutures. Results: Stiffness values were higher at 19 degrees C than at 37 degrees C for each tendon. The average gracilis tendon stiffness was 135 N/mm at 19 degrees C and 95 N/mm at 37 degrees C. The average semitendinosus tendon stiffness was 120 N/mm at 19 degrees C and 90 N/mm at 37 degress C. For both tendons, the stiffness decreased significantly as the temperature increased (paired t-tests, p less than 0.05). Discussion/Conclusions: Both tendons had similar results, so in a quadrupled construct the temperature would influence both tendons similarly. Hamstring autografts that cool to room temperature during ACL reconstruction loose stiffness as the graft temperature increases following implantation.

POSTER NO. P346

Reconstruction of the Posterolateral Corner of the Knee

Robert Baird, MD, *Birmingham, AL (*)*
James P Stannard, MD, Birmingham, AL (n)
Stephen L Brown, MD, Birmingham, AL (n)
James T Robinson, Birmingham, AL (n)
Gerald McGwin, Jr PhD, Birmingham, AL (n)
David A Volgas, MD, Birmingham, AL (n)

Purpose: To describe a reconstruction of the posterolateral corner (PLC) of the knee and report on the results of a prospective series of patients. Materials and Methods: 22 patients with PLC injuries have undergone reconstruction, with 15 having multiligamentous knee (MLK) injuries and the remaining seven having isolated PLC injuries. Our surgical technique reconstructs the popliteus, popliteofibular ligament, and fibulocollateral ligament. Patients have been followed with clinical examinations, Lysholm knee scores, KT-2000 examinations, and SF-36 outcome scores. Results: Follow up was a minimum of 24 months, with a mean of 29.5 (range 24-38) months. Mean range of motion is extension of 0.2∞ (0-5) and flexion of 133.4∞ (80-145). Mean Lysholm knee scores are 90 for the entire group. Stability was clinically graded on a scale of 0-3. The mean score for varus stress was 0.2 for the whole group, with 0.3 in the MLK's and 0.1 for the isolated injuries. Similarly, the mean score for external rotation was 0.4, with a 0.5 for MLK's and 0.3 for isolated PLC injuries. The failure rate for PLC reconstruction was 9%, with 2 failures in the MLK's (13%), compared with 0 failures in the isolated PLC group. Conclusion: Reconstruction of the PLC using an allograft reconstruction of the popliteus, popliteofibular and fibulocollateral ligaments yields a stable reconstruction with excellent functional results. Predictably, the range of motion and incidence of failure are both better on the patients with isolated PLC injuries when compared to those with multiligamentous knees. Both groups, however, show excellent overall functional results.

POSTER NO. P347

The Glass Knee - A new method of anatomic preparation and preservation of human joints.

Scott F Dye, MD, *San Francisco, CA (n)*

Introduction: Viewing complex extra-articular anatomy of the knee through standard methods of preparation and dissection requires destruction of the more superficial layers to view the deeper ones. The purpose of this study is to report a new method of anatomic preparation and preservation (developed in the field of comparative vertebrate anatomy) which results in the muscles and other tissues becoming transparent - allowing visualization of deeper structures without extensive dissection. Materials and Methods: Adult and embryonic (24 week) human knees were prepared using the following method: fixation of specimens in a 10% formalin solution for 3 days. They were then washed in distilled water for 3 days. The specimens were then skinned and transferred to decreasing changes of ethyl alcohol, from 95% to 15%. They were then transferred to distilled water for 3 hours. The specimens were then placed in a solution of satureated aqueous sodium borate solution with 1 gram of trypsin/30 ml of solution for 3 weeks. They were then transferred to 0.5 grams of KOH solution for 24 hours. They were then transferred through 0.5% KOH-glycerin series (3:1,1:1,1:3) and ultimately to pure glycerine. Results: The human knees prepared in this study show striking and exquisite details of extra-articular anatomy while remaining completely mobile and fully preserved. Discussion: This method of anatomic preparation and preservation of the human knee provides a novel and visually interesting technique to understand three-dimensional relationships of musculoskeletal macrostructures. This method can be easily applied to other human joints and musculoskeletal systems with probable similar benefits in anatomic understanding.

POSTER NO. P348

Arthroscopic Partial Medial Meniscectomy in an Otherwise Normal Knee:15.5 yr. Followup

Pietro M Tonino, MD, *River Forest, IL*
(e – Regeneration Technologies)
Tommaso Vetrugno, MD, Venezia, Japan (*)
Pietro Albenzio, Venezia, Italy (*)
Renato Viola, Vicenza, Italy (n)

Purpose: Evaluate functional long-term results of patients undergoing arthroscopic partial medial meniscectomy in an otherwise normal knee.Type of study: Retrospective case-control study. Methods: 40 of 263 partial medial meniscectomies (1984-1986); met the following inclusion criteria : maximum age at 45 years, minimum follow-up 15 years, an otherwise normal knee, no previous or subsequent injuries or surgery . We recorded the Lysholm II score , Tegner Activity Rating System and 2000 IKDC Subjective Knee Scores. Results: Follow-up was 15.5 to 17.5 years. Lysholm II score results were good-excellent in 90%.. Mean 2000 IKDC Subjective Knee Evaluation Form of the affected knee was 94.89%.The mean Tegner Activity Scale score was 6.8 prior to and 5.1 following meniscectomy.Statistically significant better scores were noted if patients participated in sports or had surgery within 12 months. Conclusions: Good-excellent functional results were found in 90% of patients at an average of 16.3 years.

POSTER NO. P349

Storage Duration and Conditions for Fresh Osteochondral Allografts Used for Cartilage Repair

Seth Williams, MD, *San Diego, CA (b – Allosource)*
Todd R Allen, San Diego, CA (*)
Prof David Amiel, La Jolla, CA (b – Allosource)
Scott T Ball, MD, San Diego, CA (n)
Van W Wong, BS, La Jolla, CA (n)
Albert C Chen, PhD, La Jolla, CA (n)
Robert L-Y Sah, La Jolla, CA (b – Allosource)
William Bugbee, MD, La Jolla, CA (n)

Introduction: Fresh osteochondral allografts are utilized in the surgical treatment of chondral and osteochondral defects. There has been concern regarding donor tissue storage conditions and duration. We hypothesized there would be no detectable changes in osteochondral allograft articular cartilage over a 28-day storage period. Experimental Method: Sixty osteochondral plugs were harvested from fresh human femoral condyles within 48 hours of donor death and stored in culture media at 4 degrees Celsius. At 1, 7, 14, and 28 days after graft procurement, the articular cartilage was analyzed for: 1.) chondrocyte viability and viable cell density by confocal microscopy; 2.) proteoglycan synthesis by quantification of radiolabeled sulfate incorporation; 3.) glycosaminoglycan content; 4.) indentation stiffness using an arthroscopic probe; 5.) compressive modulus and hydraulic permeability. Results: Matrix properties demonstrated no statistically significant differences after storage for 28 days, as measured by glycosaminoglycan content, indentation stiffness, compressive modulus, permeability, and equilibrium tensile modulus. Chondrocyte viability and viable cell density were unchanged

statistically at 7 and 14 days, and then declined at 28 days. Proteoglycan biosynthesis, as measured by sulfate uptake, was unchanged statistically at 7 days, and then declined at 14 and 28 days. Discussion and Conclusion: Prolonged storage of fresh osteochondral allografts leads to chondrocyte loss and decreased metabolic activity, but preservation of matrix properties. Statistically significant changes become evident between 14 and 28 days of storage in culture media. Surgeons performing fresh osteochondral allografting may use this data to guide clinical decisions regarding storage media and duration prior to transplantation.

POSTER NO. P350

The Effect of Osteochondral Plug Graft Angulation on Articular Contact Pressure

Jason L Koh, MD, *Wilmette, IL (n)*
Adam Kowalski, BS, Chicago, IL (n)
Eugene Lautenschlager, PhD, Chicago, IL (n)

Introduction: Small articular surface incongruities may occur after osteochondral plug grafting. We investigated the effect of angled grafts on femoral condyle articular cartilage defects on contact pressure in the knee. Methods: An 80N Instron load was applied for 120s to femoral condyles of 50 fresh swine knees covered with Fuji pressure sensitive film under 5 conditions: (1) intact surface; (2)4.5mm diameter circular defect; (3) grafted with a flush 4.5mm diameter plug; (4) grafted with a 30 degree angled 4.5mm diameter plug, with lower edge flush (tip proud to adjacent surface); (5) grafted 30 degree plug, with tip flush to adjacent surface(lower edge sunk). Angled grafts were obtained using a rotational bearing vise aligned with a 30-degree fixed angle track. The height difference at graft edges was sin(30)times 4.5mm equals 2.25mm. Film was digitally scanned and analyzed, and standard statistical tests performed. Results: Mean peak pressures of intact (8.57kg/cm2), flush (9.81kg/cm2), and sunk angled (9.15kg/cm2) were not significantly different ($p>0.5$). The defect (12.00kg/cm2) and the proud angled graft (14.50kg/cm2) were significantly ($p<0.05$) higher than intact. Discussion: It is often difficult to perfectly match the articular surface with an osteochondral graft. Slightly sunk grafts were still able to reduce elevated contact pressures to normal levels. However, proud angled grafts increased contact pressure. These results suggest that it is preferable to leave an edge slightly sunk rather than proud

POSTER NO. P351

Fresh Human Osteochondral Allograft Retrievals: Reasons for Failure

Seth Williams, MD, *San Diego, CA (n)*
Prof David Amiel, La Jolla, CA (n)
Scott T Ball, MD, San Diego, CA (n)
Todd R Allen, San Diego, CA (*)
William Tontz, Jr MD, San Diego, CA (*)
Parviz Haghighi, MD, San Diego, CA (*)
Shawn Clark Emery, MD, San Diego, CA (*)
William Bugbee, MD, La Jolla, CA (n)

Introduction: Fresh human osteochondral allografts are used to treat chondral defects. For certain indications, long-term outcomes have been predictably good in over 75 percent of cases. Precise cause of failure remains unknown. We investigated potential etiologies.Experimental Method: Failed fresh osteochondral allograft specimens were recovered at revision surgery. Specimens were prospectively analyzed for chondrocyte viability and viable cell density by confocal microscopy, proteoglycan synthesis by quantification of radiolabeled sulfate incorporation, and glycosaminoglycan content. Routine histology was performed. Fourteen freshly harvested donor grafts served as controls. Results: Fourteen patients yielded 24 tibial plateau and femoral condyle allografts. Average graft survival was 40.1 months (range 9 to 156 months). Statistically significant differences were found in chondrocyte viability, 79.1 versus 99.1 percent, and glycosaminoglycan content, 3.5 versus 4.1 percent hexosamine per dry weight. There was no statistical difference in viable cell density, 15,300 versus 15,600 cells per cubic millimeter, or sulfate uptake, 441 versus 492 counts per minute. Histology revealed creeping substitution in 14 specimens, cartilage fibrillation in 18 specimens, and inflammatory changes suggestive of rejection in 1 specimen. Discussion and Conclusion: Osteochondral allograft failure does not correlate with chondrocyte death. Although viability and glycosaminoglycan content is lower compared to controls, the chondrocytes are healthy as assessed by proteoglycan synthesis and cell density. Creeping substitution was present in most specimens, indicating replacement of allograft bone with host bone. Rejection does not seem to be a principle factor. Almost all specimens showed cartilage degenerative changes, making mechanical wear a potential cause of early failure.

POSTER NO. P352

Suture versus Screw Fixation of Displaced Tibial Eminence Fractures: A Biomechanical Comparison

Matthew R Bong, MD, *New York, NY (n)*
Anthony Romero, MD, Carlsbad, CA (*)
Erik Kubiak, MD, Brooklyn, NY (n)
Laith M Jazrawi, MD, New York, NY (n)
Fredrick J Kummer, PhD, New York, NY (n)
Jeffrey E Rosen, MD, Roslyn Heights, NY (*)
Robert J Meislin, MD, New York, NY (n)
Orrin H Sherman, MD, New York, NY (n)

IntroductionA variety of surgical procedures have been proposed to stabilize displaced tibial eminence fractures. The two most common fixation techniques involve use of cannulated screws and sutures tied over an anterior tibial bone bridge. The purpose of this study is to compare the ultimate strength of displaced tibial eminence fractures fixed with either sutures passed through anterior tibial bone tunnels or with a 4.0 mm cannulated cancellous screw/washer complex. Materials and MethodsSeven matched pairs of fresh-frozen human cadavers were stripped of all soft tissue except the ACL. Simulated Type III tibial eminence fractures created using an osteotome. Fragments of each matched pair were randomized to fixation with either a single 4.0 mm cannulated cancellous screw with a washer or an arthroscopic suture technique employing three #2 Fiberwire passed through the tibial base of the ACL and tied over the anterior tibial cortex. Specimens were loaded to failure and load deformation curves were generated. The ultimate strength and stiffness were computed for each curve. The failure mode for each test was observed. A paired two-tailed t-test was used to determine statistically significant difference between the two methods. ResultsSpecimens fixed with Fiberwire had a mean ultimate strength of 319 N (SD = 125 N). Those fixed with cannulated screws had a mean ultimate strength of 125 N (SD = 74 N). This difference was statistically significant ($p = 0.0038$). There was no significant difference between the mean stiffness of Fiberwire constructs (63 N, SD = 50 N) and the mean stiffness of the cannulated screw constructs (20 N, SD = 32 N). The failure modes of the Fiberwire constructs included 1 ACL failure, 3 with suture cutting through the anterior tibial cortex, and 3 with

suture cutting through the tibial eminence fragment. The single mode of failure for the cannulated screw constructs was screw pullout of cancellous bone. ConclusionThe initial ultimate strength of Fiberwire fixation of tibial eminence fractures in these specimens is significantly stronger than that of cannulated screw fixation. Neither construct is able to withstand the forces seen in the ACL during normal daily activities. Early rehabilitation of these injuries following surgery using these methods should be avoided. The stiffness of either construct is the same and likely a function of the biomechanical properties of the ACL. The mode of failure of either construct is dependent on bone quality.

POSTER NO. P353

Neuromuscular Function following ACL Reconstruction with Autologous Semitendinosus-Gracilis Grafts

Glenn N Williams, PT ATC, *Bear, DE (a – Foundation for Physical Therapy)*
Peter Barrance, MS, Newark, DE (n)
Lynn Snyder-Mackler, Newark, DE (*)
Michael J Axe, MD, Newark, DE (*)
Thomas S Buchanan, MD, Newark, DE (n)

INTRODUCTION: Although people who undergo ACL reconstruction with autologous semitendinosus-gracilis grafts have excellent functional outcomes, the effect that this procedure has on neuromuscular function remains unclear. METHODS: Ten young athletes with acute, isolated ACL ruptures underwent neuromuscular testing prior to ACL reconstruction with quadrupled autologous semitendinosus-gracilis grafts and after they had returned to play in sports requiring quick changes of direction and jumping (approximately 6 months later). Voluntary muscle control was assessed with an established target-matching protocol requiring fine control of force production. Electromyographic data were collected from 11 muscles around the knee and a specificity index was calculated. Subjects' results from the pre-surgery and post-return to play sessions were compared to determine the effect that the procedure had on neuromuscular function. RESULTS: Altered neuromuscular control was apparent in the muscle activity patterns of the subjects' injured knees prior to surgery, especially in the quadriceps muscles. Post-return to sports results indicated that voluntary muscle control had improved in most muscles. There was no significant difference in pre-surgery and post-return to sports semitendinosus and gracilis muscle control. The semimembranosus muscle displayed less specific muscle activity patterns following surgery, which may represent a compensation strategy for minor changes in neuromuscular function. DISCUSSION AND CONCLUSION: Voluntary muscle control improves in most muscles following ACL reconstruction with semitendinosus-gracilis autografts. Semitendinosus and gracilis muscle control does not appear to be altered significantly by the procedure.

POSTER NO. P354

Chondrocyte Viability After Osteochondral Graft Transplantation

William Butcher, MD, Milwaukee, WI (n)
Shantanu Patil, MS, La Jolla, CA (n)
Nick Steklov, MD, La Jolla, CA (n)
Bradford S Tucker, MD, Ocean City, NJ (n)
William Bugbee, MD, La Jolla, CA (n)
Darryl D D'Lima, MD, La Jolla, CA (n)
Heinz R. Hoenecke Jr., MD, La Jolla, CA (n)

Introduction: Osteochondral graft transplantation is often indicated for chondral lesions in the knee. Recent reports of chondrocyte death after mechanical injury have raised concerns regarding the long-term viability and outcome of this procedure. This study determined chondrocyte viability in osteochondral grafts exposed to simulated harvesting and insertion. Methods: Osteochondral graft transplantation was carried out in four fresh cadaver knees. A load cell was used to monitor loads applied during graft insertion. Typical insertion loads were measured between 200N and 800N. A total of 80 osteochondral grafts were obtained from six fresh human femoral condyles. These were subjected to varying loads between zero (sham) and 800N to simulate graft insertion. The cartilage was then separated from bone and cultured in Dulbecco's Modified Eagle's Medium. At 48 and 120 hours, chondrocyte viability was measured using calcein fluorescence. Glycosaminoglycan levels released during culture were measured to quantify matrix damage. Results: A mean of 95% cells were viable in unimpacted grafts. A significant decrease in chondrocyte viability was seen with increasing loads. Only 50% cells were viable at loads of 800N. Glycosaminoglycan release was higher at 120 hours compared to 48 hours. However, there was no significant correlation between glycosaminoglycan release and insertion load. Discussion and Conclusion: Typical graft insertion forces can cause chondrocyte death but may not cause immediate matrix damage. Articular cartilage has a limited pool of cells responsible for matrix maintenance. A significant decrease in chondrocyte viability can jeopardize long-term clinical results. Minimizing osteochondral graft insertion force is recommended.

COMSS POSTER NO. P355

American Orthopaedic Society for Sports Medicine

A Randomized Double-Blind, Placebo Controlled Clinical Trial Investigating the Use of Nitric Oxide Application in the Treatment of Chronic Extensor Tendinosis at the Elbow

Justin Paoloni, MD, *Sydney, Australia (*)*
Richard Charles Appleyard, PHD, St Leonards, NSW, Australia (*)
Janis Nelson, RPh, Sydney, Australia (n)
George A C Murrell, MD, Kogarah Sydney, Australia (b – Schering Plough Australia)

Extensor tendinosis ("tennis elbow") is a degenerative overuse tendinopathy of the wrist extensors at their attachment to the lateral humeral epicondyle. No treatment has been universally successful in managing this condition. Topical nitric oxide donation has been used effectively to treat fractures and cutaneous wounds in animal models via mechanisms that may include stimulation of collagen synthesis in fibroblasts. We aimed to determine if topical nitric oxide improved outcome measures in extensor tendinosis. Eighty six patients were recruited and we

completed a randomized, double-blinded, placebo controlled trial of continuous topical nitric oxide donation (1.25 mg / 24 hour glyceryl trinitrate), and showed in the nitric oxide group reduced elbow pain with activity at 2 weeks (p = 0.01), reduced epicondylar tenderness at 6 and 12 weeks (p = 0.02), and an increase in wrist extensor mean peak force and total work at 24 weeks (p = 0.03).81% of patients on GTN patches were asymptomatic in activities of daily living at six months compared to 60% of patients with tendon rehabilitation alone (p = 0.005 with Chi square analysis). Mean effect size for all outcome measures was 0.12.Topical nitric oxide donation improved early pain with activity, late functional measures, and patient outcomes in patients with extensor tendinosis.

SCIENTIFIC EXHIBIT

SCIENTIFIC EXHIBIT NO. SE068

Evaluation and Treatment of Acute Combined Posterolateral Corner/ ACL Injuries

Glen Ross, MD, *Boston, MA (n)*
Kellen Choi, MD, Boston, MA (n)
Arnold Scheller, MD, Boston, MA (n)

Introduction: Posterolateral corner (PLC) injuries are difficult to evaluate acutely, and are often combined with cruciate tears. Disrupted structures include the lateral collateral ligament, popliteus, popliteofibular ligament, biceps femoris, and posterolateral capsule. Early diagnosis allows repair of structures, rather than reconstruction. This exhibit reviews the diagnostic and imaging findings of acute combined PLC injuries, with surgical pathoanatomy and repair. Methods: 13 patients with acute PLC/ACL injuries were seen over 10 years. Clinical examination and MRI were performed. Repair was within 2 weeks. ACL reconstruction included allograft and autograft. Ten patients underwent combined procedures, 3 patients were staged. Evaluation, and radiographs were performed at 2 years. Results: Examination revealed abnormal varus stress, positive dial test, posterolateral drawer, and passive hyperextension. Lack of contained knee effusion predicted a complete PLC injury. Palpable biceps femoris tear was noted in six patients. Three had peroneal nerve palsy. MRI demonstrated LCL tears, MFC bone contusion, uncontained effusion, popliteus injury, and ACL disruption. Surgically, most cases revealed distally based injuries. LCL was avulsed from the fibula, posterolateral capsule was torn from the proximal tibia, the popliteus had a myotendonous tear, and the popliteofibular ligament was disrupted. Surgical repair focused on injury identification with anatomic restoration. Average followup was at 30 months post repair with nine patients available. Five patients demonstrated grade 1 varus laxity, four trace. IKDC showed two normal, and seven nearly normal . Eight described satisfactory outcomes. Seven resumed previous activity level. Conclusion: PLC/ACL injuries are amenable to repair, with a favorable outcome. A predictable pattern of injury exists. Anatomic repair with ACL reconstruction offers reasonable outcome, and may be superior to late reconstruction. Thorough clinical exam, supplemented with specific MRI findings, allows early and aggressive treatment.

PAPERS

PAPER NO. 061

Should Plain X-rays be Routinely Performed after Blunt Knee Trauma? A Prospective Analysis

Jean-Yves Jenny, MD, *Illkrich, France (n)*
Cyril Boeri, MD, Illkirch, France (n)
Hakima El Amrani, MD, Illkirch, France (n)
Jean-Claude Dosch, MD, Illkirch, France (n)
Michel Dupuis, MD, Illkirch, France (n)
Akli Moussaoui, MD, Illkirch, France (n)
Fabrice Mairot, MD, Illkirch, France (n)

Introduction: Ottawa rules propose to perform X-rays if at least one the following criterion is present: patient is over 55 years old, he has pain when palpating the fibular head, he has pain when palpating the anterior part of the patella, he cannot move his knee beyond 90 degrees of flexion, he cannot walk four steps after the trauma and in the emergency room. Hypothesis was that it was possible to use these rules in our institution (university trauma center) to decrease the number of performed X-rays without any inconvenience. Methods: During the first stage of the study, all patients who were examined for a recent isolated blunt knee trauma in December 2001 and January 2002 were included. All patients had a clinical examination in the emergency room, screening for the Ottawa rules, and routine anteroposterior and lateral plain X-rays of the injured knee. Sensitivity, specificity and positive and negative predictive values of the Ottawa rules for fracture diagnosis were calculated. During the second stage, all patients who were examined for a recent isolated blunt knee trauma in April and May 2002 were included. All patients had a clinical examination in the emergency room, screening for the Ottawa rules, but X-rays were only performed according to the Ottawa rules. All patients were re-examined or contacted by phone or letter 6 months after the trauma, screening for a delayed diagnosis of knee fracture. Results: 138 patients were included in the first stage. 57 patients had all negative Ottawa criteria: no fracture was observed on X-rays. 81 patients had at least one positive Ottawa criterion: 16 fractures were diagnosed. Sensitivity and negative predictive value of the Ottawa rules were 100%; specificity was 47%, positive predictive value was 20%. Following the Ottawa rules, 41% of the X-rays could have been avoided. 181 patients were included in the second stage. 65 patients had all negative Ottawa criteria and had no X-rays after the index clinical examination: no fracture was diagnosed during the whole follow-up. 116 patients had at least one positive Ottawa criterion and had X-rays at the time of the index examination: 9 fractures were diagnosed. Sensitivity and negative predictive value of the Ottawa rules were 100%; specificity was 38%, positive predictive value was 8%. Following the Ottawa rules, 36% of the X-rays have been avoided. Discussion-Conclusion: Ottawa rules allowed to decrease the number of X-rays performed after an isolated blunt knee trauma by 36 to 41%, without any delayed diagnosed knee fracture. These rules might be very cost-effective in a university trauma center.

PAPER NO. 062

Fixed-Angle Screw Plate Fixation is Stronger Than Blade Plate in Distal Femoral Fractures

Thomas F Higgins, MD, *Salt Lake City, UT*
(a – MusculoSkeletal Transplant Foundation, Synthes, Educational Resources Development Center)
Gavin T Pittman, MD, Salt Lake City, UT (*)
Jerod Hines, BS, Salt Lake City, UT (*)
Kent N Bachus, PhD, Salt Lake City, UT (a – Synthes)

Introduction: Supracondylar femur fractures represent a unique challenge, and the technically challenging blade plate has served as the gold standard for rigid fixation of these fractures. The recent advent of the fixed-angle screw plate interface has raised the possible advantages of fixed-angle plating with a more technically forgiving implant. A comparison of the biomechanical rigidity between blade plate and fixed-angle distal femoral plate is warranted before clinical practice is altered. Hypothesis: Fixed-angle distal femoral plate (FADFP) will provide better fixation for distal femoral fractures than the condylar blade plate (CBP). Material/Methods: The 8 human matched pair cadaver specimens used were studied with DEXA. A medial-based osteotomy was created and specimen pairs were randomly assigned to either CBP or FADFP. Instron crosshead measured displacement during standardized pattern of cyclic load and maximum compressive load to failure. Results: Total subsidence of fixation constructs was 1.04mm for FADFP v. 1.70mm for CBP(p=0.030). The FADFP was significantly stronger in load-to-failure (9084N v. 5591N, p=0.001). There were no detectable differences based on DEXA values. Conclusions: Total fragment subsidence was significantly less with the fixed-angle screw plate construct than the blade plate construct. The fixed-angle plate was significantly stronger in load to failure. Fixation did not correlate with bone density. Clinically, these results suggest that even in poor quality bone, fixed-angle screw-plate constructs provide superior fixation to blade plate constructs in both cyclic loading and ultimate strength.

PAPER NO. 063

Fixed-Angle Screw Plate Construct vs. Dual Plate Construct in Bicondylar Plateau Fractures

Thomas F Higgins, MD, *Salt Lake City, UT*
(a – Synthes, Educational Resources Development Center, MusculoSkeletal Transplant Foundation)
Joshua Klatt, MD, Salt Lake City, UT
(a – Synthes, Educational Resources Development Center, MusculoSkeletal Transplant Foundation)
John Droge, MS, Salt Lake City, UT (*)
Kent N Bachus, PhD, Salt Lake City, UT (n)

Introduction: Bicondylar tibial plateau fractures are challenging, especially if requiring fixation of both columns of the metaphysis. Fixed-angle plating devices may provide more rigid constructs without stripping medial cortex. Hypothesis: Fixed angle plating (FAPTP) construct will provide greater stability than traditional dual plating (DP) constructs in cadaveric bicondylar tibial plateau model. Materials / Methods: The 7 human matched pair cadaver specimens were studied with DEXA.Osteotomies simulated an unstable bicondylar tibial plateau. Optotrak IR diodes measured all planes of displacement

of fragments after pre-loading, post-cyclic loading and total subsidence during standardized pattern of cyclic load and maximum load to failure. Results: Medial pre-cycle stiffness was significantly greater for FAPTP than DP (146N/mm v. 700N/mm, p=0.019). Post Cycle stiffness was not significantly different (867N/mm v. 825N/mm, p=0.819). Total subsidence was less with DP than FAPTP (0.98 mm v. 1.92mm, p=0.064), but failed to achieve statistical significance. Load to failure data also yielded no significant difference (4778N v. 4388N, p=0.181). DEXA vs. displacement yielded no significant advantage for either fixation in osteopenic bone. CONCLUSIONS: Fixed-angle plating is stiffer in early loading, but no difference is seen after cyclic testing. Clinically, these results suggest that even in poor quality bone, fixed-angle screw-plate constructs may provide comparable fixation to dual plate constructs. This may allow adequate fixation of unstable bicondylar tibial plateau fractures without the soft tissue stripping associated with instrumenting the medial cortex.

PAPER NO. 064

The Gold Standard In Tibial Plateau Fractures? A Prospective Multicenter Study Of AIBG Vs. Alpha-BSM

Thomas A Russell, MD, *Collierville, TN (a, d, e – ETEX)*
Ross K Leighton, MD, Halifax, NS Canada (*)
Robert William Bucholz, MD, Dallas, TX (a – DePuy)
Paul Tornetta III, MD, Boston, MA (n)
Charles N Cornell, MD, New York, NY (a – ETEX)
Robert F Ostrum, MD, Camden, NJ (*)
James A Goulet, MD, Ann Arbor, MI (n)
Mark Vrahs, Boston, MA (a – DePuy)
Alan L. Jones, MD, Dallas, TX (n)

Introduction: This prospective randomized Multicenter study was undertaken to compare two methods of bone defect treatment with either a bioresorbable calcium phosphate paste (Alpha-BSM –DePuy, Warsaw, IN) that hardens at body temperature to give structural support and is gradually resorbed by a cell-mediated bone regenerating mechanism or conventional Autogenous iliac graft. Material and Methods: One hundred and twenty adult acute closed tibial plateau fractures, Schatzker grade 1-6 were enrolled from twelve study sites in North America from 1999 to 2002. All patients were prospectively enrolled with IRB supervision. Randomization occurred at surgery with a FDA recommendation of a 2-1 ratio, Alpha BSM (82 fractures) to AIBG (38 fractures) for the subarticular defect. Open reduction and internal fixation was with standard plate and screw constructs. Follow-up included standard radiographs and functional studies at one year. A single radiologist provided independent radiographic review. Results: The two groups were comparable as to age, sex, race, and fracture patterns. There was however, a significantly increased rate of non-graft related adverse affects in the AIBG group.There was an unexpected significant finding of a higher rate of late articular subsidence in the three to twelve month period in the AIBG group. Conclusion: The use of Autogenous iliac bone grafting for subarticular defects in tibial plateau fractures should be discouraged in favor of bioresorbable calcium phosphate material with the properties of Alpha-BSM. We believe further randomized studies using Autogenous iliac bone graft, as a control group for bone defect support of articular fractures is unjustified.

PAPER NO. 065

Does Medial Tenderness Predict Deltoid Ligament Incompetence in SER Type Ankle Fractures?

Nicola DeAngelis, MD, *Natick, MA (n)*
Bruce Green French, MD, Columbus, OH (n)

Introduction/Purpose: To determine prospectively if tenderness in the region of the deltoid ligament is predictive of deep deltoid ligament incompetence in the presence of an isolated lateral malleolus fracture without radiographic evidence of medial clear space widening or lateral talar shift. Methods: This study included, over a 9 month period, all patients presenting with an acute, isolated Weber B (OTA 44-B) fibula fracture without radiographic evidence of medial clear space widening or lateral talar shift. Each patient was evaluated for tenderness to palpation in the region of the deltoid ligament on the medial side of the ankle. Deep deltoid incompetence was defined as widening of the medial clear space on an external rotation stress mortise radiograph. Results: 55 patients met the criteria for the study. Positive widening/positive tenderness: 13 Positive widening/negative tenderness: 10 Negative widening/positive tenderness: 13 Negative widening/negative tenderness: 19 Conclusions/ Discussion: Medial tenderness was reported by 41% of patients with a competent deep deltoid ligament and 57% of patients with deep deltoid incompetence. 43% of patients with an incompetent deep deltoid ligament did not have medial tenderness. Medial tenderness had a sensitivity of 57%, a specificity of 59%, a positive predictive value of 50%, and a negative predictive value of 66% when used as a measure of deep deltoid ligament incompetence. These results indicate that medial tenderness is a poor predictor of deep deltoid ligament incompetence in the presence of an isolated Weber B (OTA 44-B) fibula fracture without medial clear space widening or lateral talar shift. In addition, the lack of medial tenderness does not indicate medial stability.

PAPER NO. 066

Tibial Plafond Fractures: A Randomized Trial of Post-operative Motion vs. Non-motion

John Lawrence Marsh, MD, *Iowa City, IA (a – EBI)*
Douglas R Dirschl, MD, Chapel Hill, NC (n)
Shepard R Hurwitz, MD, Charlottesville, VA (*)
Thomas A DeCoster, MD, Albuquerque, NM (a – EBI, Smith & Nephew, b – Orthofix)
Scott T Smith, MD, Knoxville, TN (n)
Valerie Muehling, MS, Iowa City, IA (a – EBI)

Introduction: This is a report of one and two-year outcome measures from a multicenter prospective trial, which compares postoperative ankle motion vs. rigid immobilization with a locked fixator hinge in the postoperative care of patients with tibial plafond fractures. Materials and Methods: Patients with a tibial plafond fracture who were treated with a hinged external fixator and met inclusion criteria were recruited from four participating investigators at three different centers, and then entered into a web-based database. From this database patients were randomized to either the experimental motion group (MG); which involved a free hinge along with a postoperative motion protocol or into the control group (NMG), which consisted of a locked hinge for eight weeks. Four outcome measures were assessed at one and two-years post injury; adverse events, ankle range of motion (ROM), the Ankle Osteoarthritis Scale (AOS), and the SF-36. Results: 44 patients were enrolled, and 40 completed one-year-outcome measures, 22 MG and 18 NMG. 26 of those 40 patients have completed two-year outcomes; 14 MG and 12 NMG. There were four adverse events in the NMG

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

compared to three adverse events in the MG. At both one and two years all outcome measurements showed no statistical differences between the two groups. Discussion: Although early post injury movement is thought to be beneficial for damaged articular surfaces, this data obtained at one and two years post injury do not demonstrate an advantage of ankle motion in the first eight weeks after tibial plafond fracture repair. Follow-up is ongoing to assess the development of arthrosis.

PAPER NO. 067

Distal Tibial Fractures Treated with Functional Bracing

Augusto Sarmiento, MD, *Coral Gables, FL (n)*
Loren L Latta, PhD, Plantation, FL (n)

INTRODUCTION: 450 closed fractures located in the distal third of the tibia were treated with functional braces. The results were analyzed regarding final shortening, angulation, and speed of healing. METHODS AND PROCEDUREOnly fractures that had <15 initial shortening and < 5_ angulation after correction of initial angular deformity we included in the study. All fractures were initially stabilized in a long leg cast prior to brace stabilization. RESULTS:Nonunion rate was 0.9%. Average shortening was 5.1 mm; time to bracing 3.6 weeks; time to healing 16.6 weeks. Patients braced < 6 weeks averaged 16.0 weeks to healing compared with 19.7 weeks for those braced after 6 weeks ($p<0.001$). There was no significant difference in high-energy injuries, final shortening or angulation between these groups. 94.2% healed with <12 mm shortening; 90.7% had <8_ angulation. CONCLUSIONS: Functional bracing of closed fractures of the tibia that have initial shortening <15mm and alignment is brought to <5_ renders satisfactory clinical results. The initial shortening that closed fractures experience does not increase with graduated weight bearing ambulation in the brace. Acceptable alignment can be maintained, in most instances, with proper brace management. Certain fractures with intact fibula have a tendency to develop varus deformity and should not be routinely braced.

PAPER NO. 068

A Comprehensive Score To Prognosticate Limb Salvage and Outcome Measures In Grade III B Open Tibial Fractures

S Rajasekaran, PhD, *Tamilnadu, India (n)*
S Rajasabapathy, FRCS, Coimbatore, India (n)
Manoj Kumar Kankane, MS(ortho), Jhansi Uttar Pradesh, India (*)
J Naresh Babu, MS(orth), Coimbatore, India (*)
Jayarama Raju Dheenadhayalan, MSorth, Coimbatore, India (n)
Shetty Prashad Ajoy, Coimbatore, India (*)
Conjeevaram Maheshwer, MD, West Lake, OH (n)

Introduction:Gustilo's grade IIIB classification includes a wide spectrum of injuries and is limited by high inter and intra observer error rates. Methods:A trauma score for grade IIIB open tibial fractures was devised to assess injury to three components; the covering tissues, musculotendinous units and bone with the severity scale in each category from one to five. Seven co-morbid conditions known to influence the prognosis were each given a score of two and summed up. Results:96 consecutive Grade IIIB open injuries of tibia were prospectively evaluated. At 3-5 year followup, of the 88 available, final score was less than five in 6 patients (Group I), between six and ten in 48 (Group II), eleven to fifteen in 29 (Group III) and above 16 in five (Group IV). All patients in Group IV and one in Group III with score of fifteen underwent amputation.There was a significant difference (p less than 0.001) between the three groups in the requirement for flap (16.7,75&100 percent), time for union (16.3,24.9 & 46.9), incidence of deep infection (0,22.9 & 60.7 percent), number of surgical procedures (1.2,3.1 & 6.3) and inpatient days (12.5,22.6 & 59.4). A score of greater than three in any one component required special skills in management and interfered with healing of other structures. Conclusion:The scoring system was found to be easy in application and accurate in prognostication of outcome.

PAPER NO. 069

Open Fractures: The Effect of Time to Definitve Treatment on Infection

Tarun Bhargava, MD, *Wichita, KS (n)*
Naftaly Attias, MD, Phoenix, AZ (n)
Dana G. Seltzer, MD, Phoenix, AZ (n)
R Curtis Bay, Phoenix, AZ (*)

Introduction: This study was undertaken to determine whether time to definitive treatment of open fractures influences probability of patient infection. Previous studies have found time interval between injury and wound debridement to be either nonsignificant or a major prognostic factor. These studies, however, have not included patients for whom the time interval exceeded 24 hours. Previous research has suggested that in order to minimize the probability of infection, operative irrigation and debridement should occur "as soon as possible" or up to twenty-four hours following injury. Methods: This study is a retrospective chart review of all open fractures treated at a level one trauma center in an urban hospital from January 1999 through June 2002. Data were collected concerning patient demographics, etiology of the injury, associated injuries, time of injury, time of arrival to hospital, time of initial operative irrigation and debridement, method of fracture fixation, and wound closure. Fracture grade and infections were also recorded. Fractures were separated by grade and time elapsed from injury to operative treatment. The time elapsed was divided into the following periods: 0-6 hours, 6-12 hours, 12-24 hours, and greater than 24 hours. Univariate and simultaneous logistic regressions were used to assess the impact of these variables on probability of infection. Results: A total of 220 patients with 245 fractures were included in the data set. Overall infection was 7.3%. Infection incidence in those treated before twenty-four hours was 5.2%, for those treated after twenty-four hours, incidence was 24.1%. Fracture grade and delay of greater than twenty-four hours prior to operative irrigation and debridement were significant predictors of infection in both univariate and simultaneous logistic regression analysis. Discussion and Conclusions: Our findings support prior research demonstrating a relationship between fracture grade and infection rate. Additionally, our study and the work of others suggest that delays of up to twenty-four hours do not adversely affect infection rate. Furthermore, we found evidence that delays of greater than twenty-four hours from injury to operative irrigation and debridement are associated with increased infection rate amongst open fractures.

PAPER NO. 070

Health Related Quality of Life in Patients with Transtibial Amputation and Reconstruction with Bone Bridging of the Distal Tibia and Fibula

Michael S Pinzur, MD, *Maywood, IL (n)*
Marco Antonio Guedes deSouza Pinto, MD, Sao Paulo, Brazil (n)
Matthew Saltzman, MD, Chicago, IL (n)
Fabio Batista, MD, Sao Paulo, Brazil (n)
Frank A B Gottschalk, MD, Dallas, TX (n)
Dainius Juknelis, MD, Maywood, IL (n)

Introduction: Bone-bridging (arthrodesis of the distal tibia and fibula) at the time of transtibial amputation is a controversial surgical technique that is anecdotally touted to improve the weightbearing capacity of the transtibial residual limb and decrease residual limb discomfort. Methods: Thirty-two consecutive patients with multiple diagnoses underwent transtibial amputation with a distal tibia-fibular bone-bridge, performed by a single surgeon. They all completed the Prosthetics Evaluation Questionnaire (PEQ), a validated outcomes instrument that was specifically created to evaluate quality of life and functional demands in subjects with a lower extremity amputation. Their responses were compared with seventeen pre-selected, highly functional transtibial amputees from two academic medical centers, who had previously undergone transtibial amputation using a traditional non bone-bridge surgical technique. Their time since amputation averaged 14.7 years. Results: The "non-selected" consecutive patients with a bone-bridged residual limb scored higher (more favorable) in the Ambulation ($p=0.037$) and Frustration ($p<0.001$) domains of the PEQ, and lower (less favorable) in the Appearance ($p=0.025$) subscale. Their scores were similar in the other six domains. Conclusions: Patients of multiple ages with multiple diagnoses consecutively underwent bone-bridging of the distal tibia and fibula at the time of transtibial amputation. Their scores on a validated outcomes instrument were, at best, better, or, at worst, comparable, with a selected group of highly functional transtibial amputees. The results of this study suggest that bone-bridging at the time of transtibial amputation may enhance patient perceived functional outcomes.

PAPER NO. 161

Internal Fixation of Traumatic Diastasis of Pubic Symphysis: Is Plate Removal Essential?

Raghu Raman, MRCS, *West Yorkshire, United Kingdom (n)*
Peter Giannoudis, MD, Leeds, United Kingdom (*)
Craig S Roberts, MD, Louisville, KY (a - Stryker HowMedica Osteonics, Smith&Nephew)
Christina Hadjikouti-Dyer, MRCS, Leeds, United Kingdom (*)

Purpose: We aim to measure the health status of patients with respect to plating of the pubic symphysis, identify the long-term effects of retaining the plate and address the issue of plate removal. Methods: Of 561 patients with pelvic ring injuries treated in our unit we identified 74 consecutive patients (18 female) with diastasis of the pubis symphysis that required internal fixation. At last follow up in addition to clinical and radiological assessment, the quality of life of the patients was assessed using the EuroQol EQ-5D. The incidence of impotence amongst the men was recorded and the women were questioned about dyspareunia, pregnancy, labor and possible future pregnancy following injury. The mean follow up was 40 months. Results: The mean age of the patients was 40.6 years and the median ISS was 25.5. There were12 VS fractures, 8 LC II fractures, 10 LC-III fractures, 25 APC II, and 19 APC-III fractures. Amongst the 15 patients (5 female) who had associated urological injuries, 5 had coexisting genital injuries. 7 patients had isolated genital injuries. 4 patients had concomitant vaginal and perineal lacerations. The pubic symphysis was stabilized with a single plate in 59 patients and double plates in 15 patients. Of three patients who developed local wound infection, 2 settled completely following antibiotic therapy. 1 patient had the plate removed as a result of deep sepsis (10 months). All patients proceeded to clinical and radiological evidence of union of the pelvic fracture. Implant failure was observed in 6 (8.1%) patients. All these patients had no functional consequencesThe plate was removed in 3 patients. Of 3 men who had erectile impotence, 2 had bladder injury and the other had penile, scrotal injury. One female who had deep dyspareunia had vaginal and perineal lacerations. 3 females and 7 men who had residual suprapubic pain had no evidence of implant failure. 2 were pregnant with the plate in situ. Both the patients had no significant suprapubic pain during the ante and postnatal periods. 6 patients who wished to become pregnant were concerned about the effects on pregnancy and labor. For men the mean EQ-5D description scores were 0.84, 0.49, 0.59 and the valuation scores were 60, 50.8 and 40 in the <29, 30-59 and >60 yrs age groups. They were significantly lower than the average sample population for their respective age groups ($p<0.04$, $p<0.009$, $p<0.01$). The mean EQ-5D description scores were 0.82, 0.83, 0.69 and the valuation scores were 88, 77.5 and 75 for the women in similar age groups. There was no significant difference compared to the average sample population. Conclusion: Traumatic diastasis of the symphysis treated by plating results in satisfactory union with moderate to good functional results. The patients had negligible problems with their mobility and self-care and the majority were back to their usual activities. The residual anterior pubic pain was very minimal and did not correlate with implant failure. This study supports the view that routine removal of the plate is not essential and the issue of implant removal in women of childbearing age requires further investigation

PAPER NO. 162

Long-Term Follow-up of ORIF of Acetabular Fractures Associated with Femoral Head Fractures

Michael Zlowodzki, MD, *Nashville, TN (n)*
Brian Thompson, Nashville, TN (*)
Keith Douglas, Nashville, TN (n)
Nader Shourbaji, Nashville, TN (n)
Philip James Kregor, MD, Nashville, TN (a – Synthes, AO Research Foundation)

Introduction: This prospective analysis delineates the clinical outcome of the surgical treatment of acetabular fractures associated with femoral head fractures (Pipkin IV injuries). Methods: During a seven year period (1995-2002), the senior author operatively treated 445 acetabular fractures. Of these, 11 were associated with a femoral head fracture. One patient with septic arthritis was excluded. Both components of the Pipkin IV injury (posterior wall fracture and femoral head fracture) were treated with O.R.I.F. The patients were followed in a prospective protocol established for the follow-up of all acetabular fractures. Average follow-up was 28 months (range: 12-60). The choice of surgical approach was: Ganz trochanteric flip osteotomy in 6 cases, Kocher-Langenbeck followed by Smith-Peterson approach in 1 case, and a Kocher-Langenbeck approach alone in 3 cases. No

heterotopic ossification prophylaxis was utilized. Patients were followed at yearly post-operative intervals and assessed via AP and Judet radiographs, modified d'Aubigne / Postel clinical scale, and radiographic grade. Results: Of the 10 Pipkin IV injuries, the clinical score was 3 Excellent, 6 Good, and 1 Poor. Radiographic grade was 5 Excellent, 4 Good, and 1 Poor. There were no post-operative infections, sciatic nerve injuries, or clinically significant heterotopic ossification. Discussion and Conclusion: The Ganz Trochanteric Flip Osteotomy combined with surgical dislocation of the hip allows for optimal visualization and fixation of both injuries, controlled reduction of the hip, and thorough debridement of the hip joint. Pipkin IV injuries are rare and potentially devastating. However, with appropriate and timely anatomical reduction, acceptable results (90 percent good or excellent) have been achieved.

PAPER NO. 163

Long-Term Functional Outcome: VS Fractures Compared to APC-III, LC-III, Complex Acetabular Fractures

Raghu Raman, MRCS, *West Yorkshire, United Kingdom (n)*
Peter Giannoudis, MD, Leeds, United Kingdom (*)

Purpose: To analyze the long-term functional outcome of vertical shear (VS) fractures to other forms of severe pelvic injuries: APC-III, LC-III, and complex acetabular fractures. Methods: We identified 31 VS fractures in 29 consecutive patients. A retrospective chart analysis was performed and the same parameters were analyzed in a control group comprising of 98 patients matched for age and sex: 34 patients with APC–III, 32 patients with LC-III and 32 patients with complex (at least bicolumnar) acetabular fractures. At last follow up, functional outcome was assessed in all patients using EuroQol EQ-5D, SF36 v2, VAS, SMFA and Majeed score as outcome tools. In addition Merle d Aubigne and Postel scores (Matta 1986) and radiologic degenerative hip scores (Matta 1994) were used to assess patients with acetabular fractures. Results: The mean age of all patients was 43.5 yrs and median ISS was 22. In the VS fracture group 35% of the patients returned to their previous jobs (49% in control group), 30% had changed jobs (30%) and 25% (14%) had retired from regular work. In the acetabular group10 patients had neurologic injury. 3 patients with acetabular fractures had total hip arthroplasties at 29,40,51months. The clinical outcome (Matta scores) of patients in the acetabular fracture group was:5 excellent (3 THA), 4 good, 13 fair,10 poor. The radiologic score (Matta 1994) for the acetabular fracture group was: 4 excellent, 8 good, 14 fair, 3 poor.The mean EQ-5D description scores were 0.43, 0.63, 0.69, 0.49 and the mean valuation scores were 46.1, 62.3, 78, and 51.4 for the VS, LCIII, APIII, and acetabular fractures respectively. The SF 36 v2 survey revealed a mean physical health score of 44.4, 62.5, 78.3, 54,2 and a mental health score of 26.2, 68, 76.5 and 56.3 for the VS, LCIII, APIII, and acetabular fractures respectively. SMFA dysfunction index was 63.3, 44.6, 38.3, 54.1 and the bother index was 60.5, 49, 34.2 and 57.2 for the VS, LCIII, APIII, and acetabular fractures respectively. There was a significant difference in the EQ-5D score, SMFA and the SF36 scores indicating a poorer outcome in the VS fracture group when compared to the AP-III ($p<0.03$) and LCIII group ($p<0.04$). There was no significant functional difference between the VS and the complex acetabular fracture group ($p>0.05$). Conclusion: Patients with VS fractures represent the spectrum of high-energy pelvic disruption. The functional outcome is significantly better in patients with APC III and LC III fractures when compared to VS and complex acetabular fractures thus reflecting the severity of the injury. Secondary osteoarthritis and neurologic injury appear to contribute to the poor outcome of acetabular fractures. Sound reconstruction of the pelvic ring is not always associated with good results probably due to the extensive pelvic floor trauma as seen in this series of patients. Younger individuals seem to have a relatively better outcome when compared to the older age group.

PAPER NO. 164

The Efficacy of Indomethacin as Prophylaxis for Heterotopic Ossification After Acetabular Fractures

Madhav A Karunakar, MD, *Ann Arbor, MI (n)*
Michael J Bosse, MD, Charlotte, NC (*)
Janette M Hall, MA, MS, Ann Arbor, MI (*)
Stephen H Sims, MD, Charlotte, NC (n)
Theodore Toan Le, MD, Ann Arbor, MI (n)
James F Kellam, MD, Charlotte, NC (n)
James A Goulet, MD, Ann Arbor, MI (n)
Mark A. Freeborn, MD, Ann Arbor, MI (*)

Purpose: To compare the efficacy of indomethacin versus a placebo for heterotopic ossification (HO) prophylaxis in a prospective, randomized trial. Methods: One hundred and nineteen patients with acetabular fractures treated operatively through a posterior approach were randomized to receive indomethacin or a placebo. Sixty-seven patients received a placebo and fifty-two received indomethacin 75 mg SR for six weeks. Four patients were lost to followup. HO severity was assessed using the modified Brooker classification. Serum indomethacin levels were obtained at two weeks. Results: There was no significant difference between the treatment groups in the incidence of HO according to Brooker class ($p=0.22$). Significant HO (Brooker grades III-IV) occurred in 8 cases (17%) in the indomethacin group and 14 cases (21%) in the placebo group. Twenty-five patients did not complete the treatment protocol for the following reasons: stopped medication due to side effects or lost medication. Nine patients (8.4%) did not receive the full medication course, sixteen patients (15%) withdrew from the study for adverse events. Twelve patients withdrew from the indomethacin group and four from the placebo group. Forty percent of patients in the indomethacin group had non-detectable serum levels. Complications identified in the indomethacin treatment group included nonunion, gastrointestinal bleed and perforated ulcer. Conclusion: In this study, a placebo provided as effective prophylaxis against the development of heterotopic ossification as indomethacin. More patients withdrew from the indomethacin group and patient compliance with indomethacin was poor. Serious gastrointestinal complications occurred in two patients treated with indomethacin.

PAPER NO. 165

Outcomes of Operative Treatment of Femoral Neck Fractures in Young Patients

George John Haidukewych, MD, *Rochester, MN (n)*
Walter S Rothwell, Rochester, MN (n)
David J Jacofsky, MD, Rochester, MN (n)
Michael E Torchia, MD, Rochester, MN (n)
Daniel J Berry, MD, Rochester, MN (a, c – DePuy)

IntroductionThere is a paucity of data evaluating the outcomes of treatment of femoral neck fractures in young patients. The purpose of this retrospective review is to evaluate a large consecutive series of femoral neck fractures in young patients treated with contemporary methods of internal fixation to learn more about the results and complications of treatment of these poten-

tially devastating injuries. MethodsBetween 1975 and 2000, 82 consecutive patients with 83 nonpathologic fractures of the femoral neck (OTA type 31B) were treated with internal fixation at our Level 1 Trauma Center. There were 53 males and 29 females with a mean age of 36 (15-50 years). 59 fractures were displaced and 24 were nondisplaced. 43 of the 59 displaced fractures were treated with closed reduction and internal fixation while 16 required formal open reduction and internal fixation. Two patients died and 8 (9.8%) were completely lost to follow-up. 73 fractures were followed to union, revision operation, or a minimum of 2 years with a mean clinical follow-up of 6.3 years (3 months-23 years) and a mean radiographic follow-up of 5.3 years (3 months-23 years). Clinical and radiographic data were retrospectively reviewed, and results and complications analyzed. Functional assessment at follow-up was performed by evaluating pain, ambulatory status, need for gait aids, and need for secondary surgeries. Reductions were graded as excellent, good, fair, or poor based on angulation and displacement. AVN and nonunion rates were calculated evaluating the influence of original displacement and quality of reduction. ResultsFor the group as a whole, 54 of 73 (74 %) fractures achieved successful bony union without evidence of avascular necrosis at last follow-up. 17 of 73 fractures (23%) developed avascular necrosis (1 Ficat Stage 1, 5 Stage 2, 5 Stage 3, 6 Stage 4). 6 fractures (8%) developed nonunion. Of the 51 fractures that were initially displaced, 5 (9.8%) developed nonunion and 14 (27%) developed avascular necrosis. Of the 22 nondisplaced fractures, only 1 (4.5%) developed nonunion and 3 (14%) developed avascular necrosis. At follow-up 11 of 73 (15%) patients required conversion to hip arthroplasty and 5 required secondary surgeries to achieve union (2 valgus osteotomies, 2 muscle pedicle bone grafts, 1 repeat ORIF). 68 of 73 (93%) fractures had good to excellent reductions, of these 14 (20%) developed AVN and 3 (4%) nonunion. Five of 73 had fair or poor reductions, 4 (80%) developed AVN, nonunion, or both. Discussion and ConclusionFemoral neck fractures in young patients remain challenging injuries to treat. Despite contemporary techniques of internal fixation and the very high percentage of excellent reductions, the incidence of avascular necrosis and nonunion remain concerning. For the 73 patients with mean clinical follow-up of 6.3 years, the native femoral head was successfully salvaged in 85% of patients. Functional status of patients with salvaged femoral heads was excellent. This data represents the largest series with the longest follow-up and supports continued efforts to obtain the best reduction possible when treating these injuries.

PAPER NO. 166

Can a Traction/Internal Rotation Radiograph Help To Better Evaluate Fractures of the Proximal Femur?

Chong Oh, MD, *New York, NY (n)*
Kenneth A Egol, MD, Jamaica, NY (n)
Kenneth J Koval, MD, New York, NY (n)

Introduction: We have noted that inexperienced physicians sometimes misclassify hip fractures based on the initial radiographic series and this may lead to errors both in surgical planning and implant choice. Therefore, we now routinely obtain a physician assisted traction/internal rotation radiograph of the affected hip in all fractures of the proximal femur. This study examines the usefulness of routinely obtaining a traction / internal rotation radiograph in the classification of proximal femur fractures by PGY2 residents in our Orthopaedic Residency. Methods: Forty-seven sets of complete radiographs were obtained in patients who sustained a proximal femur fracture. Fifteen first year orthopaedic residents (PGY2) reviewed the cases and classified them according to six possible choices: 1) Non-displaced femoral neck fracture, 2) Displaced femoral neck fracture, 3) Stable intertrochanteric fracture, 4) Unstable intertrochanteric fracture, 5) Intertrochanteric fracture w/ subtrochanteric extension, and 6) Subtrochanteric fracture. Each fracture case was first classified after reviewing the standard hip series (AP Pelvis, AP hip, and cross table lateral). A traction/internal rotation radiograph was then added to each case and any changes in the initial classification were noted. Results: After reviewing the standard hip series the residents' initial classification was in agreement w/ those of the senior authors in 69.4% of the responses. The addition of a traction/internal rotation radiograph led to a common classification in 74.3%. ($p< 0.05$). In 46% of the correctly changed diagnoses, the new classification would have led to an implant or positioning change. In a small percentage of cases (2.3%), the addition of a traction / internal rotation view led to an incorrect change in classification. Conclusion: The routine addition of a traction/internal rotation radiograph significantly increases the ability to accurately classify proximal femur fractures and thus aids in surgical planning.

PAPER NO. 167

Dynamic Hip Screw vs. External Fixation for Osteoporotic Trochanteric Fracture Treatment

Antonio Moroni, MD, *Bologna, Italy (n)*
Cesare Faldini, MD, Bologna, Italy (n)
Francesco Pegreffi, MD, Suzzara, Italy (*)
Sandro Giannini, MD, Bologna, Italy (n)

INTRODUCTION Goals of osteoporotic trochanteric fracture treatment include minimal surgical trauma and early rehabilitation. External fixation, once considered a treatment option for this type of fracture, was later abandoned due to high rates of pin loosening, infection and loss of reduction. The development of new external fixators, as well as the introduction of hydroxyapatite (HA)-coated external fixation pins prompted us to reconsider this treatment. We compared Dynamic Hip Screw (DHS) to Orthofix pertrochanteric fixator (OPF). METHODS: 40 consecutive patients were randomized to receive either 135° 4-hole DHS (group A) or OPF with 4 HA-coated pins (group B). Inclusion criteria were: female, age*65 years, AO type A1 or A2 and BMD lower than -2.5 T score. RESULTS: There were no differences in patient age, fracture type, BMD, ASA, hospital stay, or quality of reduction. Operative time was 64±6 minutes in Group A and 34±5 minutes in Group B ($p<0.005$). Average number of post-operative blood transfusions was 2±0.1 in Group A, and none in Group B ($p<0.0001$). Fracture varization at 6 months was 6±8° in Group A and 2±1° in Group B ($p=0.002$). In Group B, no pin-track infections occurred. In Group B, pin fixation improved over time, as shown by pin extraction torque (2770±1710 Nmm) greater than insertion torque (1967±1254 Nmm), ($p=0.001$). Harris Hip Score at 2 years was 62±20 in Group A and 63±17 in Group B (ns). DISCUSSION AND CONCLUSION: OPF with HA-coated pins is an effective treatment for this patient population. Operative time is short, blood loss negligible, fixation adequate, and reduction is maintained over time.

PAPER NO. 168

The Periprosthetic Femoral Fracture. An Analysis of 1049 Late Periprosthetic Femoral Fractures

Hans Lindahl, MD, *Tlollhattan, Sweden (n)*
Henrik Malchau, MD, Goteborg, Sweden
(a, e – Centerpulse, DePuy Johnson & Johnson, Smith&Nephew, Zimmer)
Peter Herberts, MD, Goteborg, Sweden
(a – Centerpulse, DePuy Johnson & Johnson, Smith&Nephew, a, e - Zimmer)
Goran Garellick, MD, Goteborg, Sweden (n)

INTRODUCTION: The postoperative periprosthetic femoral fracture is a severe complication after total hip surgery. Although, uncommon, such a fracture presents a major challenge to the orthopedic surgeon and several centers report an increase in numbers of fractures. From 1979 to 2000, 1049 periprosthetic fractures were reported to the Swedish National Hip Arthroplasty Register. This study focuses on patient and implants related factors, classification and frequencies of the fractures. METHODS: Data from the Swedish National Hip Registry, including 216 000 primary procedures and 36 000 reoperations, give a unique opportunity to analyze the prosthesis related femoral fracture. Between 1979 and 2000, 1049 cases were found. The analysis was based on hospital records and all living patients have received a self-administrated clinical outcome questionnaire. RESULTS: There were three major findings. A majority of patients had a loose stem at time for fracture (70%). There were significant implant related factors and the results after treatment of periprosthetic fracture, in Sweden, has been poor with low long-term survivorship and a high frequency of complications. DISCUSSION AND CONCLUSIONS: A future recommendation is to follow all THR patients with regularly radiographic monitoring and try to intervene surgically before they sustain their fracture. Implant related factors has to be considered when choosing implant for routine use.

PAPER NO. 169

Trochanteric vs Pirformis Entry Portal for the Treatment of Femoral Shaft Fractures

William Michael Ricci, MD, *Saint Louis, MO*
(a, e – Smith & Nephew)
John R Schwappach, MD, Denver, CO (*)
Kevin Coupe, MD, Houston, TX (a – Smith & Nephew)
Michael Tucker, Saint Louis, MO (a – Smith & Nephew)
Angel Blackwell, Saint Louis, MO (n)
Roy W Sanders, MD, Tampa, FL (a, c, e – Smith & Nephew)

Introduction: Femoral nailing through the tip of the greater trochanter is technically easier than insertion through the piriformis fossa. However, when a straight nail (in the coronal plane) is inserted through this entry portal, varus and iatrogenic comminution is often associated. The Trigen TAN nail has a 5∞ proximal lateral bend that theoretically reduces the risk of these complications. Methods: This prospective, multicenter, IRB approved study compared results for patients with femoral shaft fracture treated with a Trigen TAN nail inserted through the greater trochanter (n=38) to those treated with an identical nail without a trochanteric bend (FAN nail) inserted through the piriformis fossa (n=53). Results: All except one patient from each group healed after the index procedure. In all cases, there was < 10∞ malalignment and no iatrogenic comminution. The average operative and fluoroscopy time was reduced in the TAN group (62 minutes and 95 seconds, respectively, p<.01) compared to the FAN group (75 minutes and 153 seconds, respectively, p>.01). Patients from both groups had similar initial decline and subsequent improvement in function over time. Discussion: A femoral nail specially designed for trochanteric insertion resulted in equally high union rates, equally low complication rates, and functional results similar to conventional antegrade femoral nailing through the piriformis fossa. As a result of increased ease of insertion, decreased operative time and decreased fluoroscopy time, the greater trochanter entry portal coupled with an appropriately designed nail, represents a rational alternative for antegrade femoral nailing.

PAPER NO. 170

Complications of Pediatric Femur Fractures Treated with Titanium Flexible Intramedularry Nails

Ernest L Sink, MD, *Denver, CO (n)*

PURPOSE At our institution the use of titanium flexible nail stabilization of pediatric femur fractures has expanded beyond the simple transverse fracture to include unstable fractures. The purpose of this study is to define and analyze complications seen in children with femur fractures stabilized with titanium flexible intramedullary nails. METHODS A retrospective review was performed on 40 consecutive children with femur fractures treated with titanium flexible intramedullary nails. Patients with either comminuted or long oblique fractures were classified as having length unstable fractures. Patients were followed until complete fracture healing. Patients were analyzed qualitatively for any predictive factors or treatment variables that increased the risk of complications. RESULTS There were 8 patients that underwent unplanned surgery prior to complete femur fracture healing. Two of these eight patients required two separate procedures. Seven of the ten reoperations were to remove or modify exposed or extremely prominent nails. Three of the surgeries were for fracture manipulation secondary to loss of reduction within the first week. Seven of the eight patients requiring unplanned surgery were originally treated for length unstable fractures. Seven of these eight patients were placed into a single leg spica cast as postoperative routine. There were two cases of malunion. CONCLUSION The complications that required unplanned surgery for either prominent nails or loss of reduction occurred while treating unstable non-transverse fracture patterns.We conclude that in patients with length unstable femur fractures consideration should be given to other methods of treatment than titanium flexible intramedullary nails.

PAPER NO. 191

Prediction of Deep Venous Thrombosis and Pulmonary Embolism Rates in Orthopaedic Trauma Patients

Alexis Falicov, MD, *Seattle, WA (n)*
Sara K Holt, MPH, Seattle, WA (n)
Sean E Nork, MD, Seattle, WA (n)
Mark H Meissner, MD, Seattle, WA (*)
Bruce J Sangeorzan, MD, Seattle, WA (n)

Introduction: Pulmonary Embolism (PE) is a potentially fatal complication that can occur in the traumatized patient. Patients with orthopaedic injuries are at particular risk for development of these conditions. The purpose of this study is to develop a model that would allow one to predict the rates of DVT and PE based on the pattern of injury and patient characteristics. Methods: The orthopaedic database at a single institution over a 11 year period was reviewed. For each patient, the exact type and location of the injury was identified. Of this group, those

patients with a diagnosis of DVT and PE were identified. A stepwise logistic regression model was then constructed to predict the rates of DVT and PE formation. Results: 9,283 patients were identified with 556 DVT (5.99 percent) and 24 PE (0.59 percent). The age dependent risk for DVT and PE was found to be bimodal with one peak at 60 years of age and another at >80 years of age. With a stepwise logistic regression model, the only significant fractures were femur (RR 3.0), tibia (RR 2.5), spine (RR 1.3), and pelvis fractures (RR 3.1). Correlations were found between ipsilateral tibia-femur fractures and pelvis-femur fractures. Age was also significant (P 0.015). Discussion: Upper extremity, foot, and ankle injuries were not found to be statistically significant predictors for DVT formation. The highest risk patients are those elderly patients with bilateral lower extremity long bone fractures or those with combined lower extremity and pelvic injuries.

PAPER NO. 192

DVT Prophylaxis: A Prospective Randomized Comparison Using Mechanical and Pharmacologic Prophylaxis

Edward R Anderson, MD, *Birmingham, AL (*)*
James P Stannard, MD, Birmingham, AL (a – Aventis Inc)
Robert Lopez, MD, Birmingham, AL (*)
Donna Karr, Jasper, AL (a – Aventis Inc)
Gerald McGwin, Jr PhD, Birmingham, AL (n)
David A Volgas, MD, Birmingham, AL (a – Aventis Inc)
Jorge Alonso, Cvizcaya, Spain (n)

PURPOSE: To report on the incidence of DVT and PE in a prospective, randomized, blinded study following blunt trauma. A second purpose was to evaluate outpatient DVT's in non-ambulatory patients. METHODS: 200 patients completed the study undergoing Magnetic Resonance Venography (MRV) and ultrasound prior to discharge. The radiologists were blinded. Patients without DVT's re-randomized as outpatients if they were not full weightbearing, receiving either enoxaparin (Group 1) or aspirin (Group 2). Once ambulatory, they were re-evaluated with ultrasound. RESULTS: 97 patients were in Group A (early Enoxaparin 30mg BID) and 103 in Group B (foot pumps plus delayed Enoxaparin after 5 days). There were 11 occlusive clots (11.3%) and 2 PE's (2.1%) in Group A, compared with only 3 (2.9%) and 0 PE's in group B ($p < .025$). Patients who developed DVT required significantly more blood than those who did not develop DVT's ($p < .05$). 128 patients completed the outpatient study, with only 1 DVT and PE (in Group 1). The incidence of DVT was 0.8% for the outpatients, with a 1.5% incidence in Group 1 and a 0% incidence in Group 2. DISCUSSION/CONCLUSIONS: There have been no prospective randomized studies comparing a dual treatment strategy with anticoagulation. Our results indicate that early mechanical prophylaxis and the addition of enoxaparin on a delayed basis is a very successful strategy. Based on our results, subcutaneous injections with enoxaparin are not necessary to successfully prophylax against DVT in the outpatient setting. Aspirin was effective at a much lower cost and with no need for injections.

PAPER NO. 193

Secondary Surgery in Trauma Patients and Perioperative Liberation of Proinflammatory Cytokines

Frank Hildebrand, MD, *Hanover, Germany (n)*
Martijn Van Griensven, PhD, Hanover, Germany (n)
Christian Krettek, MD, Hanover, Germany (a – AO International/ASIT)
Hans Christopher Pape, MD, Hannover, Germany (a – AO International/ASIT)

Background: The aim of this study is to asses the associations between timing of secondary definitive fracture surgery on inflammatory changes. The study population comprises a series of trauma patients who were managed using a strategy of primary temporary skeletal stabilisation followed by delayed definitive fracture fixation. Methods: In a prospective study, 128 patients were split into an early secondary surgery group (ESS, surgery at days 2-4) and a late secondary surgery group (LSS, surgery at days 5-8). Inflammatory markers (Interleukin-6, Tumor necrosis factor _) were determined daily. Perioperatively, these markers were evaluated at 30 minutes, 7 hours and 24 hours after initiation of surgery. Results: Secondary surgery on days 2-4 was associated with a higher incidence of postoperative organ dysfunction (46.5%) than secondary surgery on days 5-8 (15.7%, $p=0.01$). A significant association between the combination of initial Il-6 values > 500 + surgery on day 2-4 and the development of MODS ($p<0.001$) occurred. Il-6 demonstrated a predictive value for the development of MODS. Conclusions: No distinct clinical advantage in carrying out secondary definitive fracture fixation early could be determined. In patients who demonstrated initially high Il-6 values, it may be better to delay the interval between primary temporary fracture stabilisation and secondary definitive fracture fixation for more than 4 days. In patients with blunt multiple injuries undergoing primary temporary fixation of major fractures, the timing of secondary definitive surgery should be carefully selected, because it may act as a second hit phenomenon and cause a deterioration of the clinical status.

PAPER NO. 194

Effects of Medullary Irrigation and Aspiration During Reamed Intramedullary Nailing

Hans Christopher Pape, MD, *Hannover, Germany (a – AO International/ASIT)*
Frank Hildebrand, MD, Hanover, Germany (n)
Mayur Chawda, Leeds, United Kingdom (*)
Peter Giannoudis, MD, Leeds, United Kingdom (*)
Christian Krettek, MD, Hanover, Germany (a – Synthes, AO International/ASIT)

Introduction: Reaming of the femoral canal has been demonstrated to cause intravasation of intramedullary contents. We investigated whether this effect can be reduced by a new reamer system that uses concomitant irrigation and aspiration of intramedullary contents. Materials and methods: In an acute sheep model (n=8 animals/group), an experimental lung contusion was induced. Femoral nailing was performed by reamed (group RFN; standard Synthes reamer, old version), (group RIA; reaming, irrigation and aspiration) or unreamed technique (group UFN). Lung permeability was investigated by repeated bronchoalveolar lavage (baseline, post contusion, post Insertion, 4 hours post op). The amount of protein leakage and urea in BALF and serum was investigated (UREA/PROTEIN RATIO). The

reactivity of polymorphonuclear leukocytes (PMNL) was measured by chemi-luminescence. Results: A significant increase in pulmonary permeability after reaming was measured only in group RFN (group RFN: baseline 42.0, contusion 102.7, fixation 178.3*, 4 hours post OP199.2*# p<0.05) (group RIA: baseline 29.6, contusion 93.7*, fixation 99.7, 4 hours post 91.5) (group UFN: baseline 40.3, contusion 105.2*, fixation 121.1, 4 hours post 110.6 The natural increase in stimulatory capacity of PMNL induced by surgery was only observed in group RIA, in all other groups immune paralysis was present. *: significantto baseline, #: sign. difference to other groups. Discussion: The marked pulmonary permeability damage induced by lung contusion was amplified significantly only in group RFN alone. Irrigation and aspiration of intramedullary contents was associated with a reduction in the systemic effects caused by embolization of intramedullary contents induced by conventional reaming.

PAPER NO. 195

Vacuum Assisted Closure (VAC) to Treat Hematomas and Surgical Incisions Following High-energy Trauma

James P Stannard, MD, *Birmingham, AL*
(a – Kinetic Concepts Inc)
James T Robinson, Birmingham, AL (n)
Edward R Anderson, MD, Birmingham, AL (*)
Gerald McGwin, Jr, PhD, Birmingham, AL (n)
David A Volgas, MD, Birmingham, AL
(a – Kinetic Concepts Inc)
Jorge Alonso, Cvizcaya, Spain (n)

PURPOSE: To evaluate the use of the VAC to augment healing of surgical incisions and hematoma's following high energy trauma. METHODS: This study is a prospective randomized evaluation of the VAC in trauma patients. The first part of the study randomized patients with draining hematoma's to either a pressure dressing (Group A) or a VAC (Group B), evaluating time of drainage, need for return to the OR, and the development of infections. Part 2 of this study randomized patients with calcaneus, pilon, and high energy tibial plateau fractures to either a standard post-operative dressing or a VAC over the sutures. Again, we evaluated time of drainage, wound breakdown, and infection. RESULTS: 44 patients have been randomized into the hematoma study following high energy trauma with fractures. Group A drained a mean of 3.1 days, compared to only 1.6 days for Group B. This difference was significant (p = 0.03). The infection rate for Group A was 16%, compared to 8% in Group B. An additional 44 patients have been randomized into the fracture study. Again, a significant difference (p = 0.02) was present when comparing drainage in Group A (4.8 days) and Group B (1.8 days). No significant difference was present at current enrollment for infection or wound breakdown. DISCUSSION/CONCLUSIONS: The VAC has been utilized with success on many complex wounds in trauma patients. Potential mechanisms of action include angiogenesis, increased blood flow, and decreased interstitial fluid. This ongoing randomized study has demonstrated decreased drainage and improved wound healing following both hematoma's and severe fractures.

PAPER NO. 196

Splinting After Wrist Fracture: A Prospective Randomized Study of Patient Comfort and Efficacy

Matthew Liebman, MD, *New York, NY (*)*
Kenneth A Egol, MD, Jamaica, NY (n)
Kenneth J Koval, MD, New York, NY (n)

INTRODUCTION: This IRB approved study was performed to compare use of a radial gutter short arm splint to a sugartong splint for initial distal radius fracture fixation in terms of its ability maintain fracture reduction and patient satisfaction. METHODS: One hundred and thirty consecutive patients were randomized to placement of a sugartong splint or a radial gutter short arm splint for fracture immobilization following closed reduction. Patients were followed at 7-10 days and repeat radiographs taken; an upper extremity DASH form was filled out at this time as well as questions specifically related to splint comfort and patient satisfaction. Unstable fractures were defined based on:standard criteria. Statistical analysis was performed separately for stable and unstable fractures using a students T-test for fracture reduction and to compare patient satisfaction. Maintenance of fracture reduction was defined as loss of reduction < 2mm or 5 degrees from initial reduction. A p-value of .05 was considered significant. RESULTS: Of 97 patients available for follow up, 52 were classified as stable and 45 as unstable fractures. A total of 33 fractures demonstrated a loss of fracture reduction at follow up; 16 fractures had been immobilized with the radial gutter splint while 17 had been immobilized with a sugartong splint; this difference was not significant. When the splint constructs were evaluated based on fracture stability, no differences were found between the splints' ability to maintain fracture reduction in nondisplaced fractures and in displaced fractures which had a stable fracture pattern. However, the sugartong splint demonstrated significantly better ability to maintain fracture reduction in displaced fractures which had an unstable fracture pattern. The patients in the short arm splint group had better DASH scores 61.3+17.2 while the sugartong group was 68.6 +18.1 at one week (P=0.042). CONCLUSION: Based on our study, we recommend use of a short arm radial gutter splint for initial immobilization of nondisplaced and displaced distal radius fractures which have a stable fracture pattern. However, a sugartong splint should be used for initial stabilzation of displaced distal radius fractures with an unstable fracture pattern.

PAPER NO. 197

Early and Delayed Excision of the Radial Head Following a Fracture - A Mean 18 Year Follow-up

Par Herbertsson, MD, *Malmo, Sweden (*)*
Per Olof Josefsson, MD, Malmo, Sweden (n)
Ralph Hasserius, Malmo, Sweden (*)
Jack Besjakov, Malmo, Sweden (*)
Fredrik Nyquist, MD, Malmo, Sweden (*)
Magnus Karlsson, MD, Malmo, Sweden (*)

INTRODUCTION The purpose was to evaluate the hypothesis that the long term outcome after an excision of the radial head following a fracture, independent of an immediate or delayed excision was done, is predominantly favourable. METHODS Thirty-one women and 30 men, mean aged 9–69 when sustaining a Mason type II fracture in 39 cases, Mason type III in 10 and Mason type IV in 12, were subjective, objective and radiographic evaluated after 11–24 years. The fractures were treated with direct radial head excision in 43 individuals and delayed excision in 18 due to residual pain. No difference in type of fracture or trauma was found when comparing the groups. RESULTS

Twenty-eight had at follow-up no subjective complaints, 27 had occasional pain whereas 6 (4 Mason IV and 2 Mason III) had pain also at rest. Flexion was decreased in the fractured versus uninjured elbow (139_ 11 versus 142_ 8 degrees) as was extension (-7_ 12 versus -1_ 6 degrees), both p<0.001. There was more degenerative changes in the fractured versus uninjured elbow (73 versus 7 percent, p<0.001) but not more elbow osteoarthritis. There were no differences when comparing individuals with immediate or delayed excision. DISCUSSION AND CONCLUSION Radial head excision following a Mason II–III fracture seems to lead to an acceptable outcome. In contrast, chronic pain follow an excision of the radial head in one third of patients with a Mason IV fracture. It seems probable that the long-term outcome is more associated with type of trauma and fracture than if early or delayed excision was advodcated.

PAPER NO. 198

Comparison of Short and Long-Arm Plaster Casts for Displaced Distal-Third Pediatric Forearm Fractures

Gavin R Webb, MD, *Buffalo, NY (n)*
Robert D Galpin, MD, Buffalo, NY (n)
Douglas G Armstrong, MD, Buffalo, NY (n)
Daniel R Schlatterer, DO, Buffalo, NY (n)

Introduction The purpose was to determine if short-arm casts are as effective as long-arm casts in the treatment of displaced pediatric distal-third forearm fractures. Methods This was a prospective randomized trial in which consecutive patients presenting to the Children's Hospital with displaced distal-third forearm fractures were randomized to short or long-arm casts. Xrays were analyzed for displacement, angulation and deviation for all injury, post-reduction, and subsequent follow-up films. Cast indices were calculated. Changes between post-reduction and final values of displacement, angulation and deviation were measured. Range of motion of both wrists and elbows was averaged and the need for physical therapy was compared. A questionnaire compared the effects of cast type on activities of daily living. Results Seventy-eight out of one hundred two possible patients were analyzed. There was 89 percent follow-up averaging 7 months. There were 46 long-arm and 32 short-arm casts. There were no significant differences between the two groups. The cases that had a loss of reduction in the cast had significantly higher cast indices. Initial elbow range of motion was considerably less with long-arm casts, but there was no difference at final follow up. Patients with short arm casts missed fewer school days, were more likely to be able to shower, and were less likely to require assistance with various activities of daily living. Discussion and ConclusionsThis study demonstrates that well-molded short-arm casts can effectively treat distal-third forearm fractures in the pediatric population and cause less interference with daily activities.

PAPER NO. 199

Effects of Fondaparinux on Human Osteoblasts

Dr Med. Georg Matziolis, *Berlin, Germany (n)*
Alexander Disch, MD, Berlin, Germany (n)
Carsten Perka, MD, Gelsenkirchen, Germany (n)

Introduction: Proliferation of osteoblasts and bone specific matrix synthesis are essential as well for fracture healing as for endoprosthetic implant integration. Thrombosis prophylaxis with heparin is associated with osteopenia, possibly delaying or inhibiting these processes. The effects of fondaparinux, a synthetic anticoagulant similar to heparin, that has shown to be superior in thrombosis prophylaxis, on bone healing is yet unknown. We examined fondaparinux in comparison to previously used heparins in-vitro using a human osteoblast model. Methods: Unfractionated heparin (UFH), dalteparin and fondaparinux were added to osteoblast cultures in the therapeutic range and two decimal powers above and below it. Total DNA content, protein and matrix synthesis were quantified. Results: In contrast to UFH and dalteparin, fondaparinux increased significantly osteoblast proliferation, bone specific matrix and protein synthesis. No inhibitory in-vitro effects of fondaparinux on human osteoblasts could be demonstrated. Discussion: We conclude that fondaparinux can avoid the heparin-related negative influence on osteoblast-dependent fracture healing and endoprosthetic implant integration when used for thrombosis prophylaxis.

PAPER NO. 200

Impact of Surgical Delay on Mortality Following Hip Fracture

Kevin J McGuire, MD, *Cleveland Heights, OH*
(a – Orthopeadic Education Foundation)
Joseph Bernstein, MD, Bala Cynwyd, PA (*)
Dan Polsky, MD, Philadelphia, PA (n)
Jeffrey H Silber, MD, Philadelphia, PA (*)

Background: Fractures of the hip are among the most deadly conditions encountered by orthopedic surgeons but it has not demonstrated conclusively whether a delay prior to surgery contributes to the mortality rate. Those studies which attempted to control for severity of illness may have not been able to detect all salient pre-operative medical conditions and account for unobserved selection bias. The objective of this study was to analyze the effect of delay on mortality for patients with hip fractures using the day of the week of admission as an instrumental variable to pseudo-randomize the population into two groups: those admitted Saturday, Sunday or Monday and those admitted Tuesday through Friday. It has been shown that patients admitted Saturday, Sunday or Monday have longer pre-operative delay to surgery, independent of medical status. An association between higher mortality and admission on Saturday, Sunday or Monday would strongly implicate delay as a cause, and not just as a marker of, increased mortality. Methods: We analyzed the claims data of 18,209 Medicare recipients 65 years of age or older who sustained a closed hip fracture and underwent surgical treatment in the state of Pennsylvania in 1995-1996. We studied the relationship between delay to surgery (measured as the number of days between admission and surgery) and mortality at 30 days, after adjusting for severity of medical comorbidities. Patients were then separated into two groups based on the day of the week they were admitted to the hospital as described. The effect of time to surgery was then re-evaluated using regression models. Results: A delay of greater than two days remained a statistically significant predictor of mortality with an odds ratio of 1.17 for 30-Day mortality (p-value 0.02) even after adjusting for patient severity. Using instrumental variables analysis based on the day of the week of admission (Saturday, Sunday, Monday versus Tuesday through Friday), we found a 15% increased risk of mortality in those delayed greater than two days. This finding was statistically significant (p-value 0.047). Conclusions: A delay of two days or more from the time of admission to surgical fixation of the hip fracture is associated with a statistically significant increase in the mortality rate even after adjusting for patient severity. This difference remained statistically significant even after using instrumental variables analysis. This suggests that a delay greater than two days independently affects mortality.

POSTER NO. P199

Locking Compression Plates for Delayed Unions and Nonunions of the Diaphyseal Humer

David Ring, MD, *Boston, MA (a – AO Foundation)*
Peter Kloen, MD, Amsterdam, Netherlands (n)
John Kadzielski, Boston, MA (n)
David Leonard Helfet, MD, New York, NY (d – Synthes-Stratec)
Jesse B Jupiter, MD, Weston, MA (b – AO Foundation)

Introduction: The operative treatment of nonunions and delayed unions of the diaphyseal humerus is often made more complex by poor bone quality that compromises the security of plate and screw fixation. Plates with screws that lock to the plate (transforming each screw into a fixed blade) are intended to improve the fixation of poor quality bone. Methods: Twenty-seven patients were followed for a minimum of 12 months after operative fixation of a delayed union or nonunion of the diaphyseal humerus with a 4.5-millimeter narrow locking compression plate. Eighteen had failed functional brace treatment, five intramedullary rod fixation, and four plate and screw fixation. The length of the plate averaged 10 holes. Twelve patients had iliac crest cancellous bone grafts, two had local graft, and 13 had demineralized bone applied to the fracture site. Results: Complications included two transient radial nerve palsies, two delayed unions requiring secondary iliac crest bone grafting (both had received demineralized bone), one iliac crest fracture, and one fracture above the plate treated operatively. All of the fractures eventually healed. There were no loose or broken implants. Using the Constant shoulder score, the results were good or excellent in twenty-four patients, and fair in three patients. Conclusions: Locking compression plates provide stable fixation of poor quality bone in patients with delayed union or nonunion of the humerus. Successful union and restoration of function are achieved in most patients. We no longer consider osteoporosis a contraindication to operative fixation of an ununited fracture of the humeral diaphysis.

POSTER NO. P200

The Magnetic Attraction of Lower Extremity External Fixators in a MRI Suite

Robert Cantu, MD, *Columbus, OH (n)*
Brian L Davison, MD, Columbus, OH (*)

PURPOSE: To determine the magnetic attraction of ten external fixators in the MRI suite. METHODS: Ten external fixators were attached to sawbones tibia. Each fixator component was screened with a hand-held magnet. The magnetic force was recorded in kilograms using a digital scale with each fixator positioned 30cm outside the MRI portal. Fixators with greater than 10 kg of force were not allowed closer to the magnet. All other fixators were tested in an identical fashion positioned even with the entry of the MR portal and 30cm inside the tube. RESULTS: None of the half-pins or transfixation wires are magnetic in our screening test. No component of the Synthes Large External Fixator, Richards Hex-Fix, and Carbon Fiber Ilizarov was magnetic. The pin /wire clamps were magnetic in the Hoffman II fixator, Hoffman II hybrid, and the Synthes hybrid fixator. The body of the 3 EBI fixators tested and the stainless steel Ilizarov rings were magnetic. The Synthes Large fixator and the Richards Hex-Fix had 0 Kg of magnetic force in all positions. The Carbon Fiber Ilizarov had 1Kg or less force. The EBI Hybrid and Hoffman II Hybrid had > 10KG of force 30cm outside the MRI Entrance. The EBI standard, EBI ankle clamp, Synthes Hybrid, and Hoffman II fixator had between 1 and 10 KG of force. CONCLUSIONS: Many external fixators experience significant magnetic attraction to the MRI scanner. A screening magnet is an acceptable means of determining which fixators are safe. The Synthes Large External Fixator, Richards Hex-Fix, and carbon Fiber Ilizarov are safe.

POSTER NO. P201

Simple Prediction of Avascular Necrosis After Femoral Neck Fracture

Dong-Kyu Shin, MD, *Taegu, Korea, Republic of (n)*
Sang Wook Lee, MD, Daegu, Korea, Republic of (n)
Chang Hyuk Choi, MD, Taegu, Korea, Republic of (n)
Sang-Bong Ko, MD, Daegu, Korea, Republic of (n)

INTRODUCTION: There is currently no reliable method determining the vascularity of the femoral head after femoral neck fracture. Authors developed simple perfusion assessment method. After inserting the cannulated screw to fix the neck fracture we checked the bleeding from the guide wire cannula of the screw head. The blood is from the head fragment and it means the intact blood supply to the femoral head. The purpose of this prospective study is to evaluate the prognostic usefulness of new perfusion assessment method on the development of avascular necrosis(AVN) after femoral neck fracture. METHODS: 46 patients with femoral neck fracture was fixed with 7.0mm cannulated hip screws after closed reduction. Two patients were lost to follow up before 2 years. Remaining 44 patients(24 men and 20 women) were followed for minimum 2 years and were included in this study. The mean age was 51 years (range, 18-76 years). According to Garden's classification, there were 11 Type I, 5 Type II , 17 Type III , and 11 Type IV fractures. All patients had a closed reduction under C-arm guidance. After acceptable reduction, 3 or 4 cannulated screw were inserted. Insertion of guide wire, drilling and tapping were done in usual manner. After the tip of the most proximal screw was passed about 1 cm over the fracture site, we removed the guide wire and observed the drainage of blood from the cannula of the screw head. Bleeding from the screw head, truely is from the femoral head was considered as intact blood supply to the head. Bleeding pattern was variable and sometimes it took 2 or 3 minutes. Patient without bleeding for five minutes was classified into the no bleeding group. At follow up, the development of AVN was evaluated with serial radiography. RESULTS: 38 patients had bleeding from the cannula of screw head and 6 patients had no bleeding. Seven of 44 patients developed AVN(16percent). Six of six patients without bleeding and one of the 38 patients with bleeding developed AVN. There were no infections or no nonunions. In all six cases of no bleeding within five minutes we performed anterior capsulotomy to decompress the joint cavity but none of them showed new bleeding. New perfusion assessment method had 86 percents of Sensitivity and 100percents of specificity for the development of the AVN. Positive and Negative Predictive values for AVN were 1.0 and 0.97 each other. DISCUSSION AND CONCLUSIONS: Although various methods have been described to predict the vascular status and AVN of the femoral head after femoral neck fracture, most of them has limitations such as unreliability, potential complication, technical difficulty and invasiveness. Authors developed new method assessing the perfusion status of femoral head after internal fixation of femoral neck fracture.. It had high sensitivity and specificity for the development of avascular necrosis of femoral head.

It doesn¡¯t need time consuming, invasive or expansive test. It dosen¡¯t need additional exposure. It can be performed easily immediately after internal fixation without any risk. Surgeon can accept the internal fixation or decide to select more suitable treatment modality such as arthroplasty in a case of aged patient. In conclusion, although it needs more large series and loger term follow study, our new perfusion assessment method was very simple, useful and reliable method for predicting the avascular necrosis of the femoral head after femoral neck fracture.

POSTER NO. P202

Toddler Fracture: Low-Energy Spiral Fracture of the Femur

Shannon David Safier, MD, *Philadelphia, PA (n)*
Rakesh Pravinkumar Mashru, MD, Philadelphia, PA (n)
Martin Joseph Herman, MD, Yardley, PA (n)
Peter D Pizzutillo, MD, Philadelphia, PA (n)

INTRODUCTION: The term "toddler fracture" describes a spiral fracture of the tibia that occurs in young children after walking age. This common injury results from low-energy mechanisms and rarely raises suspicion for intentional trauma. By contrast, a spiral fracture of the femur in young children is often regarded as either intentional or the result of high-energy trauma. The purpose of this study was to expand the traditional definition of the toddler fracture to include the spiral femur fracture occurring in the ambulatory toddler. We propose that low-energy mechanisms are the cause of spiral femur fractures in the majority of ambulatory toddlers and that fracture pattern reflects closely the mechanism of injury (high-energy vs. low-energy); child abuse is rarely associated with these injuries and its diagnosis must be made independent of fracture pattern. METHODS: A retrospective chart review of 35 consecutive ambulatory children under 5 years of age presenting to our institution between 1997 and 2002 with diaphyseal femur fractures was analyzed. Data collected included patient demographics, pre-existing medical conditions, mechanism of injury, fracture pattern, treatment, social services records and outcome. RESULTS: 35 children, average age of 2.6 years, presented with diaphyseal fractures of the femur. None had pre-existing medical conditions contributing to fracture risk. All fractures were closed injuries. Twenty-six spiral, 7 transverse, and 2 oblique fractures were identified. Twenty-five of 26 spiral fractures were the result of low-energy mechanisms (trip, fall, etc.). High-energy trauma (motor vehicle trauma, flight of stairs, etc) resulted in all of the transverse and oblique fractures. Investigation of intentional injury was initiated in only 3 cases based on history and physical findings at the time of initial presentation; 1 of these children, with a spiral fracture, was placed in foster care after evaluation (1/35 or 3%). All fractures were treated closed and placed in a 1 _ hip spica cast for 6-8 weeks. Five of 35 children required a single spica cast change during treatment for loss of alignment (3) and skin complications (2). At minimum follow-up of 6 months, all fractures had healed without sequelae. DISCUSSION AND CONCLUSION: Isolated spiral femur fractures in ambulatory toddlers are caused by low-energy trauma and are mostly accidental, analogous to the toddler fracture of the tibia. Transverse and oblique fracture patterns are more common in high-energy trauma. Overall, intentional trauma is rare in this age group and must be diagnosed on a case-by-case basis regardless of fracture pattern.

POSTER NO. P203

◆Multicentric Study on Effectiveness of Extracorporeal Shock Waves in the Treatment of Non-Unions

Olimpio Galasso, MD, *Naples, Italy (n)*
Sergio Gigliotti, MD, Naples, Italy (n)
Sergio Russo, Naples, Italy (n)
Ernesto Amelio, Verona, Italy (n)
Landino Cugola, Verona, Italy (n)
Ezio Maria Corrado, MD, Naples, Italy (n)

Twelve years have elapsed since the first report about the use of lithotripsy in the treatment of non-unions was published. The efficacy and fast effect have won them in Europe an extensive place in the management of non-unions. We here report a multicentric retrospective study on the treatment of bone pseudoarthroses by means of extracorporeal shock waves (ESW). Since 1995 a total amount of 764 non-unions have been treated and followed up. A mean of 1.8 surgical interventions had already been performed before ESW. The mean age of the pseudoarthroses was 13.8 months. An electromagnetic coil lithotriptor Modulith, SLK by Storz Medical AG was used. The protocol consisted of one cycle of 2 sittings for small bone pseudoarthroses and of 4 sittings for long bone pseudoarthroses.Nor general or local anesthesia were required. Bony healing (bridging of all four cortices in the X-rays or by tomography) was achieved in the 68 percent of patients. Femur and tibia non-unions showed a higher success rate (80 percent). Failures were more often found in atrophic and infected pseudoarthroses. No serious complications or adverse effects were observed.A recent meta-analysis of 61 papers supports the use of orthotripsy for fracture non-unions. Results let us to consider shock waves a non-invasive method with a good success rate, a great compliance of patient and a rate of complications lower than surgery.

POSTER NO. P204

The Development of a Clinical Decision Aid to Predict Re-Operations in Fractures of the Tibial Shaft

Sheila Sprague, BSc, *Hamilton, ON Canada (n)*
Mohit Bhandari, MD, Hamilton, ON Canada (n)
Diane Heels-Andsell, MSc, Hamilton, ON Canada (n)
Paul Tornetta III, MD, Boston, MA (n)
Emil H Schemitsch, MD, Toronto, ON Canada (n)
Marc F Swiontkowski, MD, Minneapolis, MN (*)
Gordon Guyatt, MD, Hamilton, ON Canada (*)

Introduction: Tibial shaft fractures are prone to devastating complications such as nonunions and infections, which both necessitate a re-operation. A prognostic clinical decision aid that predicts the need for re-operation would enable surgeons to identify high-risk patients. To date, there is no validated predictive scale to assist surgeons in defining the risk of complications in patients undergoing surgery for tibial shaft fractures. Methods: We developed a prognostic clinical decision aid for predicting re-operations in patients with tibial shaft fractures using a cohort of patients enrolled in a prospective, multi-center randomized controlled trial. We used bivariable and multivariable logistic regression analyses to determine if there was a relationship between each risk factor and re-operation. A risk scoring system was constructed. Results: We developed a scale with 4 independent risk factors for re-operation. The points assigned to each of the final four risk

factors in the clinical decision aid are: an open fracture (4 points); a fracture with cortical continuity of less than 50 percent following surgery (3 points); diabetes (3 points); and a comminuted fracture (2 points). We divided patients into three levels of risk. The risk of re-operation was 6.3 percent in the lowest risk group, 30.8 percent in the moderate risk group, and 57.6 percent in the highest risk group. Conclusion: This predictive instrument is the first to provide estimates of complication risk in low, moderate, and high-risk patients undergoing surgery for tibial shaft fractures. Future studies should aim to further validate this scale in other patient cohorts.

POSTER NO. P205

Biomechanical Analysis of Sliding in Keyed and Nonkeyed Compression Hip Screws

Gillian Eastwood, MRCS, *Great Manchester, United Kingdom (a,b – Smith&Nephew)*
Anthony William Miles, MD, Bath, United Kingdom (n)

INTRODUCTION : Compression hip screws are considered to be the gold standard for treatment of trochanteric proximal femoral fractures. Two implant designs exist; the 'keyed' and 'nonkeyed' barrel profiles. Many biomechanical studies have been published on the performance of sliding hip screws, but most have used only static testing, and none to our knowledge have sought to compare the two barrel profiles. This study aimed to compare the sliding characteristics of keyed and nonkeyed systems in both static and dynamic loading. METHOD : Tests were performed on the implants using a multi axis servo-hydraulic testing machine. The machine possessed both linear and torsional actuators, such that hip flexion/extension could be simulated during testing. Load to initiate sliding in both implants was measured in a variety of testing conditions; screw engagement in barrel (20-38mm), angle of hip flexion (0-40 degrees), perpendicular loading force (50-190N), and cycle frequency (0-1Hz). RESULTS : Results showed a tendency towards greater sliding in the nonkeyed system, although these were significant only for screw engagement testing ($p<0.001$). However, load to initiate sliding in both implants was significantly higher in dynamic as compared to static testing ($p<0.001$), and increased as torsional frequency increased. The nonkeyed system did not demonstrate any tendency for screw rotation within the barrel during dynamic testing. CONCLUSION : We conclude that the nonkeyed system does show a trend towards improved sliding characteristics, and does not display the tendency for screw rotation within the barrel under loading, often quoted as a misgiving of this implant. Also, since forces to initiate sliding are significantly higher when these implants are loaded dynamically (which mimics more closely the in vivo performance), future biomechanical studies should include dynamic testing for any hip fracture implant.

POSTER NO. P206

Anterior Curvature of the Femur: Consequences of its Mismatch with Current Intramedullary Nails

Kenneth A Egol, MD, *Jamaica, NY (n)*
Eric Chang, MD, New York, NY (n)
Kenneth J Koval, MD, New York, NY (n)
Fredrick J Kummer, PhD, New York, NY (n)

Introduction: We have recently encountered problems with anterior cortical penetration during antegrade insertion of intramedullary nails for the stabilization of hip fractures and hypothesize that this is due to a mismatch in curvature between these nails and the femur. Therefore, this study was performed to determine the curvature of 948 femurs and compare it to that of current intramedullary nails. The relation of femoral curvature to age, sex, femoral sizing and race was also analyzed. Methods: The curvature of 892 femurs from the skeletal collections of two museums was measured by processing the digital images of the femurs with a computer curve-fitting program. 56 additional, embalmed femurs from our collection were also digitally imaged and then x-rayed and their medullary curvatures similarly determined for comparison. Population demographics and femoral dimensions were also incorporated in the analysis. Curvatures of eight current, antegrade intramedullary nails were obtained from manufacturers and confirmed by measurements from their templates after digitization. Results: There was close correlation (r=. 975) between the femoral curvatures determined from the digital images and the x-rays. We found the average femoral anterior radius of curvature was 124cm (+/-36 cm). There was no effect of age on femoral curvature nor was there a relation between femoral width or length to curvature. Black donor femurs had a greater radius of curvature than white donor femurs ($p<0.001$). Radii of curvature of the intramedullary nails ranged from 150 to 300 cm (e.g. straighter than the femurs). Conclusions: The anterior curvature of the femur affects intramedullary nail insertion, revision prosthesis design and the biomechanics of the proximal femur. This study found a significant mismatch between the curvatures of current, antegrade intramedullary nails and a large number of femurs. Two previous studies, using smaller numbers of femurs, determined the radius of femoral curvature and also showed that it was significantly less than that of various intramedullary nails. Although the curvature of intramedullary nails is one factor effecting their insertion, current intramedullary nails are mismatched to average femoral curvature.

POSTER NO. P207

◆Cemented vs. Uncemented Hip Arthroplasty for Treatment of Osteoporotic Femoral Neck Fractures

Antonio Moroni, MD, *Bologna, Italy (n)*
Matteo Romagnoli, MD, Bologna, Italy (*)
Gian Luca Grandi, MD, Bologna, Italy (n)
Sandro Giannini, MD, Bologna, Italy (n)

INTRODUCTION: Hip arthroplasty is the standard treatment for elderly osteoporotic patients with displaced femoral neck fractures. Cemented implants are often preferred; however, lengthy intraoperative time and complications associated with the use of bone cement are ongoing surgical concerns. Further, the limited amount of cancellous bone found in the osteoporotic proximal femur may affect the long-term outcome of cemented fixation. We wanted to compare functional results and complication rates of cemented vs. uncemented hip arthroplasties in osteoporotic patients. METHODS: 40 consecutive patients with femoral neck fractures (AO B2 or B3) were randomized to receive either a Muller cemented or Furlong hydroxyapatite (HA)-coated implant. Inclusion criteria were: female, age *75, fracture resulting from minor trauma and bone mineral density (BMD) lower than -2.5 T score. RESULTS: There were no differences in patient age, ASA and intraoperative time. At 3 years, Harris Hip Score was 46±36 (group A) and 62±33 (group B) ($p<0.05$). SF-36 was 35±32 (group A) and 54±32 (group B). Subjective assessment was 5±4 (group A) and 7±3 (group B). Mortality during the follow-up period was 33% (group A) and 15% (group B) ($p<0.05$). At 3 years, x-rays showed radiolucent lines at the bone/cement interface (group A), but with the Furlong implants (group B), there was evidence of osteointegration and no radiolucency was seen. One cemented stem was revised. DISCUS-

SION AND CONCLUSION: Because of better functional results and lower mortality, we recommend HA-coated uncemented arthroplasty for treatment of osteoporotic femoral neck fractures.

POSTER NO. P208

First Generation of Computerized Fluoroscopic Navigation in Percutaneous Pelvic Surgery

Rami Mosheiff, MD, *Jerusalem, Israel (n)*
Amal Khoury, MD, Jerusalem, Israel (n)
Yoram Weill, MD, Jerusalem, Israel (n)
Meir Liebergall, MD, Jerusalem, Israel (*)

Purpose: To evalute the results of percutaneous pelvic and acetabular surgery using fluoroscopic navigation systemPatients and Methods: The "Stealth-Station" Treatment Guidance Platform by Medtronic was utilized in the percutaneous insertion of 45 cannulated screws, in 29 patients, including sacroiliac screws, pubic ramus screws, posterior column screws and a supra acetabular transverse screw. Preliminary fluoroscopic views are acquired when the operating team stands at a distance from the radiation source. The system enables a simultaneous display of these radiographic projections. No further fluoroscopic imaging is used later on during the surgical procedure, except for verification, when needed. Results: After a relatively short learning curve, the system's preparatory time, including reference arc placement and the acquisition of the initial pelvic images was 10 minutes in average. The number of acquired views for each guide wire insertion was determined, ranging from 2 to 4 images, for the different types of cannulated pelvic screws. We had no case of guide wire misplacement. Conclusions and significance: The use of fluoroscopic navigation system is very helpful in the special context of pelvic or acetabular fractures mainly due to their 3 dimensional complexities and the narrow "safe zones". The system reduces fluoroscopic radiation time, yet improves the precision of the procedure. We believe that the use of fluoroscopic navigation is adequate for a selected patients' population with pelvic fractures amenable to percutaneous screw fixation

POSTER NO. P209

Neuromuscular Electrical Stimulation Enhances Fracture Healing: Results of an Animal Model

Mauricio Silva, MD, *Los Angeles, CA (n)*
Sang-Hyun Park, PhD, Los Angeles, CA (n)

Introduction: Neuromuscular electrical stimulation (NMES) could simulate physiological muscle functions known to be associated with the normal bone healing process. This study evaluates the effect of NMES on fracture healing, using an animal model. Methods: Thirty rabbits received unilateral, transverse, mid-tibial, 3-mm gapped osteotomies that were stabilized with double-bar external fixators. The femoral vein was ligated to induce venous stasis. From the fourth postoperative day, the study group was treated with one hour daily of NMES for four weeks, while the control group was treated without NMES. Callus area and mineral content at the osteotomy gap were measured, biweekly, using computerized tomographic (pQCT) examinations. Biomechanical properties of healing were evaluated with a torsion test, eight weeks after the index operation. Results: Osteotomies treated with NMES exhibited 30.9 percent (p, 0.01) higher mineral content and 27.2 percent (p, 0.009) larger callus area than control osteotomies at 8 weeks. The maximum torque, torsional stiffness, angular displacement at maximum torque, and energy required to failure of specimens in the study group were 61.9 percent (p, 0.006), 29.3 percent (p, 0.03), 33.6 percent (p, 0.008), and 124.2 percent (p, 0.0001) higher, respectively, than those in the control group at 8 weeks. Discussion and Conclusion: The results of the present study demonstrated that the use of NMES can enhance callus development and mineralization, with the consequent improvement in biomechanical properties of the healing bone. The use of NMES could improve the bone healing process in patients with acute fractures, likely resulting in early rehabilitation.

POSTER NO. P210

Severe Skiing and Snowboarding Injury: Four-Year Results From the Colorado Trauma Registry

Bob Nguyen, MD, *Boston, MA (n)*
John C Richmond, MD, Boston, MA (n)
Holy Hedegaard, MD, Denver, CO (n)

Objectives: Describe the epidemiology of severe skiing and snowboarding injury. Describe the specific types of injury. Estimate the direct costs of treating these injuries. Methods: Data obtained from the Colorado Trauma Registry, that includes information on all hospitalizations and deaths due to injury. Results: Between 1998 and 2001, a total of 6294 injuries were identified, consisting of 5027 skiing and 1267 snowboarding injuries. Significant differences ($p < 0.001$) were found in the age, injury severity score (ISS) and average cost of treatment between the injured skier and the injured snowboarder. The average skier was aged 37, had an ISS of 11.3 and treatment of his injuries averaged $15,867. In contrast, the average snowboarder was aged 24, had an ISS of 9.8, and treatment of his injuries averaged $12,443. Both cohorts were predominantly male, accounting for 72% of skiers and 85% of snowboarders. Compared with females in the same sport, male skiers were 1.7 times and male snowboarders were 2.1 times more likely than females to be injured. Males were 1.6 times more likely to be injured skiing, while females were 3.35 times more likely to be injured skiing as compared to snowboarding. All of these relationships were statistically significant ($p < .05$). Skiers suffered 37.4% of their injuries in the lower extremity and 11.3% in the upper extremity, while snowboarders sustained 18.1% of their injuries in the lower extremity and 21.5% in the upper extremity. Spinal trauma was noted in 7.5% of skiing injuries and 10.1% of snowboarding injuries. Head injury accounted for 15.8% of snowboarders' injuries and 14.2% of skiers' injuries.There were eleven deaths in skiers and two in snowboarders, equivalent to 0.28 per million skier/snowboarder days. Eleven of thirteen deaths were associated with severe closed head injury. The incidence of skiing injury in 1998 was 6.6 per 100,000 skier-days and that for snowboarders 6.4 per 100,000 snowboarder-days. In 2001, skiing injury increased to 9.7 per 100,000 ($p < 0.001$) and snowboarding injury declined to 4.4 per 100,000 ($p < 0.001$). The difference in injury rate between skiing and snowboarding was also significantly different in 2001 ($p < 0.001$). Conclusions: In contrast to previous studies, we find that the incidence of skiing injury has increased, is higher than that of snowboarding injury, and is associated with a greater severity index and financial burden. Neurologic trauma is becoming more common as a result of increased risk-taking activity in more experienced skiers and snowboarders.

POSTER NO. P211

◆Bioresorbable Fillers Reduce Stress Risers From Screw Holes

John Alford, MD, *Chicago, IL (n)*
Paul Fadale, MD, Providence, RI (n)
Joseph Crisco, PhD, Providence, RI (n)
Douglas C Moore, MS, Providence, RI (n)
Michael G Ehrlich, MD, Providence, RI (n)

INTRODUCTION: Empty screw holes following hardware removal are stress risers that weaken bone and can cause refracture. We hypothesize that bioresorbable hole fillers will reduce these stress risers, providing immediate and lasting increased strength compared to bones with empty holes and allow for bone replacement. METHODS: Mid-diaphyseal holes in femurs of 75 Rabbits were filled with either a metal screw or a bioresorbable screw. An identical hole in the contralateral femur served as an empty control. At intervals of 12 hours, 1 week and 13 weeks, harvested femurs were torqued to failure. Failure properties and histology of the filled and empty bones were compared. RESULTS: A bioresorbable filler produced an immediate 30 percent increase (p=0.03) in maximum torque and 73 percent increase (p=0.009) in energy to failure. A metal screw produced a 17 percent increase (p=0.01) in maximum torque and a 58 percent increase (p=0.006) in energy to failure. At 1 week, resorbable and metal-filled femurs remained stronger: (energy for resorbable screws p= 0.05, energy for metal screws p= 0.003) than their contralateral empty controls. At three months, filled femurs and healed contralateral femurs had equal strength. There was no change in stiffness. Histology demonstrated bone replacement of resorbable fillers, without inflammation. DISCUSSION/CONCLUSION: Bioresorbable fillers immediately increase mechanical strength of bones with empty screw holes, and maintain that strength during bone replacement in a rabbit model. The higher peak load and total energy suggest a reduction in the likelihood of refracture following hardware removal.

POSTER NO. P212

Orthopaedic Traumatology from afar: Are the Commonly Used Forms of Digitized Radiographs Equal?

David C Markel, MD, *Southfield, MI*
(e – Howmedica Osteonics)
Ryan Beekman, MD, New York, NY (n)
Berton R Moed, MD, Saint Louis, MO (*)

Purpose: To compare the diagnostic accuracy of conventional analog radiographs with digital representations of the same radiographs for fracture detection, articular involvement, comminution, and treatment plan in acute trauma setting. Methods: Thirty acute orthopaedic trauma cases were selected at random from a Level I trauma center. Each case was digitized via three methods such that there were four subsets of thirty cases. Three Orthopaedic attendings and three senior Orthopaedic residents completed a detailed questionnaire about each fracture case, with subsets reviewed at thirty day intervals. Results: The fracture detection sensitivity was 99% for analog radiographs, 96% for digital photographs, 94% for scanned images, and 93% for eTrauma™ images. The differences between groups were not statistically significant (p<0.05) except for eTrauma™ images compared to original radiographs evaluated by resident physicians. The original radiographs were significantly different in their ability to show fracture comminution when compared to the eTrauma™ images. Intraobserver and interobserver reliability for all reviewers showed kappa values of greater than 0.40 for fracture detection, comminution, articular involvement, type of treatment, but not for assessment of image quality. All values were statistically significant. Significance: A wide variety of cost effective methods can be used to digitize analog radiographs with good diagnostic accuracy. However, digitized images are not a perfect representation of the originals in regards to fracture detection or treatment plan. The gold standard remains original radiographs, and our data supports their continued use when rendering final treatment decisions

POSTER NO. P213

Persistent Anterior Knee Pain Following Tibial Intra-medullary Nailing

Nasir Ali Quraishi, MRCS, *London, United Kingdom (n)*
Asif Chaudhury, MBBS, London, United Kingdom (n)
T O Boerger, Leeds, United Kingdom (n)

IntroductionWe assessed the prevalence of anterior knee pain after tibial intra-medulllary nailing. We compared the prevalence of anterior knee pain, sensory disturbance, pain on kneeling and the Lysholm knee score in patients who had their nails removed with those in whom the implant remained in situ. MethodsThis retrospective study assessed 60 patients who had tibial fractures treated using a locked AO nail at a district general hospital between 1990 and 1996 (minimum follow up was five years). Patients were asked to complete a questionnaire detailing anterior knee symptoms ResultsAt a mean follow up of 66.6 months, 32 patients with an average age of 51 years (range 26-88) had a tibial nail in situ. Sixty percent had anterior knee pain; 93.7 percent had anterior knee sensory disturbance; 96.8 percent had pain on kneeling; the average Lysholm knee score was 83.5. Twenty-eight patients out of 60 had their nail removed in an attempt to reduce knee pain. Of these 53.5 percent had persistent anterior knee pain; 89.2 percent had anterior sensory knee disturbance; 71.4 percent had pain on kneeling and the average Lysholm knee score was 84.4. DiscussionThe incidence of anterior knee pain and associated symptoms were found to be similar in the two groups. Metal removal did not facilitate the desired reduction of symptoms. Patients have to be informed of the high incidence of the above symptoms and of an almost fifty percent chance that anterior knee pain will persist when nail removal is contemplated.

POSTER NO. P214

Routine Removal of External Fixators without Anesthesia

Steven Ryder, MD, *Kogarah, NSW Australia (n)*
John T Gorczyca, MD, Rochester, NY (n)

Introduction: This study is performed to evaluate the discomfort experienced during routine removal of all external fixators without anesthesia, and to identify variables associated with increased discomfort during this procedure. Methods: Eighty-one external fixators were removed from 76 patients without anesthesia. Patients rated their discomfort on a visual analog scale. Patients were then asked, if they had to have the external fixator removed again, would they choose to have it performed without anesthesia.Site of fixator, diagnosis, presence of closed head injury (CHI), use of olive transfixion wires, presence of pin-site inflammation, and duration of external fixation were recorded. Results: The average visual analog pain scale score (VAS) was 3.6 out of 10. Patients with pin-site inflammation had a VAS of 4.82 (p = 0.007 with multiple regression). There was a trend toward a lower VAS for wrist spanning fixators and a higher VAS for knee spanning

fixators (2.8 vs 4.3, p = 0.110 with multiple regression). No significant correlation existed between presence of CHI, olive wires, duration of fixation and VAS. Seventy-two of 81 (89 percent) stated they would undergo fixator removal without anesthesia again. Twenty-six of 30 (87 percent) with pin-site inflammation stated they would undergo fixator removal without anesthesia again. Discussion and Conclusions: Routine removal of all external fixators without anesthesia is a well tolerated by the majority of patients. Pin-site inflammation is associated with a higher degree of discomfort during external fixator removal, but this is not a contraindication to performing this procedure without anesthesia.

POSTER NO. P215

The Influence of Bone Density on the Fixation Strength of Bicondylar Tibial Plateau Fractures

Ahmad Mohamad Ali, MD, *Essex, United Kingdom (n)*
Lang Yang, MD, Sheffield, Uzbekistan (*)
Richard Eastell, MD, Sheffield, United Kingdom (*)
Micheal Saleh, Sheffield, RD United Kingdom (*)

Our hypothesis is that the bone quality has different influence on the stability of fixation of tibial plateau fractures which is related to the fixation techniques. Objective: To assess the influence of bone density on the fixation strength of bicondylar tibial plateau fractures in two fixation methods. Method: Sixteen cadaver tibias were randomised into two groups to receive either dual plating or ring external fixation to stabilise a bicondylar tibial plateau fracture created with a standard method. The randomisation was stratified by BMD measured by DXA (above and below the mean). Cyclic axial compression tests were performed with increasing peak loads. Inter-fragmentary shear displacements were measured using four extensometers. Failure was defined as over 3mm displacement. Results: There was a strong correlation between failure load and BMD [r=0.81, P<0.001]. The mean failure load of the low BMD group (2701 N) was significantly less than that with the high BMD (4530 N) [t-test=0.003]. The failure loads of the two fixation groups were not significantly different (3520 N for the dual plating and 3710 N for the external fixation) [t-test=0.78]. BMD had a significant effect on the failure load in the dual plating group [t-test=0.03], but not in the external fixation group [t-test=0.1]. Discussion: Failure of fixation has been reported as a common complication of bicondylar tibial plateau fractures with a rate as high as 30%. Osteoporosis and poor bone quality are considered important contributory factors. In our study this influence was evident with plating, but not with ring fixation. Ring fixation may be the preferred method of fixation for tibial plateau fractures in the elderly and osteoporotic patients.

POSTER NO. P216

A Biomechanical Evaluation of Syndesmosis Screw Fixation in Weber C Ankle Injuries

Markku Nousiainen, MD, *Toronto, ON Canada (n)*
Alison McConnell, MSc Leng, Toronto, ON Canada (n)
Mohit Bhandari, MD, Hamilton, ON Canada (n)
Emil H Schemitsch, MD, Toronto, ON Canada (n)

INTRODUCTION: Syndesmosis screws are indicated in repairing Weber C ankle injuries if either the fibular fracture is more than 4.5 cm above the tibiotalar joint with an associated deltoid ligament tear or if rigid fixation of bimalleolar fractures cannot be obtained. This study examined the controversial issues of ankle position during screw insertion and the effect number of cortices of fixation has on ankle joint biomechanics. METHODS: Nine pairs of fresh frozen cadaver legs were stripped, preserving the ankle joint ligaments, capsule, and interosseus membrane. After baseline values for maximum ankle dorsiflexion, tibiofibular syndesmosis width, and tibiotalar rotation were obtained under a 700N axial load, a Weber C injury was simulated. A 3.5 mm fully threaded cancellous screw was inserted through 3 and then 4 cortices; the aforementioned measurements were repeated. Ankles were then externally rotated to failure to determine stiffness. Statistical analysis involved Wilcoxon and Mann-Whitney tests. RESULTS: Syndesmosis width, tibiotalar rotation, maximum ankle dorsiflexion, and failure stiffness were not significantly different between the groups which had either 3 or 4 cortices of fixation. Compared to intact specimens, syndesmosis width and tibiotalar rotation were significantly different when screws were inserted in either plantar- or dorsiflexion. CONCLUSION: Ankle joint biomechanics are altered depending on ankle position during screw insertion position but not number of cortices of purchase. Ankle joint range of motion is not affected by either.

POSTER NO. P217

The Effects of a Cyclooxygenase-2 Inhibitor on Fracture Healing in a Rat Model

Michael Herbenick, MD, *Dayton, OH (n)*
Dominic Sprott, MD, Dayton, OH (n)
Harold Stills, DVM, Fairborn, OH (n)
Matthew Lawless, MD, Dayton, OH (n)

Introduction Few studies have demonstrated the influence Cyclooxygenase-2 (COX-2) inhibitors have on fracture healing. Our objective was to determine if COX-2 inhibitors affect strength and amount of healing fracture callus. MethodsForty-eight rats underwent retrograde intramedullary femoral pin placement and closed fracture. The control group received food without celecoxib and the study group received approximately 5 milligrams per kilogram of celecoxib ground and sprinkled into the rats' daily feed. Six rats from both control and study groups were randomly sacrificed at 2, 4, 8, and 12 week intervals. The femurs were removed, dissected free of soft tissues, and callus length and width measured. A three-point bending technique was applied until the femurs failed. Both the elliptical callus area and the load to failure were recorded for the control and treatment groups. ResultsThere was no significant statistical difference between the control and study groups with regards to callus size. However, there was significant statistical difference between the control and study groups with regards to the amount of force required for femoral refracture (p equals 0.0199). DiscussionMany anti-inflammatories have been shown to impair fracture healing. COX-2 inhibitors are becoming more commonly used for acute pain. However, the effects of these medications on fracture healing have not been adequately studied. This study shows a significant decrease in callus strength with the use of celecoxib. Therefore, we would not recommend routine use of celecoxib in post-fracture pain control.

POSTER NO. P218

Subchondral Insufficiency Fracture of the Femoral Head

Takuaki Yamamoto, MD, *Fukuoka, Japan (n)*
Peter G Bullough, MD, New York, NY (n)
Yukihide Iwamoto, MD, Fukuoka, Japan (n)

INTRODUCTION: Subchondral insufficiency fracture of the femoral head (SIF) is a recently proposed concept, which needs to be differentiated from osteonecrosis. The purpose of this study is to document its clinicopathological appearance and

frequency. MATERIALS AND METHODS: A retrospective review of 464 consecutively removed femoral heads (from 419 patients) with both radiologic and histologic evidence of subchondral collapse was performed both radiologically and histopathologically. RESULTS: Ten cases previously diagnosed as osteonecrosis of the femoral head were histopathologically re-interpreted as SIF. All these cases were osteopenic females over 65 years old (average age 75). Initial symptom was acute onset of hip pain. Radiologically, at the onset of hip pain no obvious changes were seen, however, a subchondral collapse was subsequently noted mainly in the superolateral segment of the femoral head. Magnetic resonance imaging showed a diffuse low intensity on T1 weighted images and high intensity on T2 or on fat-suppression (bone marrow edema pattern). In addition, one of the most characteristic radiologic findings was a low intensity irregular-shaped band on T1 weighted image, which histologically corresponds to the fracture line. Bone scintigram, available in 4 cases, showed increased uptake in the femoral head. Histopathologically, fracture callus and granulation tissue were found beneath the subchondral bone end plate. There was no evidence of osteonecrosis. DISCUSSION: SIF should be included in the differential diagnosis of acute onset of coxarthrosis, especially in the elderly female.

POSTER NO. P219

One Lag Screw or Two Lag Screws for Optimal Fixation of Unstable Intertrochanteric Femur Fractures

Erik Kubiak, MD, *Brooklyn, NY (n)*
Samuel Sanghong Park, MD, New York, NY (n)
Kenneth A Egol, MD, Jamaica, NY (*)
Matthew R Bong, MD, New York, NY (n)
Fredrick J Kummer, PhD, New York, NY (n)
Kenneth J Koval, MD, New York, NY (n)

Introduction: To compare the stability and lag screw sliding characteristics of intramedullary hip screws with either one large diameter lag screw (IMHS; Smith and Nephew, Memphis, TN) or two small diameter lag screws (TAN; Smith and Nephew, Memphis, TN) in an unstable intertrochanteric fracture model. Methods: Eight matched pairs of osteopenic cadaveric human femurs were stabilized with either a distally locked IMHS intramedullary hip screw or a TAN intramedullary hip screw. Each specimen was statically loaded from 500N to 1250N then cyclically loaded at 1250N for 10, 100, 1000, and 10000 cycles. Lag screw sliding, lateral and inferior head displacements were obtained at each test interval. All specimens were then loaded to failure. Results: There was no significant difference between the TAN and IMHS after static or cyclical loading with respect to screw(s) sliding or inferior and lateral head displacements. The IMHS constructs failed at an average of 2247N and the TAN constructs failed at an average of 3237N (P less than 0.05). Discussion: Both implants provide similar stabilization of intertrochanteric proximal femur fractures. There was no lateral migration of the proximal fragment as evidenced by the lack of screw sliding and lateral displacement of the proximal femur which maintains the normal biomechanics of the proximal femur. The two screw construct demonstrates improved fixation of the femoral head as evidenced by its higher ultimate failure strength.

POSTER NO. P220

Money Talks: Pro-Industry Results in Medical and Surgical Randomized Trials

Mohit Bhandari, MD, *Hamilton, ON Canada (n)*
Jason W Busse, MSc, Hamilton, ON Canada (n)
Victor M Montori, MD, Hamilton, ON Canada (n)
Holger Schunemann, MD, Hamilton, ON United Kingdom (n)
Dianne Jackowski, BSc, London, ON Canada (n)
Sheila Sprague, BSc, Hamilton, ON Canada (n)
Emil H Schemitsch, MD, Toronto, ON Canada (n)
PJ Devereaux, MD,MSc, Hamilton, ON Canada (*)

INTRODUCTION: Academics are debating if industry-funding influences research findings and conclusions. We evaluated whether reported industry funding in surgical trials predicted authors' conclusions among a consecutive series of medical and surgical trials. METHODS: We included randomized controlled trials published between January 1999 and June 2001 in eight leading surgical journals. We abstracted the following reported data from eligible trials: funding sources (industry-for profit, not for profit, undeclared), statistical significance of outcome measures, study quality scores, sample size, whether a priori sample size calculations were conducted, and type of intervention. RESULTS: We identified 332 randomized trials. Quality scores for surgical trials were significantly lower than those for drug trials or non-surgical trials. In 37 percent of trials, authors declared industry funding. Drug trials were significantly more likely to have declared industry funding than surgical or non-surgical trials. Of all trials declaring industry funding, over 60 percent favored the new treatment or industry product. An unadjusted analysis of the current sample of trials revealed that industry funding was significantly associated with a statistically significant result in favor of the new industry product. Adjusting for sample size, study quality and type of intervention, those trials reporting industry funding remained significantly more likely to have a statistically significant pro-industry result. Surgical trials were 5 times more likely to conclude a pro-industry result than drug trials. DISCUSSION: In a review of 332 randomized trials in surgery and medicine, authors' declaration of industry funding was significantly associated with pro-industry results.

POSTER NO. P221

Tibial Pilon Fractures Treated via Posterolateral Approach

Renn J Crichlow, MD, *Boston, MA (n)*
Reuben Gobezie, MD, Boston, MA (*)
Brent Ponce, MD, Mission Hill, MA (n)
Mark S Vrahas, MD, Boston, MA (a – Synthes)

Introduction: Historically complication rates associated with operative fixation of tibial pilon fractures range from 30-70 percent. OTA type C fractures are associated with the highest rate of complications. Our novel solution to these problems has been to treat these fractures via a posterior approach to the tibial diaphysis. This approach was felt to offer a more robust soft tissue envelope, which may decrease soft tissue complications. Methods: results from twenty-four patients collected over a 2-year period are reviewed. Data was collected from patient charts and radiographs obtained at follow up visits. Results: the predominant mechanism of injury was fall or MVC. According to the OTA/AO classification, there were 11 type A, 2 type B, 11 type C injuries, 7 were open fractures. Thirteen of 24 patients had

an uncomplicated post op course. There were 2 with delayed union with union by 6 months. There were 3 non-unions treated with revision ORIF and ICBG. There were 3 deep infections that required re-operation, 1 required a free tissue transfer for coverage. Postoperative radiographs revealed that 22 of 24 patients had articular surface step off of less than 2mm. Major complications (skin slough, wound dehiscence, infection, nonunion, malunion or implant failure) occurred in 8 of the 24 patients. Two patients required tibiotalar fusion. Conclusion: these results compare favorably with other series in the literature. This series demonstrates a novel approach to treatment of tibial pilon fractures that offers advantages over conventional approaches with regard to soft tissue and wound complications.

POSTER NO. P222

Tibial Non-Union Treated via Posterolateral Approach and Plate Fixation

Renn J Crichlow, MD, *Boston, MA (n)*
Brent Ponce, MD, Mission Hill, MA (n)
Reuben Gobezie, MD, Boston, MA (*)
Mark S Vrahas, MD, Boston, MA (a – Synthes)

Background: historically, postero-lateral bone grafting alone, compression plating, and exchange rodding have been used for treatment of tibial non-unions. These methods are less effective in treatment of atrophic non-unions and high-energy metaphyseal fractures. Our novel solution to these problems has been to treat these non-unions via a posterior approach, application of bone graft and plate fixation. This approach was felt to offer the advantage of a larger, more robust soft tissue envelope, rigid internal fixation and greater surface area to apply bone graft material. Methods: Results from twenty patients collected over a 2-year period are reviewed. Charts and follow up radiographs were evaluated. Union was defined as bridging trabeculae on two orthogonal radiographs. Results: 16 of 20 patients presented with aseptic non-unions, 4 were septic non-unions; none had segmental bone loss. Fall was the predominant mechanism of injury. The average time to index procedure was 12 months. Autogenous bone graft was used in 16 of 20 patients, allogeneic bone graft in 4 of 20. Average f/u was 10.5 months. There were 2 persistent non-unions, and 4 delayed unions in the 20. There was 1 persistent deep infection. Radiographic evaluation revealed malalignment of greater than 5 degrees in 3 of 20 patients. There was 1 revision. There were no wound complications requiring antibiotics. Conclusion: these results compare favorably with other series in the literature. This series demonstrates a treatment strategy that offers advantages over conventional approaches with regard to soft tissue and wound complications.

POSTER NO. P223

Predicting the Need for Surgery after Isolated Fibular Fracture Using the Ankle Stress Test

Samuel Sanghong Park, MD, *New York, NY (n)*
Erik Kubiak, MD, Brooklyn, NY (n)
Kenneth A Egol, MD, Jamaica, NY (n)
Rudi Hiebert, MA, New York, NY (*)
Fredrick J Kummer, PhD, New York, NY (n)
Yossef C Blum, MD, Bronx, NY (*)
Kenneth J Koval, MD, New York, NY (n)

Introduction: This cadaveric study sought to determine: (1) how ankle position affects the medial clear space (MCS) in stress radiographs; (2) which MCS measurement, absolute width or increase in width, better predicts deep deltoid ligament disruption after distal fibular fracture; and (3) what value of MCS measurement is most predictive. Methods: Fluoroscopic mortise views were taken of six fresh cadaveric ankles mounted in a fixture permitting both positioning in neutral flexion, dorsiflexion, and plantarflexion, and application of controlled internal and external rotational stresses. Ankles were then destabilized according to the supination-external rotation mechanism of Lauge-Hansen. During each destabilization stage, images were taken in the same combination of flexion and rotation. The absolute MCS and changes in MCS were determined. Results: Absolute MCS of 5mm or more on radiographs taken in dorsiflexion with stress applied in external rotation was the criteria most predictive of deep deltoid ligament transection after distal fibular fracture. In dorsiflexion-external rotation, absolute MCS of 4mm or more yielded lower specificity and positive predictive value, while 6mm or more yielded lower sensitivity and negative predictive value. All other stress conditions and use of increases in MCS of 2 or 3mm were less predictive. Discussion/Conclusion: Ankle stress radiographs should be taken in dorsiflexion-external rotation, the condition most predictive of deep deltoid ligament disruption after distal fibular fracture. In dorsiflexion-external rotation, absolute MCS of 5mm or more was more reliable than 4 or 6mm, as well as increases in MCS of 2 or 3mm, in predicting deep deltoid ligament status.

POSTER NO. P224

Cervical Spine Alignment in the Soldier: Before and After Helmet Removal

Michael Sean Hooker, MD, *Kaneohe, HI (n)*
Michael Wirt, MD, Kaneohe, HI (n)
Zac Fisher, MS, Kaneohe, HI (n)
Alex Freitas, MD, Kaneohe, HI (n)
David Mark Christensen, MD, San Antonio, TX (n)

Introduction: Civilian and military trauma protocols recommend immobilization without helmet removal. The current guidelines are based on studies in helmeted athletes. Our study evaluates the effects of the Kevlar protective helmet on the cervical spine in immobilized soldiers. Methods: The amount of cervical spine flexion was measured from scout computer tomograms of 10 male and 10 female soldiers immobilized to a spine board in four test conditions: 1) no protective equipment (control), 2) no protective equipment and 15 pounds of axial traction applied to each wrist 3) Kevlar helmet, 4) Kevlar helmet and shoulders supported by a _ inch "neutralization" pad. Results: Kevlar helmets caused an increase in cervical spine flexion for both men and women. A Kevlar protective helmet in conjunction with a neutralization pad created differences between males and females with increased flexion in the cervical spine of women (4.47 degrees) and increased extension (-1.72 degrees)in the cervical spine of men. Discussion: This is the first study evaluating the alignment of the cervical spine in helmeted trauma victims other than in male contact sports participants. This is also the first study to compare the effects of helmets on women to men.

POSTER NO. P225

The Accuracy of Fine Wire Tensioners for Hybrid and Ring External Fixation

Craig S Roberts, MD, *Louisville, KY*
(a – Stryker Howmedica Osteonics, Smith&Nephew)
Valentin Antoci, Sr, MD, Louisville, KY (*)
Valentine Antoci, Jr, Philadelphia, PA (n)
Michael J Voor, PhD, Louisville, KY (n)

Introduction: The tension achieved on a transfixation wire used in hybrid and ring external fixation is based on the accuracy of the tensioner. The purpose of our study was to compare the accuracy of five commerically available fine wire tensioners used in hybrid and ring external fixation. Methods: We performed calibration tests using a servo-hydraulic test frame (MTS Bionix 858, Minneapolis, MN, USA) with an axial-torsional load transducer with an axial capacity of 25,000 N and a torsional capacity of 250 N-m (MTS Model 862.10A-05, Minneapolis, MN). The Ilizarov tensioner (Smith and Nephew, Memphis, TN), the EBI DynaFix tensioner (EBI Medical Systems, Parsippany, NJ), Synthes hybrid tensioner (Synthes USA, Paoli, PA), Hoffmann II hybrid tensioner (Howmedica Stryker, Rutherford, NJ), and the Ace-Fischer external fixator tensioner (DePuyACE Medical Company, El Segundo, CA) were tested. Results: The EBI tensioner was the most accurate (minus 0.17 percent to plus 0.09 percent error). The Smith and Nephew tensioner had a minus 13.97 percent to minus 8.61 percent error, the Howmedica tensioner had a minus 12.48 percent to minus 10.86 percent error, the Synthes tensioner had a minus 0.2 percent to plus 24.28 percent error, and the DePuyACE tensioner had errors ranging from minus 36.76 percent to minus 30.92 percent. Discussion and Conclusion: Most of the tensioners that we tested undertensioned compared to their calibration markings. Surgeons need to use their own discretion when tensioning wires, and not the markings on the tensioner.

POSTER NO. P226

Inter- & Intra-Observer Variation of Garden's and Pauwels' Classification Systems

Panayiotis J Papagelopoulos, MD, *Athens, Greece (n)*
Petros J Boscainos, MD, Athens Attiki, Greece (n)
Nicolaos Gandaifis, Athens Attiki, Greece (n)
Dimitrios Kostopoulos, MD, Kifissia, Greece (n)
Konstantinos Nikolopoulos, MD, Kifissia, Greece (n)

Several classifications systems of femoral neck fractures have been applied in clinical practice to enable decision making on choice of treatment and for research purposes on fracture morphology and comparison on the outcome among different therapeutic modalities. We assessed the reliability of the most common classification systems for femoral neck fractures: Garden's and Pauwels' classification.Unlabelled AP radiographs of 135 randomly selected patients with non-pathological femoral neck fractures were assessed by four observers (two orthopaedic consultants and two orthopaedic residents) according to Garden's and Pauwels classification. After three months, the set of radiographs was reassessed by the same observers. All 4 observers agreed on Garden classification for 18 fractures (13.33%) and on Pauwels classification on 26 fractures (19.26%), although there was better overall agreement for Garden classification (Kendall's W=0.2). Inter-observer agreement was poor for both classifications (Kappa coefficient < 0.40). Assessing Garden's classification as non-displaced (type I and II) and displaced (type III and IV) provided fair agreement among observers (Kappa coefficient > 0.40).There is poor agreement on the Garden's and Pauwels' classification systems among observers. Garden's classification modified as displaced and non-displaced provides better reliability for assessing femoral neck fractures. Intra-observer variation is smaller than inter-observer variation.

POSTER NO. P227

Effect of Positioning on Pulmonary Pathophysiology in Fat Embolism in a Canine Model of Trauma

Khalid Syed, MD, *Toronto, ON Canada (n)*
Michael Blankstein, Toronto, ON Canada (*)
Masaki Nakane, MD, FRCP, Toronto, ON Canada (*)
Mohit Bhandari, MD, Hamilton, ON Canada (*)
Emil H Schemitsch, MD, Toronto, ON Canada (n)

Introduction: For femoral nailing, patients may be positioned supine or in lateral decubitus. The purpose of this study was to determine the effect of positioning on pulmonary pathophysiology associated with fat embolism during intramedullary nailing. Methods: Twelve dogs were randomly assigned for supine or lateral positioning and parameters including airway pressures, heart rate, blood pressure, cardiac output, pulmonary artery pressure, wedge pressure, right atrial pressure and blood gases were measured. The dogs were then subjected to pulmonary contusion and fat embolism by reaming and pressurization of the intramedullary canal. The dogs were euthanized and samples were taken from both lungs. Changes in relative blood flow between the contused and uncontused lungs were also studied by injection of colored microspheres during the experiment. Results: Two-way ANOVA showed no significant difference in the measured parameters between supine and lateral positioning. Arterial blood pressure, right atrial pressure, wedge pressure and the drop in blood pressure were all higher while the drop in cardiac output was lower in the supine dogs. The blood flow to the contused lung increased in the lateral position after pulmonary contusion and fat embolism. None of these were statistically significant (P<0.05). Conclusion: This study shows that positioning produces no difference in the physiologic changes that accompany fat embolism during reamed intramedullary nailing of long bone fractures. Hence, the positioning of a trauma patient undergoing reamed intramedullary nailing should not be based on concern for the severity of fat embolism that may accompany it.

POSTER NO. P228

The Effect of Sacral Fracture Malreduction on the Initial Strength of Iliosacral Screw Fixation

Kathleen Beebe, MD, *West Orange, NJ (a – AO North American Resident Trauma Research Grant)*
Mark C Reilly, MD, Newark, NJ (a – AO Foundation)
Regis Renard, MS, Newark, NJ (a – AO Resident Research Grant)
Chris Sabatino, MS, Newark, NJ (n)
Michael Saul Sirkin, MD, Newark, NJ (n)
Michael David Stover, MD, Maywood, IL (n)
Fred F Behrens, MD, Newark, NJ (n)

Introduction: It has been previously demonstrated that the area of fracture interdigitation is significantly affected by sacral fracture malreduction. It is our hypothesis that internal fixation of sacral fractures in a malreduced position will lead to a decrease in the strength of iliosacral screw fixation, due to the limitation

of fracture bony contact. Methods: Six cadaveric pelves were cleared of all extraneous soft tissues. Dual energy x-ray absorptiometry (DEXA) was performed on all pelves and the pelves divided into 2 groups of roughly equivalent bone density. The intact stiffness of each pelvis was determined using a MTS servohydrolic test machine. Osteotomies were performed on one side of each pelvis through the sacral foramina with separation of the pubic symphysis. Fixation with 2 partially threaded 7.3 cannulated screws was performed with 3 pelves reduced anatomically and 3 pelves malreduced cranially by 1cm. Sagittal CT scanning was performed to allow for calculation of the cross sectional overlap at each fracture site. The pelves were retested using the MTS machine and load verses displacement curves were generated and compared to intact stiffness. Results: The pelves that were anatomically reduced had a 46.7 plus or minus 7.3 percent return to intact stiffness while the pelves fixed at 1 cm of vertical displacement returned to 28.2 plus or minus 8.9 percent of the initial intact stiffness (p = .0494). Linear regression analysis demonstrated a statistically significant association between cross sectional area and final stiffness of the internally fixed fractures (R2 = 0.920 and p = 0.0024)Conclusions: This study demonstrates that cranial malreduction of transforaminal sacral fractures, in a cadaveric fracture model, results in reduced final stiffness of iliosacral fixation.

POSTER NO. P229

◆Volar vs Dorsal Fixation for Comminuted Distal Radius Fractures: Effects of Plate Type on Stability

Frank Liporace, MD, *New York, NY (n)*
Salil Gupta, MD, Brooklyn, NY (*)
Kenneth A Egol, MD, Jamaica, NY (n)
Kenneth J Koval, MD, New York, NY (*)
Fredrick J Kummer, PhD, New York, NY (n)
Martin A Posner, MD, New York, NY (n)

Stability of distal radius fractures fixed by standard dorsal or volar locked plating was compared. The hypothesis was that volar locked plating would be as stable as dorsal plating after cyclic loading. Dorsal wedges were removed from six pairs of radii to simulate comminuted distal radius fractures. Specimens were fixed with a dorsal distal radius plate or a volar locked plate and loaded at five points (volar, dorsal, radial, ulna, central), vertically at 1N/s (max 90N) on the articular surface, generating load-displacement curves. They were then subjected to 5,000 cycles of an 80N load centrally. Then reloading, in an identical manner to initial testing, was done to obtain post-cyclic load-displacement curves. Stiffness for each trial was compared before and after cycling (p-value < 0.05). Initially, locked volar plating was 50 to 200% stiffer than dorsal plating in each loading condition except dorsal. Volar plating was stiffer than dorsal plating in ulnar and volar loading. After cycling, locked volar plating was stiffer for all loading points except dorsal. Stiffness of dorsal plating decreased for ulna, volar, and dorsal loading after cycling. Volar plate fixation stiffness was not reduced after cyclic loading. Conclusions: Fixed-angle volar plates provided greater stability of simulated distal radius fractures under physiologic cyclic loads in all but the dorsal direction. Dorsal plates lost fixation stability after cyclic loading while volar locked plates maintained their stiffness. This may suggest that early active range of motion can be done in patients fixed with a locked volar plate.

POSTER NO. P230

◆Locking-screw DHS and Retrograde IM Nailing in the Treatment of Femoral Neck and Shaft Fractures

Mark Wesley Hanna, MD, *Atlanta, GA (n)*
John G Vachtsevanos, MD, Gainesville, GA (n)
George E Wright, MD, Atlanta, GA (n)
William C Hutton, DSC, Decatur, GA (*)

Background: A dynamic hip screw (DHS) and retrograde nail can be used for fixation of ipsilateral femoral neck and shaft fractures. Bicortical DHS side plate screws prevent the use of a full-length retrograde nail which theoretically weakens the construct. Unicortical locking side plate screws may offer a solution. We performed a biomechanical study comparing DHS's fixed with four unicortical locking screws to those fixed with two conventional bicortical screws. Methods: Twenty-eight composite femurs with base of neck osteotomies were instrumented with a retrograde nail and either a DHS with two bicortical side plate screws (standard group) or a newly designed DHS with four unicortical locking side plate screws (locked group). The nail was 6 cm longer in the locked group. Sixteen femurs were ramp loaded (part I) and twelve underwent cyclic loading (part II). The peak load to failure and number of cycles to failure were recorded, respectively. The mode of failure was also noted. Results: The locked group withstood 245 N greater average peak load in part I (p=0.03) and an average of 578152 more cycles to failure in part II (p=0.02). Fractures occurred in 14/14 standard femurs and 6/14 locked femurs. Discussion and Conclusion: The locked group showed improved resistance to ramp loading and cyclic loading, as well as improved resistance to fracture. The combination of a DHS with four unicortical locking screws and a full-length retrograde nail is a potential alternative in the fixation of ipsilateral femoral base of neck and shaft fractures.

POSTER NO. P231

Biomechanical Evaluation of Plates Used for the Internal Fixation of Distal Femur Fractures

Daniel R Schlatterer, DO, *Buffalo, NY (n)*
Lawrence B Bone, MD, Buffalo, NY (*)
Jorge Bustillo, MD, Mars, PA (*)
John Medige, PhD, Buffalo, NY (*)
Craig Howard, Buffalo, NY (*)
William Michael Mihalko, MD, Clarence Center, NY (*)

Introduction: Internal fixation of distal femur fractures has been accepted over non-operative treatment, yet the choice of implant is still debated. Stabilization of any fracture contributes to fracture union, early pain-free weight bearing, and optimal patient outcome. Newer implants have been designed to provide increased stability relative to those products currently in use. The purpose of this study was to compare an eight-hole dynamic condylar screw (DCS), a less invasive stabilization system (LISS), a condylar buttress plate (CBP), a peri-lock plate (PLP), and a locking condylar plate (LCP) in axial and torsional loads. Methods: Each plate was mounted on synthetic composite femur bones using standard implantation techniques. A 1 centimeter supracondylar gap osteotomy was created 6 cm proximal to the femoral condyles. Displacement transducers were attached adjacent to the osteotomy. Axial and rotational displacements were tested independently on a material testing system and a torsional testing system. Maximum axial loads were 700 Newtons, and rotational torques reached 22 Newton meters. Results: Axial stiffness was greatest for the DCS and least for the PLP. The CBP demonstrated the greatest torsional strength. The DCS, LISS and

the LCP were similar in torsion, and the PLP was the least resistive to torsion. Conclusions: The mechanical stiffness of 5 commercially available plates for supracondylar femur fractures is not uniform. Newer plates, however, with multiple distal screw holes and locking mechanisms between the plate and screws, do compare favorably with the DCS plate. Supracondylar femur fractures stabilized by any of these tested implants must continue to be protected from weight bearing until clinical and radiographic signs of bony union.

POSTER NO. P232

Ulnar Nerve Complications Following ORIF of Distal Humerus Fractures

Scott David Burgess, MD, *Durham, NC (n)*
Terry M Messer, MD, Raleigh, NC (n)
Laurence E Dahners, MD, Chapel Hill, NC (n)

The literature regarding ulnar nerve complications following open reduction and internal fixation of intra- and extra-articular distal humerus fractures is limited. The question of whether or not to transpose the ulnar nerve acutely remains unanswered. The present study is a retrospective comparison of patients with distal humerus fractures treated with ORIF with and without transposition of the ulnar nerve. Fifty patients from two centers received operative treatment for distal humerus fractures between December 1998 and December 2001. Twenty-four patients underwent ulnar nerve transposition at the time of the original surgery and 26 did not. Two patients in the transposed group and 3 of those not transposed had pre-operative ulnar nerve symptoms. Although the two groups were different with regard to age and number of open injuries (greater in those undergoing transposition), the incidence of post-operative ulnar neuropraxia was the same. Ten patients, five in each group, had post-operative ulnar nerve complaints at their last clinic follow-up. Of those with ulnar neuropraxia, eight had no documented pre-operative symptoms. Two patients not originally transposed later underwent ulnar nerve transposition with improvement of symptoms. This study, although retrospective, suggests that the incidence of ulnar neuropraxia following ORIF of distal humerus fractures is high and may not be affected by ulnar nerve transposition at the time of original surgery.

POSTER NO. P233

Pin Tract Infection with Contemporary External Fixation: How Much of a Problem?

Craig S Roberts, MD, *Louisville, KY*
(a – Stryker Howmedica Osteonics, Smith&Nephew)
Angelo D Parameswaran, BA, Louisville, KY (*)
David Seligson, MD, Louisville, KY (a – Smith&Nephew, b – Stryker)
Michael J Voor, PhD, Louisville, KY (n)

Introduction: Pin tract infection is the major complication of the external fixation of fractures. The purpose of our study was to assess the incidence of pin tract infection with external fixation using contemporary techniques. Methods: After IRB approval was obtained, a patient registry database was used to generate a list of 585 patients placed in external fixation at a level one trauma center of which 285 were available for this study. Results: The mean age for all 285 patients was 42.5 years of age (range, 14 to 87), with no significant difference in age or follow-up among the three groups. The mean follow-up was 6.3 months (range, 5.4 to 11.1 months). There were 102 upper extremity fixators, 153 lower extremity fixators, and 30 pelvic fixators. Thirty-two of 285 fractures (11.2 percent) were complicated by infection. The incidence of infection according to montage was 3.9 percent (3 of 77) for ring fixators which was significantly different (p less than 0.04) from the 12.9 percent incidence (23 of 178) for unilateral fixators and the 20.0 percent incidence (6 of 30) for hybrid fixators (p equals 0.004). The incidences of pin tract infection for the unilateral fixator group and the hybrid fixator group were not significantly different. Discussion and Conclusion: Patients with hybrid external fixators had a similar risk of pin tract infection as those who had unilateral fixators. Despite contemporary techniques, pin tract infection after external fixation remains a challenging problem.

POSTER NO. P234

General Health Status Recovery During the First Two Years Following High Energy Tibial Plafond

Geoffrey F Haft, MD, *Iowa City, IA (a – EBI Medical)*
John Lawrence Marsh, MD, Iowa City, IA (a – EBI Medical)
Todd Owen McKinley, MD, Iowa City, IA (a – EBI Medical)
James V Nepola, MD, Iowa City, IA (*)
Douglas R Dirschl, MD, Chapel Hill, NC (*)

Background: The rate at which patients recover their general health status following high energy tibial plateau fractures has not been systematically examined. Methods: 24 patients with high energy tibial plafond fractures treated with external fixation, percutaneous reduction, and limited internal fixation completed prospective follow-up at six time points in the 2 years after injury. At each visit, a general health status instrument, the SF-36, and a joint specific instrument, the Ankle Osteoarthritis Scale (AOS), were administered. Results: The average mental component summary (MCS) and physical component summary (PCS) of the SF-36 both showed statistically significant increases between 1 month and 1 year ($p<.05$). Between 1 and 2 years, there were small non-significant gains in both PCS and MCS. While the PCS remained greater than 1 SD below norms at all time points, the MCS stayed at or above norms from 3 months to 2 years. At all times, average AOS scores remained consistently greater than 1 SD below controls. Conclusion: Patient reported outcomes indicate stagnant improvement in physical function after 1 year. The fact that most patients had normal SF-36 MCS scores by 2 years while their PCS and AOS scores remained low suggests that many patients have adapted their lives to their injury despite some continued pain and loss of function in their ankle.

POSTER NO. P235

Fluoro Navigation vs. Triplanar Fluoroscopy for Percutaneous Iliosacral Screw Insertion

Cory Alan Collinge, MD, *Fort Worth, TX (*)*
David A Coons, DO, Irving, TX (*)
Paul Tornetta III, MD, Boston, MA (n)
John Aschenbrenner, Fort Worth, TX (n)

Introduction: Percutaneous iliosacral screw [IS] fixation using standard triplanar fluoroscopic [STF] imaging is commonly used to treat complex pelvic ring injuries, although it is technically demanding and requires liberal use of fluoroscopy. Fluoro based navigation systems [FluoroNav] have been developed that may advance surgical techniques. The purpose of this study is to compare the efficiency and safety of IS insertion using FluoroNav with standard STF guidance. Methods: Forty-eight percutaneous IS were placed into S1 of 24 cadavers. Instrumentation and 6.5 mm lag screws were alternately inserted using 1) STF technique and 2) a FluoroNav system (Stryker Navigation System). Operative and fluoroscopy times were recorded. Screw placement was assessed post-operatively using an anatomical dissec-

tion. Results: Forty-six of 48 IS were placed within the desired corridor from the ilium into S1. Minor penetration of the S1 cortex ocurred at the anterior cortex [FluoroNav] and superior end plate [STF]. Total surgical times averaged 7.3 min. using STF and 6.7 min. for FluoroNav. Total time for FluoroNav included a mean of 3.5 min. for screw insertion, but also 1.1 min. for applying the referencing system, 1.0 min. for calibration, and 1.1 min. for image acquisition. The mean fluoro time was 26 sec. for STF and 6.4 sec. for FluoroNav ($p < 0.05$). Discussion and Conclusions: Percutaneous IS may be safely placed using STF or FluoroNav imaging. Total surgical time was similar using these imaging methods. Screw insertion time was significantly less using FluoroNav compared to STF, although this time savings was offset by that required for set-up/calibration. FluoroNav required less surgical fluoroscopy time than was necessary for the STF method.

POSTER NO. P236

Lateral Neutralization versus Posterior Antiglide Plating of Closed Distal Fibula Fractures

Sam Akhavan, MD, *Cleveland, OH (n)*
Mihir Patel, MD, New York, NY (n)
Brendan M. Patterson, MD, Cleveland Heights, OH (n)
Randall Evan Marcus, MD, Cleveland, OH (n)
Heather A Vallier, MD, Cleveland, OH (n)

Twentynine LA and 23 PA plate fixations of distal fibula fractures were performed. Patients contacted to obtain Function Foot Index Scores. The data for rates of reoperation and postoperative symptoms was analyzed using Fisher's exact test and the results comparing the FFI scores were analyzed using the Mann-Whitney test. Ankle ROM was analyzed using the two-tailed student's t-test. Thirteen out of 29 patients with LN plates had symptoms related to the hardware starting at 3 months post-operatively compared to 0 out of 23 with PA plating ($p=0.0001$) after a mean follow-up period of 15.2 months (range, 3 to 72). Six with LN plates underwent hardware removal, while none with PA plates required re-operation ($p=0.02$). FFI sub-scale scores obtained in the LN group were significantly worse for pain ($p=0.02$) but not disability or function when compared to the PA plate group. In addition, the PA group had significantly better total FFI scores than the LN group ($p=0.03$). Although this is a small retrospective study, our results demonstrate that PA plating for distal fibula fractures is associated with significantly lower rates of hardware irritation and hardware removal. In addition, these patients had better total FFI scores and pain sub-scale scores compared to patients with LN plates.

POSTER NO. P237

Anterolateral Plating for the Surgical Management of Tibia Nonunion

Matthew L Jimenez, MD, *Des Plaines, IL (a – Synthes)*
Tracy L Anderson, MS, Des Plaines, IL (n)

Introduction Traditionally, tibia nonunions have been treated using a variety of implant and grafting techniques. The purpose of this study is to report the efficacy of tibia nonunion osteosynthesis using an anterolateral surgical approach with plate fixation. Methods: This is a single surgeon prospective observational cohort study of 57 tibia nonunions. All fractures were managed with a 4.5 mm narrow LCDC plate, placed through an anterolateral surgical approach, and contoured to rest below the tibialis anterior muscle. Data is presented on wound healing, fracture union, morbidity, and complications. Results The average patient age was 42 years, with 61% males and 39% females. A smoking history was obtained in 30% (average 22 pack years). Nonunion sites included 57 tibias (80% were located in the distal third of the tibia). Initially, 26% of the injuries were open tibia fractures, and 88% were considered high-energy injuries. The average duration of nonunion was 12 months. The number of surgical procedures prior to the index operation ranged from 1-8. Seven patients (12%) had a history of wound drainage. None were infected at the time of index procedure. Overall, fifty-five (96%) nonunions healed clinically and radiographically. One patient became infected (2%). One patient had hardware failure (2%). Three patients (5%) required myocutaneous free tissue transfer as part of the index procedure for wound management. Discussion Surgical management of tibia nonunions remains a challenging problem for both patient and surgeon. Anterolateral plating of tibia nonunions is safe and efficacious. This surgical approach provides significant fracture stability, and preservation of fracture biology, while protecting the often tenuous distal-medial skin flap from iatrogenic insult.

POSTER NO. P238

Platelet Activation Following Forced Liberation of Bone Marrow Fat Contents into the Circulation: An Animal Study

Michael Blankstein, *Toronto, ON Canada (n)*
Emil H Schemitsch, MD, Toronto, ON Canada (n)
Robert J Byrick, MD, Toronto, ON Canada (*)
Masaki Nakane, MD, FRCP, Toronto, ON Canada (*)
Annie Bang, Toronto, ON Canada (*)
John Freedman, MD, Toronto, ON Canada (n)
Robin R Richards, MD, Toronto, ON Canada (n)
M B Garvey, MD, Toronto, ON Canada (*)

Introduction: The objective of this study was to use a recently developed rabbit model of fat embolism to assess the systemic hemostatic response to pulmonary fat embolism. Methods: 15 NZW rabbits were randomly assigned into one of two groups: control and fat embolism (FE). In FE group (n=8), the intramedullary cavity was drilled, reamed and pressurized with a 1-1.5 ml bone cement injection. In the control group (n=7), a sham knee incision was made, exposing both femoral condyles, but was immediately closed without further manipulations. All animals were mechanically ventilated for an additional period of four hours. For flow cytometric evaluation of platelet activation, blood samples were taken at various intervals and stained with fluorescence-conjugated antibodies against CD41, CD62P and annexin V. Results: Platelet count decreased significantly at 2 and 4 hours post knee manipulation only in the FE group. Annexin V binding increased significantly in the FE group at 2 and 4 hours post knee manipulation. Lastly, CD62P expression only increased significantly in the FE group at 2 hours post knee manipulation. Discussion and Conclusion: Our findings demonstrate platelet activation following forced liberation of bone marrow contents into the circulation, as demonstrated by CD62P elevation (a marker of platelet degranulation) and increased annexin V percent binding (a marker of procoagulatory surface expression). Platelet activation also coincided with significantly lower platelet counts in the FE group at 2 and 4 hours post embolism, suggesting platelet aggregation. These findings suggest that fat embolism plays an integral role in post-traumatic platelet activation.

POSTER NO. P239

Limiting Loss to Follow-up in a Multi-Centre Randomized Controlled Trial in Orthopaedic Trauma

Pamela Leece, BSc, *Hamilton, ON Canada (n)*
Sheila Sprague, BSc, Hamilton, ON Canada (n)
Mohit Bhandari, MD, Hamilton, ON Canada (n)

Introduction: Even the best-designed randomized controlled trials suffer when patients are lost to follow-up. Incomplete follow-up biases the results of a trial when patients who drop out are different from those for whom follow-up is complete. This is exaggerated further when there are differential dropout rates between treatment groups. Previously, randomized controlled trials in orthopaedic trauma have typically reported 10 percent (but up to 30 percent) loss to follow up. Only by striving to achieve a 0 percent loss to follow-up rate, can we be certain that this type of bias does not affect our results. Methods: In our ongoing multi-centre, randomized controlled trial comparing reamed and non-reamed intramedullary nailing of tibial shaft fractures, we have implemented several innovative strategies to minimize loss to follow-up in our trial design, when patients become at risk for loss to follow-up, and when a study site identifies a patient as lost. Results: Through these primary, secondary, and tertiary interventions, we have achieved 95 percent complete one-year follow-up for the first 440 patients enrolled in the trial. Seven patients have been lost due to withdrawal of consent and we are unable to locate 15 patients. Conclusion: We have successfully minimized the loss to follow-up rate in our orthopaedic trauma trial by incorporating innovative prevention and retention strategies into the design and conduct of the trial. Through planning, organization, and committing time and resources to minimizing loss to follow-up, other orthopaedic trauma trials can hope to achieve the same high rates of follow-up.

POSTER NO. P240

The Management of Diaphyseal Long Bone Fractures with Intramedullary Expandable Nails

Olimpio Galasso, MD, *Naples, Italy (n)*
Gaetano Romano, MD, Naples, Italy (n)
Antonio Del Regno, MD, Naples, Italy (n)

Four years elapsed since the treatment of long bone fractures with Fixion™ intramedullary self locking nails had been proposed. The aim of this prospective study was to evaluate on a 2 years follow up the efficacy of diaphyseal fracture's treatment using the Fixion™ nail.A consecutive series of 102 acute diaphyseal fractured patients operated on with the expandable nailing system, fulfilling inclusion and exclusion criteria, were selected. No reaming or interlocking screws had been ever used. Eighty-two (41 tibial, 25 femoral and 16 humeral fractured) out of 102 patients with a mean age of 46.2 years (15-72) were undertaken over a 24 months follow up (80.3 percent of response rate). Radiological examinations were performed 30 and 50 days after surgery and every 40 days until consolidation occurred. Roentgenographic success criterion was bridging of all four cortices in the anteroposterior and lateral radiographic views. Clinical outcome was evaluated according the Musculoskeletal Function Assessment.Bony healing with fragment alignment and exact length of bone was achieved in the 95 percent of fractures with a mean consolidation time of 9,7 weeks. Two cases of hardware failure were observed, 2 oligoatrophic pseudoarthroses occurred. No infections were reported. Seventy-six patients returned to their previous occupation, 5 patients had to change office due to residual disturbances; one patient was out of work. Results achieved let us to consider the Fixion™ system an effective minimally invasive procedure for long bone diaphyseal fractures both considering the high success rate and the reduced X-ray exposure and time of surgery.

POSTER NO. P241

OP-1 Implant as an Adjunct to Mechanical Fixation in Humeral Nonunions

Kenneth A Egol, MD, *Jamaica, NY (n)*
Anand Susarla, MSIV, Washington, DC (a – Stryker Biotech)
Frank Liporace, MD, New York, NY (*)
Nirmal C Tejwani, MD, New York, NY (n)
Kenneth J Koval, MD, New York, NY (e – Stryker Biotech)

Purpose: The goal of this study was to evaluate outcomes in recalcitrant humeral nonunions treated with Osteogenic Protein-1 (BMP-7). Materials: This consisted of a cross-sectional review of 12 patients with humeral nonunions treated with OP-1. Average follow up was 180.5 days (range: 103-243 days), with 7 women and 5 men. Average age was 58.6 years (range: 26-84). Success was assessed clinically and radiographically (3/4 cortices). Four nonunions were proximal, four midshaft, and four distal. Five were smokers (5/12). Average nonunion time was 323.4 days (range: 152-1001 days). Three had prior nailing, five had prior plating and the remaining four received conventional treatment prior to implantation of OP-1. All had supplemental bone grafting. All received one vial of OP-1. Results: Eleven of twelve achieved radiographic and clinical healing. Average healing was 162 days (36-528) with median of 122 days. Eleven of twelve patients reported renewed arm function. There were no postoperative infections and hardware failure.None required reoperation. Conclusion: Our series shows OP-1 can rectify recalcitrant nonunions with a median healing time of 4 months. This time is significantly lower than previous reports. Our case series lacked statistical power to assess surgical technique on outcome, but these results do provide preliminary evidence that OP-1 provides novel results for treating nonunions.

POSTER NO. P242

The Treatment of Long Bone Nonunion with rhBMP: Results of a Prospective Pilot Study

Michael D McKee, MD, *Toronto, ON Canada (a – Stryker Biotech, e - Zimmer)*
Emil H Schemitsch, MD, Toronto, ON Canada (n)
James P Waddell, MD, Toronto, ON Canada (n)
Lisa Wild, RN, Toronto, ON Canada (n)

THE TREATMENT OF LONG BONE NONUNION WITH rhBMP: RESULTS OF A PROSPECTIVE PILOT STUDY PURPOSE: We sought to determine the safety and efficacy of a human recombinant osteogenic protein (rhBMP-7) in the treatment of recalcitrant human long bone nonunion. METHODS: In a prospective pilot study, we studied thirty-one patients with recalcitrant long bone nonunion that had failed previous treatment. There were 21 men and 10 women with a mean age of 49.4 years (range 22 years to 76 years). The involved bones included 6 tibiae, 9 clavicles, 10 humerii, 4 femoral and 2 ulnae. Eighteen patients had received prior autogenous bone grafting in an attempt to promote union. All patients underwent standard nonunion repair and addition of the rhBMP-7 to the nonunion defect. RESULTS: Mean follow-up was 23 months (range 6 to 62 months), and no patient was lost to follow-up. Twenty-seven patients healed their nonunion at a mean of 13 weeks postoperatively. There were four failures including two early mechanical failures and one deep infection. DISCUSSION and CONCLUSIONS: The bone substitute was technically feasible to use, was

not associated with any adverse events, and promoted union in twenty-seven of thirty-one (88%) of patients with refractory long bone nonunion that had failed conventional bone grafting. As part of a standard protocol, this bone graft substitute appears to be safe and effective in providing sufficient biological stimulation for bony union.

POSTER NO. P243

Clinical Presentation of Urethral Injuries in Patients with Pelvic Fractures

Patrick Dawson, MD, *Portland, OR (n)*
Daniel Janoff, Portland, OR (n)
Michael Conlin, MD, Portland, OR (n)
Douglas R Dirschl, MD, Chapel Hill, NC (*)
Thomas J Ellis, MD, Portland, OR (n)

Introduction: The medical literature contains few reports of large series of urethral injuries. The purpose of this study is to determine the incidence, clinical presentation, and pelvic fracture patterns associated with traumatic urethral injuries. Methods: Between 1995 and 1999, 35 urethral injuries were identified from trauma registries at two level-one trauma centers. The trauma registry recorded 1,048 pelvic fractures during the same interval. A retrospective review of clinical charts and radiographs was performed. Urethral tears were classified as stretch injuries or complete tears by a urologist Results: In patients with pelvic fractures, the incidence of urethral injuries was 3.4%. However, all 35 patients with urethral injuries had an associated pelvic fracture. There were thirty five male patients with an average age of 34 years. According to the AO-OTA classification system, five (14%) were Type A pelvic fractures, nine (25%) were Type B1 fractures, 12 (33%) were Type B2 fractures, and 20 (28%) were Type C fractures. Eight patients had stretch injuries to the urethra, and 27 had complete tears. Of males, 13 (37%) presented without blood at the urethral meatus, and 27 (77%) lacked a high riding prostate. Conclusion: Urethral tears are commonly associated with pelvic fractures. No correlation of urethral injury with pelvic fracture pattern could be identified. The absence of blood at the urethral meatus or the lack of a high riding prostate does not reliably exclude a urethral injury. Therefore, high index of suspicion for urethral injuries is indicated for patients with pelvic fractures.

POSTER NO. P244

◆Novel Use of Calcium-Phosphate Cement Reduces Articular Fragment Motion

Steven A Olson, MD, *Durham, NC (n)*
Jon David Hernandez, MD, Cincinnati, OH (*)
Michael Wayne Kadrmas, MD, Durham, NC (n)

Hypothesis:The use of calcium phosphate cement with internal fixation will decrease intra-articular fracture micromotion of a posterior wall acetabular fracture (OTA 62A1.1) more than with internal fixation alone. Methods: Ten cadaveric pelves will be used for this investigation. The pelves were rigidly mounted to the sacrum and attached via a custom mount to an Instron load cell. A simulated abductor mechanism was used to load the hip as described by Bay, et al. A large posterior wall osteotomy was created as described by Olson, et al. There was no marginal impaction in this model. The hips were tested with the acetabulum intact, with the posterior wall fragment removed, after anatomic reduction and standard internal fixation, and following reduction of the posterior wall using calcium phosphate cement as a grout coating all cancellous bone surfaces with internal fixation. Fragment displacement was determined with extensometers applied to the superior and inferior aspects of the posterior wall in the specimens after internal fixation with and without calcium phosphate cement. Statistical analysis was performed with repeated measures ANOVA. Results:Fragment micro motion was noted to be significantly decreased with the use of calcium phosphate cement as a grout. Displacements or standard techniques averaged 129 microns superiorly and 95 microns inferiorly. These were reduced to 78 microns superiorly and 46 microns inferiorly ($p < .05$). Discussion/Significance:The results of this study suggest that a novel application of calcium phosphate cement may help decrease articular fragment motion that may be achieved by conventional internal fixation.

POSTER NO. P245

Radiation Exposure with Use of the Mini-C-Arm for Routine Orthopedic Imaging Procedures

Brian Badman, MD, *Gainesville, FL (n)*
Bradley Butkovich, MD, Gainesville, FL
Lynn Rill , PhD, Gainesville, FL (*)
Manuel Arreola, Gainesville, FL (*)
Robert A VanderGriend, MD, Gainesville, FL (n)

The use of mobile fluoroscopic devices in orthopedic procedures results in significant concern with regard to radiation exposure to the surgeons and their support staff. The perceived increased risks are well documented with regard to large c-arm devices. However, no study to date has documented the relative radiation risk associated with the use of a mini c-arm. The current study was designed to determine the amount of radiation received by the surgeon during use of the mini-c-arm in comparison with documented measurements associated with the large c-arm. Using a radiation dosimeter, measurements were carried out with tissue equivalent anthropomorphic phantoms to quantitatively determine exposure rate levels at various locations and distances for two common upper and lower extremity procedures routinely done with the mini-c-arm. Results demonstrate that regardless of position, distance or relative duration of exposure, exposure rates resulting from use of the mini-c-arm are on the magnitude of eighty times less than those reported in the literature for the large c-arm device. As such, the mini-c-arm should be utilized whenever feasible, to eliminate many of the concerns and burdens associated with the large c-arm, specifically cumulative radiation hazards, positioning considerations, relative distance from the beam, and use of protective shielding.

POSTER NO. P246

Validation of CT-Reconstructed Images for the Evaluation of Acetabular Fractures.

Joseph Borrelli, MD, *Saint Louis, MO (*)*
Michael Peelle, MD, Saint Louis, MO (n)
William Michael Ricci, MD, Saint Louis, MO (n)
Beth McFarland, MD, Saint Louis, MO (*)

Introduction: Three pelvic radiographs (AP, iliac oblique and obturator oblique views) continue to be the standard for the assessment of acetabular fractures. Unfortunately, plain radiographs are often suboptimal due to the patient's body habitus, variations in technique, and the need to move the acutely injured patient for image acquisition. The purpose of our study is to demonstrate CT-reconstructed images are equivalent to plain radiographs for the assessment and classification of acetabular fractures. Methods: The three standard pelvic views were reconstructed using CT scan data and printed onto X-ray films for 11 patients with acetabular fractures. Five orthopaedic surgeons completed comprehensive questionnaires first evaluating these CT-reconstructed images based on

◆ The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e. the drug or medical device is being discussed for an off label use). For full information, refer to page xxxx

image quality and fracture classification, and then by directly comparing them to corresponding plain film images. Results:All patients had surgically confirmed fracture diagnosis; 4 had elementary fracture patterns and 7 had associated types. Respondents correctly classified the fracture in 70% of patients when using the CT-reconstruction images and in 68% using plain radiographs. Six percent of responses to fracture pattern were changed after reviewing the plain films, however, only half resulted in correct diagnosis. Regarding aesthetic quality and visibility of the fracture lines, respondents preferred CT-reconstructed images in 47% of cases, plain X-rays in 21% of cases, and both equally in 32%. Conclusions:CT-reconstructed images of the pelvis are equivalent to plain radiographs for the classification of acetabular fractures.

POSTER NO. P247

Temporary Stabilization of Pelvic Fractures with the Tpod Device in The Polytrauma Patient

Robert B Carrigan, MD, *Philadelphia, PA (n)*
Christopher T Born, MD, Cherry Hill, NJ (n)
Mary Kate Fitzpatrick, MSN, Philadelphia, PA (n)
Patrick Reilly, MD, Philadelphia, PA (n)

BACKGROUND: Pelvic fractures in the polytrauma patient are a significant source of mortality. Placement of a pelvic external fixator has long been the treatment of choice for acute management of the unstable patient with concomitant unstable pelvic ring injury. The purpose of this study was to determine the effectiveness of the Trauma Pelvic Orthotic Device (TPOD) in stabilizing pelvic fractures. METHODS: A retrospective analysis of 17 patients admitted to our institution, that had application of the TPOD for unstable pelvic fractures (based on fracture pattern according to Burgess/Young), was reviewed. Radiographs and CT scans of the pelvis with the T-POD in place and after definitive fixation, for each patient were analyzed. Pubic diastasis and pelvic cross-sectional area were measured from CT reconstructions and compared using a student's T-testRESULTS: For APC type fractures the TPOD had an average pubic diastasis reduction of 75.1% that was not statistically different than reduction achieved via definitive fixation 71.2 % ($p < 0.05$). For APC, VS and LC fracture types no statistically significant difference was noted in cross-sectional area between the TPOD group and after pelvic fractures after definitive fixation($p< 0.05$) CONCLUSION: The TPOD was effective in reducing pubic diastasis in APC fractures, and as effective in maintaining pelvic cross-sectional area as definitive internal or external fixation for all fracture patterns.

POSTER NO. P248

Risks to the Superior Gluteal Neurovascular Bundle During Percutaneous Iliosacral Screw Insertion

Cory Alan Collinge, MD, *Fort Worth, TX (*)*
David A Coons, DO, Irving, TX (*)
John Aschenbrenner, Fort Worth, TX (n)

Introduction: The recommended insertion site on the ilium for percutaneous iliosacral (IS) screws lies in the vicinity of the superior gluteal neurovascular structures (SGNAV) along the outer ilium. Injury to the superior gluteal vessels has been reported during the insertion of IS screws, but little is known as to the true risks to the SGNAV. The purpose of this study is to evaluate the risks to the SGNAV during the insertion of percutaneous IS screws in a cadaver model. Methods: Twenty cadaver pelvi for a total of 40 sides were studied. Percutaneous IS screws were placed into the S1 body using fluoroscopic guidance. The superior gluteal neurovascular bundle was then visualized via a posterior dissection. The distance between the screw head and the neurovascular bundle was measured and injury to these structures was noted. Distances from the screw to the crista glutea, greater sciatic notch, and iliac crest were also measured to assess whether the screws were inserted at the desired location. Results: The mean distance from IS screws to the deep superior branch of the SGNAV was 6.4mm. Four of 40 of IS screws caused major injury to the SGNAV. These screws were all within the targeted area of insertion. Mean distances from the screw head to the crista glutea, sciatic notch, and iliac crest were 19.8mm, 33.0mm, and 50.3mm, respectively. Conclusions and Discussion: The important superior branch of the SGNAV is at significant risk during the insertion of percutaneous IS screws even when "well placed." The use of washers may further increase the risk of injury when using this technique.

POSTER NO. P249

Systemic IL-6 Concentrations-An Indicator for Surgery Induced Second Hit

Frank Hildebrand, MD, *Hanover, Germany (n)*
Hans Christopher Pape, MD, Hannover, Germany (n)
Martijn Van Griensven, PhD, Hanover, Germany (n)
Christian Krettek, MD, Hanover, Germany (a – AO/ASIF Foundation)

Introduction: Multiple organ dysfunction syndrome (MODS) continues to be a major complication in trauma patients. The pathogenesis seems to be triggered by the early inflammatory response with synthesis of inflammatory cytokines, as Interleukin-6 (IL-6). The objective of this study was to evaluate whether the proinflammatory response also continues during the later posttraumatic clinical course.Patients and methods: Trauma patients were consecutively included in this prospective study. Inclusion criteria: Injury Severity Score (ISS) >16, age 18-60 years, survival >48 hours. Blood samples were drawn once daily (14 days) for determination of IL-6 concentrations (ELISA). MODS was evaluated using the Marshall-Score Results: 126 patients were included in this study. Patients were divided in two groups, according to the development of MODS (-MODS (102 patients)/+MODS (23 patients)). +MODS patients showed significantly higher IL-6 concentrations until day 7 after trauma, with two peaks at day 0 and at day 3. The number of operations at day 2 or day 3 was 7 in the +MODS group and 3 in the -MODS group. Summary and Conclusion: The early increase of Il-6 serum concentrations is trauma induced. The secondary peak in +MODS patients on day 3 is related to surgery. The early increase of IL-6 serum concentrations seems to be associated to the later development of MODS.This study reconfirms systemic IL- 6 levels to represent adequate markers for severity of trauma. Moreover, secondary increases were found to occur in association with further surgical procedures. For the clinical development of MODS (increase of MODS-Score from day 4 to day 9), IL-6 did not appear to play a major role, thus representing a dysergic reaction.

COMSS POSTER NO. P250

Orthopaedic Trauma Association

Is Medial Tenderness Predictive of Deep Deltoid Ligament Incompetence in Supination-External Rotation Type Anke Fractures?

Nicola A DeAngelis, MD, *Natick, MA (n)*
Bruce G French, MD, Columbus, OH (n)

Introduction/Purpose: To prospectively determine if tenderness in the region of the deltoid ligament is predictive of deep deltoid ligament incompetence in the presence of an isolated lateral malleolus fracture without radiographic evidence of medial clear space widening or lateral talar shift. Methods: This study included, over a 9 month period, all patients presenting with an acute, isolated Weber B (OTA 44-B) fibula fracture without radiographic evidence of lateral talar subluxation or medial clear space widening. Each patient was evaluated for tenderness to palpation in the region of the deltoid ligament on the medial side of the ankle. Deep deltoid incompetence was defined as widening of the medial clear space on an external rotation stress mortise radiograph. Results: 55 patients met the criteria for the study. Positive widening/positive tenderness: 13. Positive widening/negative tenderness: 10. Negative widening/positive tenderness: 13. Negative widening/negative tenderness: 19. Conclusions/ Discussion: Medial tenderness was reported by 41% of patients with a competent deep deltoid ligament and 57% of patients with deep deltoid incompetence. 43% of patients with an incompetent deep deltoid ligament did not have medial tenderness. Medial tenderness had a sensitivity of 57%, a specificity of 59%, a positive predictive value of 50%, and a negative predictive value of 66% when used as a measure of deep deltoid ligament incompetence.These results indicate that medial tenderness is a poor measure of deep deltoid ligament incompetence in the presence of an isolated Weber B (OTA 44-B) fibula fracture without medial clear space widening or lateral talar shift. In addition, the lack of medial tenderness does not indicate medial stability.

COMSS POSTER NO. P251

Limb Lengthening and Reconstructive Society

LLRS (ASAMI North America) The Limb Lengthening and Reconstruction Society

James C Binski, MD, *Dayton, OH (e – Smith & Nephew)*
John G Birch, MD, Dallas, TX (c – Encore Orthopedics, Inc.)

This poster presents case examples depicting various methods of treating acute and chronic skeletal deformities. External as well as internal fixation devices are shown including Circular, Monolateral, and Hybrid Fixators, Intramedullary rods and plates. Applications in acute and chronic trauma include periacetabular fractures, malunions, non-unions, bone loss, and osteomyelitis. Distraction osteogenesis as well as bone transport is described including the problems encountered along the way. Pediatric applications include limb deficiency syndromes, limb length inequality, and Blount's disease. Contractures, osteotomies, arthrodesis, and soft tissue distraction around the foot and ankle complete the indications. A brief history is given on the Ilizarov method and its founder. The major advances in this method over the past forty years are highlighted. Finally, there is a section on recent advances in technology (i.e., Taylor Spatial Frame, autodistraction, internal lengthening nails) and basic science research (i.e., muscle response to lengthening; bone enhancing techniques, and whole limb allotransplantation).

COMSS POSTER NO. P491

Orthopaedic Trauma Association

The Effect of Low Molecular Weight Heparin on Fracture Healing in a Standardized Rat Femur Fracture Model

Rena L Stewart, MD, *Indianapolis, IN (n)*
David J Hak, MD, Sacramento, CA (n)
Scott J Hazelwood, PhD, Sacramento, CA (n)

Introduction: Low molecular weight heparin (LMWH) is widely used for thromboembolic prophylaxis. This study proposes to determine if LMWH delays or arrests fracture healing. Methods: Seventy-two Long-Evans rats underwent retrograde insertion of a 0.8mm K-wire into the medullary canal of the femur. A closed, mid-diaphyseal, transverse fracture was created by three-point bending. Half of the animals received Fragmin 70 units/kg subcutaneously daily for 14 days and half received control injections of normal saline. Fracture healing was evaluated with serial radiographs. Biomechanical and histological evaluation was performed at 2, 3 and 6 weeks. Results: Radiographs revealed no fractures were healed at 2 weeks. At 3 weeks, none of the LMWH group fractures were healed, while 50% of the control fractures had healed. All fractures in both groups were healed at 6 weeks. The LMWH group displayed significant reduction in biomechanical parameters at 2 and 3 weeks. At 6 weeks, no significant differences were seen. Histological analysis confirmed delayed fracture healing at 2 and 3 weeks.

	Maximum Torque (Nm)		Stiffness (Nm/radians)	
Time	LMWH	Control	LMWH	Control
2 Week	0.260*	0.397	0.329*	0.780
3 Week	0.248*	0.609	0.338*	0.814
6 Week	0.688	0.707	0.645	0.930

Biomechanical evaluation of LMWH versus control (* $p < 0.05$ for Student's T test) Discussion and Conclusions: We found significant biomechanical, histological and radiographic differences in early fracture healing with the use of LMWH, but no significant differences at 6 weeks. This suggests LMWH retards rather than arrests fracture healing. The clinical impact of LMWH in fracture patients warrants further investigation.

SCIENTIFIC EXHIBITS

SCIENTIFIC EXHIBIT NO. SE055

Newer Techniques for the Fixation of Fractures in Osteoporotic Bone

Erik N Kubiak, MD, *New York, NY (n)*
Kazuho Iseka, MD, New York, NY (*)
Sam Park, MD, New York, NY (n)
Kenneth Egol, MD, New York, NY (n)
Fred Kummer, PhD, New York, NY (n)
Kenneth J. Koval, MD, New York, NY (n)
Joseph D. Zuckerman, MD, New York, NY (*)

Purpose: The goal of fracture fixation is the early return to and preservation of function, particularly in elderly osteoporotic patients. This exhibit will present our laboratory experience with new devices designed for the treatment of osteopenic bone. Methods: We have evaluated the use of newer fixation devices and cement augmented traditional fixation methods. Biomechanical testing was performed on cadaveric models for the following fractures: femoral neck; malleous; proximal

humerus fractures; vertebral body; proximal tibia; and Colles fractures. Static and cyclical loading was performed on all fixation methods tested. Among the new devices were sliding side plate hip screws, Schuhli nuts, locked plates, intramedullary nails with internal compression, and pin plates. Also studied were various types and reorientations of locking bolts and screw holes in intramedullary nails, the use of axilliary K-wires with standard bone plates and modified lag screw designs for use with as sliding hip screw. Polymethylmethacrylate and several types of biodegradable calcium-phosphate and calcium-sulfate cements used for fixation were also tested. Results: Although many of the newer devices showed enhanced fixation stability compared to traditional methods of fixation, in most cases, cement augmentation significantly improved fixation stability of fractures in osteoporotic bone. Biodegradeable cements lack tensile and shear strengths necessary for their use in highly loaded applications. Discussion: Augmentation with cement and implant modifications variably improve fixation in the laboratory. Biomechanical studies provide a background which guides the clinical application of these new techniques.

SCIENTIFIC EXHIBIT NO. SE056

◆How to Augment Fixation and Improve Clinical Outcomes for Osteoporotic Fracture Patients

Antonio Moroni, MD, *Bologna, Italy (n)*
Cesare Faldini, MD, Bologna, Italy (*)
Francesco Pegreffi, MD, Bologna, Italy (*)
Sandro Giannini, MD, Bologna, Italy (n)

Introduction: Fracture fixation of osteoporotic bone is an ongoing surgical challenge. Although there are many techniques to enhance fixation, few focus on the quality of the bone/screw interface. Coating screws with hydroxyapatite (HA) has been shown to improve bone/screw interface strength in osteoporotic bone. Methods: We report 3 different fixation-augmentation studies in osteoporotic bone. Results: Screw extraction and insertion torque were compared in osteoporotic wrist fracture patients who received either standard or HA-coated external fixation screws. Mean screw extraction torque in the standard screw group was 191±154 vs. 600±214 Nmm in the HA-coated group ($p<0.0005$). With the standard screws, extraction torque was lower than the corresponding insertion torque ($p<0.0005$); with the HA-coated screws it was higher than the corresponding insertion torque ($p<0.0005$). Another external fixation osteoporotic fracture study of trochanteric fractures showed screw extraction torque (2770±1710 Nmm) greater than screw insertion torque (1967±1254 Nmm), ($p=0.001$); confirming that stable fixation can be achieved, even under highly loaded conditions. We then compared fixation with Dynamic hip screw to standard versus HA-coated lag and cortical AO/ASIF screws. Femoral neck shaft angle reduced over time in the standard screw group (134±5° postop vs.126±12° at 6 mos.), whereas in the HA-coated screw group, no reduction occurred (134±7° postop vs. 133±7° at 6 mos.). Lag screw cutout occurred in 4 standard screw cases, but not in the HA-coated screw group ($p<0.05$, ß=0.8). Discussion and Conclusion: These studies show that HA-coated screws effectively augment fixation and provide better clinical outcomes for osteoporotic fracture patients.

SCIENTIFIC EXHIBIT NO. SE057

◆Radiation-Free, Computer-Assisted Targeting System (CATS)

William Krause, PhD, *Charlottesville, VA (a, d, e – Bioengineering Consultants Ltd., b - Ascension Technology)*

Intramedullary nails that allow interlocking have been one of the most significant recent advances in the management of long bone fractures. A significant problem of interlocking fracture fixation devices encountered by the surgeon is the insertion of the distal interlocking screws. One of the primary reasons for the problem is that the procedure is technically demanding, requires a significant amount of fluoroscopic and operating time and has a moderate learning curve. A simplified, nonradiographic, computer assisted, targeting system (CATS) has been developed and evaluated in intact and simulated fractured human cadaver femurs. The system utilizes electromagnetic micro-sensors inserted down the central canal of the nail proximal to the intended fixation hole or in the nail insertion tool and in the drill guide. The surgeon simply aligns a 3-D crosshair over a fixed crosshair on the computer screen and drills through the unseen hole in real time. Fourteen cadaver femurs were obtained, nails inserted and targeted. The results of the feasibility study showed that CATS could find and interlock the unseen holes in the nails. CATS targeted the unseen holes in over 93% of the attempts totally without any radiographic assistance. CATS provide an effective system to target and drill the unseen holes of any intramedullary nail or other fracture fixation devices. CATS has numerous advantages over other electromagnetic or optical targeting systems and traditional fluoroscopic methodologies.

SCIENTIFIC EXHIBIT NO. SE058

Logic and Clinial Application of Intramedullary Blocking Screws

Hans W. Stedtfeld, MD, *Nuremberg, Germany (a, b – Aesculap)*
Peter Landgraf, MD, Nuremberg, Germany (*)
Andreas Ewert, MD, Rostock, Germany (b – Aesuclap)
Thomas W. Mittlmeier, MD, Rostock, Germany (a – Aesuclap)

Following intramedullary fixation of metaphyseal long bone fractures high rates of axial malalignment have been reported. Blocking screws have been recommended to enhance primary stability. The logic of positioning these screws, however, and the option to use them as a reduction tool have not been analysed, yet. A 2-D model of an idealized fractured long bone consists of 3 essential elements: the diaphyseal and metaphyseal fragments and a rubber band simulating soft-tissue imbalance and axial deformity. A plastic rod representing an intramedullary nail can be introduced from both sides. Plastic sticks representing blocking screws can be plugged into holes at various positions of the two 'fragments'. The model allowed to derive general rules for positioning of blocking screws valid in any metaphyseal long bone fracture. The standard position of the blocking screw is: 1. in the metaphyseal fragment 2. close to the fracture 3. at the concave side of the axial deformity. In selected situations of high-degree instability an additional screw can be placed at the short fragment, on the convex side of the deformity and distant from the fracture. The basic biomechanical effect is an intramedullary three-point fixation. Clinical application has proven validity of the rules in fractures of the proximal humerus (n = 7), the subtrochanteric area (n = 5), the distal femur (n = 9), the proximal (n = 12) and distal tibia (n = 15) which all healed uneventfully within the limits of <5° of axial deformity.

PAPERS

PAPER NO. 081

Comparisons of Peripheral Bone Mineral Density in Adolescent Female Athletes from Different Sports

Laura M Gehrig, MD, *Shreveport, LA (n)*
James William Bellew, MD, Shreveport, LA (*)
George Gehrig, Shreveport, LA (n)
James A Albright, MD, Shreveport, LA (*)

Introduction: Physical activity during adolescence is critical to the development and expansion of healthy bone. To what extent sports of varying skeletal loading impact bone development during adolescence is unclear. Therefore the purpose of this study was to compare lower extremity bone mineral density (BMD) in adolescent female athletes 8-17 years of age participating in sports involving varying degrees of skeletal loading. The hypothesis of this study was that athletes in impact-loading sports, such as soccer, would have greater BMD than those in active-loading sports, such as swimming. Methods: Areal densities (g/cm-2) of the calcaneus were recorded from the dominant leg in a single session with use of a peripheral densitometer. Subjects were adolescent female athletes involved in their respective sport for at least one year, training at least 10 months per year, and at least 5 hours per week. Fifteen soccer players (15.2±1.22 years; 164.1±7.2cm; 55.2±4.4kg), fourteen tennis players (10.8±2.2 years; 149.4±13.1cm; 41.7±12.7kg), twenty-nine swimmers (12.0±2.1 years; 155.9±9.6cm; 46.2±11.5kg), and nineteen Olympic-style weightlifters (13.6±1.3 years; 158.7±9cm; 61.3±18.7kg) were examined. Because of the known correlation between body mass index (BMI) and age with BMD, BMI and age were used as covariates. Therefore, to test the effect of sport on BMD, a one-way ANCOVA was used. Post-hoc comparisons between groups were analyzed using Fischer's LSD. Results: The ANCOVA showed a significant effect of sport suggesting that BMD differs between sports ($F=8.695$, $p=<.001$). Post-hoc between-group comparisons showed that the BMD of the soccer players was 26% greater than that of the swimmers ($p<.001$), 21% greater than the tennis players ($p=.003$), and 4% greater than the weightlifters ($p=.001$). Discussion/Conclusion: Adolescence is considered the optimal period of bone growth and expansion therefore physical activity during this period is critical. These data suggest that the skeletal loading associated with soccer and weight-lifting may result in greater bone growth than swimming, or tennis.

PAPER NO. 082

Deep Infection in Orthopaedic Oncology Prostheses

Lee Jeys, FRCS, *Birmingham, United Kingdom (n)*
Rajeev Suneja, MD, Salford, United Kingdom (*)
Robert John Grimer, FRCS, Worcester, United Kingdom (n)

Introduction - Endoprosthetic replacement (EPR) following Bone Tumour excision is common. Major complications of EPRs include infection, with disastrous consequences. This paper investigates causes of infection, management & sequalae. Methods - 11, 000 patients were treated over 34 years. Information collected prospectively on a database, includes demographic data, diagnosis, treatment, complications, and outcomes. Data identified infection in EPRs, management & outcome. Factors including operating time, blood loss, adjuvant therapy, type of prosthesis and treatment outcomes were evaluated. Results - Data was analysed on 1265 patients over 34 years. Total follow up time was over 6500 patient years. 137 (10.8%) patients have been diagnosed with deep infection (defined as positive culture [n=128] or clinically infected prosthesis with pus in EPR cavity [n=9]). 49 (34%) required amputations for uncontrollable infection. The commonest organisms were Coagulase Negative Staphylococcus, Staphylococcus aureus and Group D Streptococci. The only satisfactory operation was 2 stage revision, with 71% success in curing infection. Systemic antibiotics, antibiotic cement & debridement had little chance of curing infection. Infection rates were highest in the Tibial (23.1%) & Pelvic (22.9%) EPRs ($p<0.0001$). Patients who had radiotherapy had higher rates of infection ($p<0.0001$) & as did patients with extendable EPRs ($p=0.007$). Patients subsequently undergoing patella resurfacing & rebushing had higher rates of infection ($p= 0.019$ & $p=0.052$). Conclusion - Infection is a serious complication of EPRs. 2 stage revision is the only reliable method for limb salvage following deep infection. Prevention is the key to reducing the incidence of this serious complication.

PAPER NO. 083

Five and Ten Year Survival of 126 MRS Segmental Prostheses with Emphasis on Mode & Time to Failure

Robert Mikael Henshaw, MD, *Washington, DC (n)*
Martin M Malawer, MD, Washington, DC (*)
Kristen Kellar-Graney, BA, Washington, DC (n)
Felasfa M Wodajo, MD, Washington, DC (*)

Introduction: This study examines the long-term MRS survival at 5 and 10 years. Methods: 181/332 reconstructions performed between 1980-2002 used MRS implants. 126 patients had follow-up more than 5 yrs, median time from surgery was 115 m. Ages ranged from 8.6 to 78.1 yrs. There were 58 d. femurs, 27 p. humeri, 20 p. femurs, 16 p. tibias, & 5 total femurs. At analysis, 56 patients had died, & 24 patients were lost to follow-up; median time to lost to follow-up was 50 m. Results: 41 (32%) patients experienced some complication requiring additional surgery. Only 11 (8.7%) prosthetic failures occurred, including 8 infections that led to 7 amputations (3 DF, 3 PT, 1 TF) and 1 prosthetic removal (PH). 1 additional amputation was performed for locally recurrent disease. Prosthetic failures unrelated to infection included: one aseptic loosening (DF), 1 fractured stem (PT), and 1 periprosthetic fracture (DF). Survival: Overall prosthetic survival by KM analysis was 91% at 5 years [95%CI:0.87-0.94] and 80% at 10 years [95%CI:0.68-0.92] for all sites. KM survivals by site were as follows: DF 93% (5 yr) and 80% (10 yr), PH 99% (5 and 10 yr), PF 100% (5 and 10 yr), PT 80% (5 yrs) and 63% (10 yr). The overall limb-sparing rate for all patients was 94%. Conclusions: 1. Long-term 5 and 10 yr results mirror the favorable early outcome of endoprosthetic reconstruction reported for the MRS. 2 These results are superior to those previously presented for custom prostheses (prior to 1988) and far surpasses the early hopes of limb-sparing surgeons during the 1980's.

PAPER NO. 084

◆Functional Outcome Of Proximal Femoral Replacement With An Endoprosthesis

Christian Ogilvie, MD, *Merion Station, PA (n)*
Robert S Bell, MD, Toronto, ON Canada (n)
Jay Wunder, MD, Toronto, ON Canada (n)
Peter Ferguson, MD, Toronto, ON Canada (n)
Anthony M Griffin, MD, Toronto, ON Canada (n)

Introduction. Endoprosthetic proximal femur replacement (EPFR) disability has not been described using a validated, patient reported system. The aim of this study was to assess disability after an EPFR, and compare functional outcomes of different abductor reconstructions. Methods. We prospectively collected the Toronto Extremity Severity Score (TESS), the MSTS87 and the MSTS93 scores. Two surgeons from 1992 to 2001 performed 49 EPFRs. We included EPFRs for bone or soft tissue tumors with a minimum 1-year follow up with the MSTS or TESS scales, using the most recent scores. A TESS was available on 29 patients, MSTS score on 33. Implants: Howmedica Kotz Modular Femoral Reconstruction System in 29 patients and Wright Medical SOS in 4 patients. Uncemented stems were used in 25 cases, cemented stems in 4 cases, and total femurs in 4 cases. Total hip arthroplasty was used in 10 hips and bipolar arthroplasty in 23. Abductor repairs: none in 8 cases, soft tissue repair in 16 cases, and greater trochanter attachment to the prosthesis in 9 cases. Results. Mean follow up: 3 years for the TESS and the MSTS scores. The MSTS87 mean was 22.9 (3.7) of 35 points. 19 patients were rated good, 13 fair, and 1 poor. The MSTS93 mean was 67.4 (11.6) percent. The TESS mean was 76.1 (16.1) of 100 points. Functional results of abductor repairs did not vary significantly. Discussion and Conclusion. The mean TESS was relatively higher than either MSTS scale. This is the first description of patient reported disability after EPFR.

PAPER NO. 085

Surgical Treatment and Outcome of Primary and Recurrent Pelvic Chondrosarcoma

Davide Donati, MD, *Bologna, Italy (n)*
Ahmed El Ghoneimy, MD, Bologna, Italy (*)
Franco Bertoni, MD, Bologna, Italy (n)
Claudia DiBella, MD, Bologna, Italy (*)
Mario Mercuri, MD, Milano, Italy (n)

We reviewed 150 patients with pelvic chondrosarcoma. The average follow-up period was 104 months. 113 patients (75%) were treated by resection (LSSR), while 37 (25%) were subjected to a hemipelvectomy. The tumors were removed with wide margins in 66%, wide contaminated 13%, marginal 15%, and intralesional in 6%. 35 patients had local recurrence (23%), following a mean duration of 34 months from surgery. A lower incidence was noted in wide margins (p= 0 ,016). Tumors crossing the SI joint had more inadequate margins, than acetabular tumors (p=0,02). More wide margins has been obtained with hemipelvectomy than LSSR (p= 0.029). Among the central tumors, the margins were adequate in 47 surgeries (72%) while, in peripheral tumors, the margins were wide in 37 (58%) (p= 0,133). The difference in survival between grade 1 and 2 was not statistically significant as it turn to be in comparison with grade 3 tumors.Grade 1 and 2 patients who experienced local recurrence had a 5 years survival of 70% or more, while grade 3 chondrosarcomas who had local recurrence, had a 5 years survival of less than 10%. We conclude the importance to achieve wide margins in pelvic chondrosarcoma. In grade 3 or more hemipelvectomy would be addressed in order to improve the margins adequacy. In lower grades, a wide contaminated surgery can be performed without significant difference in overall survival.

PAPER NO. 086

Periosteal Osteosarcoma: A Reexamination of Outcomes

Peter S Rose, MD, *Rochester, MN (n)*
Ian Dickey, MD, Rochester, MN (*)
David J Jacofsky, MD, Rochester, MN (n)
Doris Wenger, MD, Rochester, MN (n)
Krishnan K Unni, MD, Rochester, MN (n)
Franklin H Sim, MD, Rochester, MN (n)

IntroductionPeriosteal osteosarcoma is a rare sarcoma; few recent reports have examined current management and long-term follow-up. MethodsA retrospective review of all cases of periosteal osteosarcoma seen at our institution. ResultsThe twenty-nine patients identified represent 1.5 percent of osteosarcomas in the Clinic's experience. Average age was 20.6 years (range 9-47; 13M:16F). Pathologic grading showed 9 grade 2 (of 4) and 17 grade 3; MSTS stage was 9 IB, 16 IIB, and 1 III; (grading information unavailable on 3). Seventeen patients had amputations, 11 limb salvage, and one lesion was located in a rib. Surgical margin was radical in 10, wide in 16, marginal in 2, and intralesional in 1. Nine patients received adjuvant treatment, 5 with modern chemotherapy agents. In the two patients receiving neoadjuvant chemotherapy, tumor necrosis was poor.Five patients died of disease with average survival 26 months (range 21-34). Local recurrence occurred in 5 of 11 patients receiving limb sparing procedures; 3 progressed to metastatic disease and death. Pathologic grade did not influence outcome. Five patients died of unrelated causes with average survival 164 months (range 23-352). One patient was lost to follow-up. Average follow-up for the entire cohort was 12.5 years (range 2- 51). Conclusions: Periosteal osteosarcoma represents an uncommon malignancy with overall 83 percent disease free survival. No local recurrence or metastatic disease was observed after 3 years from diagnosis. Adequate surgical treatment is essential for tumor control. While current management includes neoadjuvant therapy, the small numbers in this series do not confirm the benefit of such therapy.

PAPER NO. 087

Epiphysis Preservation and Intercalary Allograft Reconstruction in Osteosarcomas of the Knee

D Luis Muscolo, MD, *Buenos Aires, Argentina (n)*
Miguel Angel Ayerza, MD, Buenos Aires, Argentina (n)
Louis Alberto Aponte-Tinao, MD, Buenos Aires, Argentina (n)
Maximiliano Ranalletta, MD, Buenos Aires, Argentina (n)

Introduction: The purpose of this study was to analyze 13 patients with high grade metaphyseal osteosarcoma of the knee, treated with a transepiphyseal resection with preservation of both epiphysis and an intercalary allograft reconstruction. Methods: We retrospectively reviewed 13 patients with metaphyseal high grade osteosarcoma around the knee, in which transepiphyseal resections were performed and reconstructed with an intercalary allograft. Patients were followed for a mean of 55 months (minimum 26 months) and were functionally evaluated according to the MSTS scoring system. Results: At final follow-up, 11 patients were continuously disease free. One of the patients died of bone and pulmonary metastases with no evidence of local recurrence and the remaining patient had no

evidence of disease after resection of a soft tissue local recurrence. No patient presented a local recurrence in the remaining epiphysis. Seven patients suffered complications that included three fractures, two diaphyseal nonunions, one deep infection, and one soft tissue local recurrence. However, limb preservation was obtained in 100% of the patients and allograft survival rate was 69%. The average functional score of the 12 available patients by the MSTS scoring system was 27 points at final follow-up. Conclusions: Preservation of the epiphysis is a reasonable alternative in very selective patients with a metaphyseal osteosarcoma located at the knee. Crucial factors in order to obtain local tumor control and an acceptable functional result are chemotherapy response, preoperative assessment of tumor extension close to the epiphysis, and appropriate fixation techniques for intercalary allografts.

PAPER NO. 088

Cement Filling Compared with Bone Allografting after Curettage of Giant-Cell Tumor of the Knee

Louis Alberto Aponte-Tinao, MD, *Buenos Aires, Argentina (n)*
D Luis Muscolo, MD, Buenos Aires, Argentina (n)
Miguel Angel Ayerza, MD, Buenos Aires, Argentina (n)
Eduardo Abalo, MD, Buenos Aires, Argentina (n)
Santiago Bongiovanni, Buenos Aires, Argentina (n)

Introduction: The purpose of this study was to compare cement filling versus bone allografting after intralesional curettage of giant-cell tumor of the knee, with regard to their effectiveness in the eradication of the tumor, their rates of complications and their potential effect on joint morbidity. Methods: A retrospective study over 43 patients with a GCT localized in the knee that were treated with intralesional curettage combined with phenol, was undertaken. The mean follow-up was seven years. The defect was filled with cement in 22 patients and with fragmented bone allograft in 21. Local recurrence, reconstructive complications and radiographic evaluation of potential joint deterioration were analyzed in both groups. Results: There have been 4 local recurrences (9%), two in each group. Three patients of the cemented group required a second surgical procedure due to an articular collapse in two and an intraarticular cement impingement in one. In the allografted group, two patients suffered complications due to a fracture and a massive resorption. Radiographically, articular deterioration was observed in 10 out of the 17 non complicated patients from the cemented group and in 3 out of the 17 of the bone allografted group. This difference was statistically significant (p=0.019). Conclusions: The incidence of local recurrence and reconstructive complications that needed a second surgical procedure was not different between these two groups. However, the incidence of radiographic deterioration of the articular knee joint was significantly higher in patients in which the cavity was filled with cement than those filled with fragmented bone allograft.

PAPER NO. 089

Comparative Efficacy of HRT, Etidronate, Calcitonin, Vit D and Vit K in Postmenopausal Osteoporosis

Yoichiro Ishida, MD, *Yamaguchi, Japan (n)*
Shinya Kawai, Ube, Yamaguchi, Japan (*)
Hiroshi Fujii, MD, Ube City, Yamaguchi, Japan (*)

INTRODUCTION: This trial aimed to assess the comparative effectiveness of several medications on bone mineral density (BMD), biochemical bone markers, and a new vertebral fracture incidence in postmenopausal women with osteoporosis. METHODS: A total of 389 postmenopausal women aged 50-75 with osteoporosis were randomly allocated into six groups: hormone replacement therapy (HRT); etidronate; calcitonin (CT); vitamin D3; vitamin K2; and control (no treatment). Thoracic and lumbar spine radiographs, BMD at distal 1/3 radius, and markers of bone turnover were assessed at baseline and at every 3 months during the 2-year study period. RESULTS: Mean changes in BMD relative to baseline after the 2-year treatment in HRT, etidronate, CT, vitamin D, vitamin K and control was 2.0%, -1.0%, 1.6%, -3.6%, -1.9% and -3.3%, respectively. In control, the incidence of new vertebral fractures after the 2-year treatment was 25.8%. In HRT, etidronate, CT, vitamin D and vitamin K, the fracture incidence was reduced by 63%, 53%, 58%, 34%, and 45% compared to control. Logistic regression analysis revealed that changes in BMD relative to baseline at month 3 predicted changes in BMD after 2 years and the new vertebral fracture risk. Changes in urinary N-telopeptide of type I collagen (NTX) and urinary deoxypyridinoline (DPD) relative to baseline after 3 months were significant predictors of the incidence of new vertebral. CONCLUSIONS: Our results demonstrate the importance of measurements of BMD and markers of bone resorption at month 3 in identifying women for whom drug therapy to prevent vertebral fracture is appropriate.

PAPER NO. 090

Langerhans Cell Histiocytosis (LCH) of the Spine in Children

Sumeet Garg, *Brookline, MA (n)*
Samir Mehta, MD, Collingswood, NJ (n)
John P Dormans, MD, Philadelphia, PA (*)

Introduction: This is the largest series to date examining the presentation, natural history, and outcomes in children with LCH of the spine. Methods: 130 children with LCH were treated at our institution between 1970 and 2003. Of these, the 26 with biopsy-proven spinal LCH were retrospectively reviewed. Vertebral collapse was classified as grade I (0-50% collapse) or grade II (50-100% collapse) and sub-classified as A (symmetric) or B (asymmetric). Results: 26 children ranging in age from 0.2 - 16.4 years (mean 8.2) had 44 involved vertebrae (20 cervical, 14 thoracic, 10 lumbar). Long-term follow-up was available for 23 patients (41 vertebrae) ranging from 2-22.7 years (mean 9.3 years). Lesions showed a predilection for the cervical spine ($p<0.02$) and a relative paucity of lesions involved the thoracic spine ($p<0.006$). Collapse was grade IA in 20 children, IB in 3, IIA in 10, and IIB in 9. Grade I lesions were significantly associated with symmetric collapse ($p<0.03$). Cervical ($p<0.03$) and lumbar ($p<0.04$) lesions were associated with multi-level spinal disease. Only two patients had systemic disease. Local pain was the presenting symptom in all children. Only three patients presented with neurologic symptoms (radicular pain), none of who had neurologic deficits. Despite heterogeneous treatment, all patients are alive and well and have no evidence of disease including resolution of all presenting symptoms at follow-up. Conclusions: The natural history of LCH of the spine in the absence of systemic disease or spinal deformity is such that only follow-up to monitor recovery and spinal balance is necessary.

PAPER NO. 221

Cross-sectional Study of Bone Mineral Density in Adult Survivors of Solid Pediatric Cancers

Timothy A Damron, MD, *Syracuse, NY*
(a – Georg Fund, Syracuse Community Foundation)
Irene Cherrick, Syracuse, NY (n)
Susan Shaw, Syracuse, NY (*)
Christopher Anker, Syracuse, NY (*)
Sean Holdridge, BS, Syracuse, NY (*)
Joseph A Spadaro, PhD, Syracuse, NY (n)
Jennifer Kelly, MD, Syracuse, NY (n)
Matthew Allen, PhD, Syracuse, NY (n)
William Grant, MD, Syracuse, NY (n)

Currently, there is no conclusive evidence that survivors of pediatric solid malignancies are at risk for osteopenia/osteoporosis due to the small numbers of patients analyzed previously. The purpose was to perform a cross-sectional study of bone mineral density in adult survivors of solid pediatric tumors. The hypothesis was that pediatric solid cancer survivors show significantly lower bone mineral density (BMD) compared to established age group controls. Patients who were treated for solid tumors and lymphomas with chemotherapy beginning at age less than 16, were less than 35 years of age at follow-up, who were not treated for ALL, and who did not receive cranial irradiation, total body irradiation, or non-autologous bone marrow transplant (groups already known to be at high risk for osteoporosis) comprised the patient population. The study group consisted of 38 patients with diagnoses of lymphoma (17), sarcoma (8), Wilm's tumor (5), neuroblastoma (4), ovarian germ cell tumor (1), yolk sac carcinoma (1), Triton tumor (1), and hepatoblastoma (1). Mean age at follow-up was 22 years. Time of follow-up from diagnosis of cancer averaged 12.6 years. Using a criteria of osteopenia (Z-score < -1.0) and osteoporosis (< -2.0) for any one or more of total body, spine, total hip or femoral neck density, 12/38 patients had decreased bone mineral density. A further 6/38 patients had isolated upper extremity osteopenia/osteoporosis. Survivors of childhood solid tumors, including sarcomas, lymphomas, Wilm's tumors, and brain tumors, are at increased risk of developing premature osteopenia/osteoporosis and warrant ongoing screening evaluations.

PAPER NO. 222

Leiomyosarcoma of Somatic Soft Tissues: A Very Bad Actor

Francis J Hornicek, MD, *Boston, MA (n)*
Mark C Gebhardt, MD, Boston, MA (a – HowMedica)
Henry J Mankin, MD, Brookline, MA (n)

Leiomyosarcoma of Somatic Soft Tissues: A Very Bad ActorPurpose: To describe the malignant behavior of 66 cases of leiomyosarcoma of somatic soft parts and compare the results with 1256 other sarcomas of soft tissue. Materials and Methods: The authors' institution has treated 66 patients with leiomyosarcoma of somatic soft tissues. None of these were uterine or bowel related and the general consensus was that they arose from smooth muscle of blood vessels. The anatomical sites were mostly thigh, leg, pelvis, and arm but 10 were in the foot, ankle, forearm and hand. Most of the lesions were histologically graded as 3. In all but 6 cases the disease was either Stage II or Stage III. Results: Forty-one of the patients developed metastases and 33 of these died (81%). Seven had a local recurrence and 5 of these died (71%). Large size (over 500 cm3) had an 82% death rate but even those between 100 cm3 and 500 cm3 had a death rate of over 50%. When the 66 leiomyosarcoma patients were compared with 482 MFH cases, 204 liposarcomas, 180 synovial sarcomas, 87neurofibrosarcomas, etc, only the MFH (41% death rate) and the clear cell sarcoma (47% death rate) came close to the overall 50% death rate at 3 years for the leiomyosarcomas. Conclusions: Leiomyosarcoma of soft parts is a highly malignant tumor, which is fortunately rare. Despite radiation and chemotherapy treatment, over 60% will develop metastases and 50% of the patients will be dead in three years. The malignancy may be related to the origin in smooth muscle of blood vessels, which may allow more rapid vascular invasion and spread to lungs and other sites as well as a high incidence of local recurrence. The lesions should be treated aggressively with chemotherapy, radiation if indicated and wide or even radical surgery.

PAPER NO. 223

Twenty Year Follow-up of Bone Allograft Transplantation

Kevin A Raskin, MD, *Brookline, MA (n)*
Mark C Gebhardt, MD, Boston, MA (a – HowMedica)
Francis J Hornicek, MD, Boston, MA (n)
Henry J Mankin, MD, Brookline, MA (n)

Twenty year follow-up of Bone Allograft Transplantation Purpose: To describe the current status of 156 massive bone allografts followed for 20 or more yearsMaterials and Methods: The authors performed 156 cases of bone allograft transplantation between 1971 and 1982. Using a computer database system, allograft type (osteoarticular, intercalary, allo-arthrodesis or alloprosthesis), gender, anatomical site, diagnosis, complications were analyzed for their effect on graft survival. Results: There were 156 patients in the series. 14 of the patients developed metastases, 10 died of disease and 15 developed a recurrence. The average follow-up for alloimplants was 12.4 _ 8.6 years. There were 117 osteoarticular, 30 intercalary, 8 allograft-prostheses, and one allograft-arthrodesis performed. The average age for the patients at the time of surgery was 31 (range 11 to 67) and 59 patients had one re-operation, 16 two, 12 three and 4 four reoperative procedures and 63 patients had none. Allograft survival at 20 or more years following the surgery was 76% good or excellent. The types of grafts demonstrated the intercalary did best (87%). The osteoarticular grafts had a 74% success rate at 20 years and the allo-prosthesis a 75% success. Infections were the most severe complication with only 1 success out of 16 patients There were 20 non-unions with only one failure (5%) and 37 fractures with 8 failures (22%). If no complications ensued, 90% of the grafts remained successful for 16 _ 7 years. Conclusion: Bone allograft reconstruction of massive skeletal defects secondary to tumorous and non-tumorous conditions is a viable option for these challenging orthopaedic conditions. Most of the failures occur within 4 years of implantation. Once this early failure period is over, the majority (76%) of the grafts survive and do quite well for a prolonged period.

PAPER NO. 224

Operative Management of Sacro-Coccygeal Chordomas

Bruno Fuchs, MD, *Rochester, MN (n)*
Michael J Yaszemski, MD, PhD, Rochester, MN (n)
Carrie Inwards, MD, Rochester, MN (*)
Franklin H Sim, MD, Rochester, MN (n)

Sacrococcygeal chordoma presents a difficult diagnostic and therapeutic problem with a high incidence of local recurrence. The report aims to define the importance of adequate surgical treatment on outcome and survival. 58 patients underwent surgical treatment for sacrococcygeal chordoma between 1979 and 2001. The series included 19 women and 39 men with an average age of 56.2 (range, 13 to 76) years at diagnosis. A a posterior approach was performed in 25 patients, and a combined antero-posterior approach in 33 patients. A wide surgical margin was achieved in 22 patients, 14 marginal and 22 intralesional. At average follow-up of 92.2 (range, 18 to 276) months. 33 patients were alive with no evidence of disease. Twenty-one patients had local recurrence. Recurrence free survival at 5 years was 67% and at 10 years 57%. The overall survival was 74%, 51%, 42% at 5 years, 10 years, and 15 years, respectively. All patient with wide margins survived (100 %) which was significantly different from patients who had either marginal or intralesional excision (p=0.0001). Tumor volume univariately assessed, however, does not seem to compromise the possibility of obtaining a wide margin (p=0.21). A wide margin is the most important predictor of survival in patients with sacrococcygeal chordoma. Tumor volume per se has no negative impact on survival as long as a wide margin is obtained. Therefore, for large tumors and tumors above S3 we prefer combined antero-posterior approach.

PAPER NO. 225

Outcome of Fibular Osteosarcoma

Michaela Maria Schneiderbauer, *Basel, Switzerland (n)*
Sean P Scully, MD, PhD, Rochester, MN(n)

INTRODUCTION: Osteosarcoma of the fibula occurs in an expendable bone and this leads to debate about the optimal surgical treatment. The purpose of this study was to evaluate the treatment, survival, and factors that influence survival in patients with fibular osteosarcoma. METHODS: Patient data were investigated by retrospective chart review. The statistical tests used were t-test, Cox-test, and the Kaplan-Meier method. RESULTS: Fifty-four patients treated for fibular osteosarcoma between 1919 and 1999 were included in this study (mean age: 26.4 years). Metastases occurred in 62.7 percent of the patients and local recurrence in 20.3 percent. The median and mean survival time after surgery were 3.7 and 7.8 years respectively. The occurrence of metastasis, treatment before 1975, and proximal versus distal location of the tumor were significantly associated with a poor survival. Patients with resection seemed to fair better than patients with above the knee amputations in terms of survival. The local recurrence rate was not associated with survival at a level of statistical significance. DISCUSSION AND CONCLUSION: This study shows that many patients with fibular osteosarcoma succumb to their disease only a few years after initial diagnosis. Survival improved significantly with the advent of chemotherapy. Metastasis and local recurrence rates are fairly high and the extent of surgery alone does not seem to improve the outcome. Further understanding of the underlying biological principles of metastasis in osteosarcoma will be necessary to prevent the often fatal metastatic process.

PAPER NO. 226

Meta-Analysis of the Treatment of Giant Cell Tumors of the Extremities

Kimberly J Templeton, MD, *Kansas City, KS (n)*

Introduction: Controversy exists regarding the ideal substance(in regard to local recurrence), bone graft or PMMA, with which to fill in the bone defect after treatment of giant cell tumor of the extremities. Method: A MEDLINE search was performed for articles listed under "giant cell","tumor", and "bone" in the English literature for the years 1984-2003, resulting in 990 articles. Articles that did not list curettage for extremity lesions were eliminated. This resulted in 45 articles that form the basis of this review. Results: These studies yielded a total patient population of 635, with primary lesions only. The most common sites were distal femur, proximal tibia, and distal radius. 306 patients received bone grafts; 329 patients received PMMA. Local recurrence occurred in 124 patients (range 2-322months). Recurrence was not related to the presence of a pathologic fracture but was related to the site of the tumor (proximal tibia 24%, distal radius 48%) and treatment modality: recurrences were seen in 61 (39%) of patients treated with bone graft alone; 24(22%) treated with adjuvants and bone graft; 4(4.8%) treated with PMMA alone; and 32(14.5%) treated with adjuvants and PMMA. There were 6 pulmonary metastases, all in patients with a local recurrence; 5 had been treated with bone graft alone. 14 studies reported functional outcome: most patients were in the good or excellent group, regardless of the use of bone graft or PMMA. Complications were few. Those patients treated with bone graft were more likely to experience a non-union or fracture; those treated with PMMA were more likely to develop pain in the adjacent joint. Conclusion: Patients with giant cell tumors of the extremities appear to have a higher local recurrence rate if they receive bone graft rather than PMMA, especially if treated without adjuvant modalities. Regardless of the treatment method, most patients report good or excellent functional results.

PAPER NO. 227

Metastatic Soft Tissue Sarcoma to Bone

Carol Morris, MD, *New York, NY (n)*
Kristy Simmons, New York, NY (*)
John H Healey, MD, New York, NY (n)
Murray Brennan, MD, New York, NY (n)
Patrick J. Boland, MD, New York, NY (n)

Introduction: The purpose of this study was to describe the incidence, the role of treatment, and outcome for bone metastases from soft tissue sarcoma. Materials and Methods: Patients with bone metastases were identified from a prospectively maintained soft tissue sarcoma database collected from 1982 to 2001. Patients with at least 1 year follow-up were included. The influence of several variables and role of treatment was analyzed. Results: Of 4885 patients diagnosed with soft tissue sarcoma, 293 (6%) developed clinically detectable bone metastases. Only 39% of patients with bone metastases presented without other sites of metastatic disease. The most common histopathology associated with bone metastases was leiomyosarcoma (n=86), meaning 10% of all patients with leiomyosarcoma developed bone metastases while patients with angiosarcoma were most plikely to develop skeletal metastases (19%). The median survival time of patients with bone metastases was 33 months. At 1 year follow-up, 58% of patients who underwent surgical management of their bone metastasis were alive compared to 53% of patients who did not have surgery (p=0.52). In 23% of patients who developed bone metastases,

bone was the only site of metastatic disease. For patients with only bone metastases, at 1 year 65% were alive after surgical treatment compared to 39% without surgical treatment (p=<0.05). Fifteen long term survivors (>5years) were identified with only 3 of those patients without eveidence of disease (NED) >5 years after development of a skeletal metastasis. Conclusions: Bone metastases from soft tissue sarcoma are not common with the majority of patients having other sites of distant disease burden. While surgery is largely palliative aggressive treatment can improve survival in patients with solitary lesions.

PAPER NO. 228

Minimizing Radiation for Soft Tissue Sarcomas: Results with Neoadjuvant Chemo at Median 55 Months

Felasfa M Wodajo, MD, *Washington, DC (n)*
Daria Laureen Brooks, MD, Silver Spring, MD (n)
Yvette Ho, BS, Washington, DC (n)
Kristen Kellar Graney, MD, Washington, DC (n)
Jacob Bickels, MD, Rehovot, Israel (*)
Dennis Priebat, MD, Washington, DC (*)
Robert Mikael Henshaw, MD, Washington, DC (n)
Martin M Malawer, MD, Washington, DC (*)

Introduction Wide resection and radiation therapy (RT) has been the standard for high-grade soft tissue sarcomas of the extremities. The role of radiation is to reduce the risk of local recurrence. High doses, often more than 6000 cGy, are typically used for sarcomas. At these doses, short term and long-term complications are common, including wound breakdown, stiffness and swelling of extremities, avascular necrosis, pathologic fractures and even secondary sarcomas. We present here the results of an on-going neoadjuvant chemotherapy protocol for extremity soft tissue sarcomas in use at our institution since 1988. This protocol does not utilize RT unless there is a poor response to induction chemotherapy Methods Between 1980 and 2002, the same surgical team performed 270 surgical resections of intermediate and high-grade soft-tissue sarcomas. Patients with tumors larger than 5 cm, deep to fascia and without significant medical co-morbidities were considered for a chemotherapy protocol consisting of doxorubicin, intra-arterial cis-platinum and ifosfomide. A total of 62 patients were entered. Radiation was not routinely used; our indications were only patients with tumor necrosis less than 90% and/or very close margins to neurovascular structure. Results The median follow-up was 55 months (range 3- 162 months). The most common histological subtype was malignant fibrous histiocytoma (27), followed by liposarcoma (17) and leiomyosarcoma (6). Five patients had intermediate grade tumors while 13 (21%) had previous attempts at surgical resection. There were six local recurrences (9.6%), at a median interval of 17.3 months. Sixteen patients (26%) had distant recurrence, at a median of 16 months, and eleven patients (18%) have died of disease at a median of 23 months. The mean and median tumor necroses were 73% and 84%.A total of 26 (42%) patients underwent adjuvant radiation with an average dose of 6282 cGy. Nine patients experienced wound complications, two of which required split-thickness skin grafting while others underwent debridement and wound closure. No free flaps were performed. Discussion The role of chemotherapy for soft tissue sarcoma has remained controversial, as it has been difficult to demonstrate a survival advantage. This is in part due to the rarity of the disease and also due to relatively high survival of patients even without chemotherapy. Nevertheless, 50-60% of patients can expect to die of their disease with up to 20% patients also experiencing local recurrence, as reported in several large series where only surgery and adjuvant radiation were used. Despite our protocol being reserved for high-risk patients, i.e. those with large, deep tumors, the local recurrence rate in this series was only 9.6%. Furthermore, in the setting where adjuvant and neoadjuvant radiation therapy are used exclusively, many patients will require free-flaps for wound closure due to radiation induced wound complications. In our series, no patients required free flaps. Most of the 15% patients with minor wound complications were managed with simple debridement and primary closure. We were able to avoid adjuvant radiation for 58% of our patients. With continued experience, we may be able to further limit the use of radiation in the future. Analogous to the evolving treatment strategy of Ewing's sarcoma, we suggest the paradigm of treatment of deep, high-grade sarcomas be reevaluated based on this study, with the aim of avoiding radiation therapy and its complications, especially since most sarcomas occur in young adults.

PAPER NO. 229

Synchronous and Metachronous Multiple Osteosarcoma: Results of Contemporary Treatment

Nicola Fabbri, MD, *Bologna, Italy (n)*
Franklin H Sim, MD, Rochester, MN (n)
Dundar Sabah, Izmir, Turkey (n)
Marco Manfrini, MD, Bologna, Italy (*)
Frank J Frassica, MD, Baltimore, MD (*)
Mario Mercuri, MD, Milano, Italy (*)

Introduction. Multiple bone involvement occurring either at presentation or later in the disease course is uncommon in the setting of high-grade osteosarcoma. Purpose of the study was to investigate this of patients' population in order to assess results of contemporary treatment modalities. Methods. There were 19 synchronous and 53 metachronous high-grade osteosarcoma cases. In the synchronous group there were 4 patients with a known genetic disorder: 1 Li-Fraumeni, 1 t (6; 22), 1 Bloom syndrome, and 1 Rothmund-Thomson syndrome. Patients received contemporary treatment ranging from palliative radiation therapy to aggressive preoperative chemotherapy combined with multiple removal of the osteosarcomas by either amputation or limb salvage surgery. Nine patients had preoperative chemotherapy combined with surgical management of all the lesions. In the metachronous group there were 53 patients in which secondary bone involvement manifested at some point after treatment of the initial lesion. Thirty-five patients were aggressively managed using either high-dose radiation therapy and/or surgery. Results. In the group of 19 synchronous cases there were 2 long term survivors (10.5%); both had preoperative chemotherapy followed by surgery of all the involved sites. Survival in the group of 9 patients treated with aggressive chemotherapy and surgery is therefore 22% (2 out of 9 patients). Overall 3-year survival rate of the 53 metachronous patients was 23% (11 of 53 patients). In the subgroup of 35 cases managed with high-dose radiation therapy and/or surgery the 3-year survival rate was 34%. All the survivors had a disease-free interval from the initial presentation longer than 2 years. Discussion and Conclusion. Multiple osteosarcoma is traditionally associated with a fatal prognosis. The synchronous multifocal variety was associated in this series with 21% incidence of known genetic disorders. The use of contemporary chemotherapy associated with aggressive surgical management of the involved sites seems to offer the only chance for survival. Metachronous osteosarcoma may be associated with respectable survival rate if aggressively

managed. Success rate in this subset of patients is better than historical results reported in the literature. Multiple bone involvement occurring less than 2 years from initial presentation usually portends the worse prognosis.

PAPER NO. 230

Long-Stem Femoral Arthroplasty for Proximal Femoral Metastases. An Analysis of 160 Consecutive Patients

Alan W Yasko, MD, *Houston, TX (n)*
Valerae O Lewis, MD, Houston, TX (n)
Kristy L Weber, MD, Wildwood, MO (n)
Patrick P Lin, MD, Houston, TX (n)

Introduction Long-stem femoral arthroplasty for stabilization of impending or established pathologic fractures of the proximal femur is reported to result in frequent adverse hemodynamic and implant-specific events. It is hypothesized that pre- and intra-operative maneuvers can result in low patient morbidity associated with this procedure while providing a durable construct for patients with progressive metastatic disease. The efficacy and morbidity of long-stem femoral arthroplasty was analyzed in a consecutive series of cancer patients. MethodsA comprehensive review of the medical records and radiographs was performed for 160 consecutive patients who had this procedure performed for metastatic disease arising in the proximal femur. Medical comorbidities, intraoperative course, postoperative recovery and outcome at last follow-up or until patient death were analyzed. ResultsPreoperative medical optimization and intraoperative maneuvers to avoid perioperative desaturation and hypotension resulted in only 8 (5%) patients developing intraoperative hemodynamic instability requiring sympathomimetic administration. There were two perioperative deaths resulting from cardiopulmonary complications. The median hospitalization was 7 days. Satisfactory pain control was achieved in greater than 90% of patients. All patients who ambulated preoperatively (89%) resumed ambulation following surgery. Four (2.5%) implant-related events prompted reoperation. Discussion Recognition of the inherent risk of adverse clinical events in the surgical management of patients with skeletal metastases of the proximal femur can preempt complications. This procedure results in successful pain palliation and functional preservation with low morbidity.

POSTERS

POSTER NO. P173

Angiogenesis and Osteosarcoma-A Clue to New Therapeutic Strategy for Osteosarcoma

Mitsunori Kaya, *Hokkaido, Japan (n)*
Takuro Wada, MD,PhD, Sapporo, Japan (n)
Satoshi Nagoya, MD, Sapporo, Japan (n)
Satoshi Kawaguchi, Muroran, Japan (n)
Junichi Takada, MD, Sapporo, Japan (n)
Kazuo Isu, Sapporo, Japan (n)
Toshihiko Yamashita, MD, Sapporo, Japan (n)

Introduction For the further improvement of prognosis for patients with osteosarcoma, 1) prediction of the pulmonary metastases and 2) clarification of the mechanism of progression of pulmonary metastasis are necessary. Angiogenesis is essential for tumor metastasis. We investigated the clinical significance of angiogenesis for pulmonaly metastases of osteosarcoma. Materials and Methods We immunohistochemically stained biopsy specimens of 43 osteosarcomas using anti-VEGF antibody and evaluated the correlation of VEGF expression to pulmonary metastasis and survival (mean follow-up periods, 12.2yrs). Peripheral venous blood samples were taken from 16 patients before biopsy and the correlation of pre-therapeutic serum VEGF levels and disease relapse was evaluated (mean follow-up periods, 3.8yrs). Most pulmonary metastases have relapsed soon after primary tumor removal, we have evaluated the effect of primary tumor removal for systemic angiogenesis. Angiogenesis-inducing ability of the serum obtained from the patients was quantitatively analyzed using Matrigel plug assay. Results The patients with VEGF-positive tumor highly relapsed with pulmonary metastasis (5.3% in VEGF-negative versus 87.5% in VEGF-positive, $p<0.05$) and were poorer in survival ($p<0.05$). The serum VEGF levels were higher in patients in relapsed group ($p=0.0009$). The angiogenesis-inducing activity of patients with disease relapse increased after primary tumor removal. Discussion and Conclusion Our results suggest that patients with VEGF-positive tumor or high serum VEGF levels are highly expected to relapse with pulmonary metastasis after primary tumor removal through the systemic angiogenesis activation. Therefore, such patients will be good candidates for anti-angiogenic therapy. This therapeutic strategy may prevent the progression of pulmonary metastasis and enable osteosarcoma patients to coexist with dormant metastasis which will lead to the improvement of their prognosis.

POSTER NO. P174 - WITHDRAWN

POSTER NO. P175

Enchondromas: Pattern of Referral and Their Outcome

Sameer Nagda, MD, *Philadelphia, PA*
(a,e – Stryker Howmedica Osteonics)
Rakesh Donthineni-Rao, MD, Sacramento, CA (n)
Brian Vannozzi, MD, Philadelphia, PA (*)
Richard D Lackman, MD, Philadelphia, PA (*)

Introduction: Enchondromas are benign cartilaginous tumors, often found incidentally and diagnosed by the radiographic appearance. Active growing enchondromas/low grade chondrosarcomas are diagnosed by symptoms at the site and possibly an aggressive appearance on the radiographs. The influence for the request for referral was studied and also the outcome to understand the confidence in diagnosing these tumors. Materials & Methods: We retrospectively reviewed charts of patients over three consecutive years noting any mention of an enchondroma in the differential diagnosis and reviewed the radiology report, patient's symptoms, our initial diagnosis, follow-up and any decision for a biopsy/surgical management were included. Results: A total of 115 were identified with an average age of 61 years. Nearly 80% were located in the distal femur and proximal humerus, with lesser numbers in the other bones. 75% had pain of the affected area and the rest found incidentally. Only 12 patients mentioned night pain as well, although none of these resulted in a biopsy. Although all the patients were referred by another clinician, the radiology reports mentioned 'malignancy / neoplasm / sarcoma' either alone or in combination about 50% of the reports and sometimes along with the possibility of an enchondroma. Adjacent arthritis +/- tendinopathy was mentioned on the radiology reports in 40%. Our initial evaluation noted 'scalloping/cortical erosion; lytic areas; cortical breaks; soft tissue extension' suggestive of an active lesion in 12

cases and only 8 (7% of total) underwent a biopsy. 65% were diagnosed with a clinical/radiographic diagnosis of an adjacent joint arthritis or tendinopathy. The final diagnosis was an enchondroma in all our patients. The non-operative cases have been stable over two years. Conclusions: About 50% of the imaging reports mentioned a malignancy in the differential diagnosis of an enchondroma encouraging a referral to a specialist. Very few had the classic signs of an aggressive/growing cartilage tumor. Only a small percentage underwent an open biopsy. Otherwise 50% of the patients were sent back to the referring physician for future follow up. Even small, well defined lesions are often confused for a sarcoma or other malignancies. This may reflect on the deficiencies of education on bone tumors for both the radiologists and also the general orthopedists.

POSTER NO. P176

Rotating Hinge Knee Mechanisms and Tumor Endoprostheses

Yu-Po Lee, MD, *Los Angeles, CA (n)*
William G Ward, MD, Winston-Salem, NC (a – DePuy, Howmedica, Centerpulse, e – Smith&Nephew)
Cynthia M Kelly, MD, Golden, CO (n)
Michael Kabo, PhD, Los Angelos, CA (n)
Frederick Dorey, PhD, Los Angeles, CA (*)
Jeffrey John Eckardt, MD, Los Angeles, CA (*)

INTRODUCTION: Constrained knee mechanisms are generally required for tumor endoprosthetic reconstructions because oncologic considerations necessitate resection of all the stabilizing ligaments. A rotating hinge knee has the unique advantage of allowing axial rotation and thus diffuses the stress within the prosthesis and at the bone-cement-prosthesis interface, thus potentially reducing the incidence of fatigue fracture and aseptic loosening. MATERIALS AND METHODS: Between December 1980 and July 2001, 314 endoprostheses utilizing rotating hinge knees were implanted at UCLA. The reconstruction was a distal femoral replacement (DFR) in 243, a proximal tibial replacement (PTR) in 45, and a total femoral replacement (TFR) in 26. The indication for the endoprosthetic reconstruction was a primary tumor in 226, a failed endoprosthesis in 61, a failed trauma ORIF in 12, a failed total joint arthroplasty in 6, for metastatic disease in 3, and other conditions in 6. All causes of mechanical failure were analyzed. The Musculoskeletal Tumor Society rating system was used to evaluate functional results. RESULTS: Mechanical failure was classified as aseptic loosening, fatigue failure, or failure of the polyethylene bushings, and occurred in 17.1 percent (54/314) of the reconstructions. Mechanical failure occurred in 42/243 DFRs, 10/45 PTRs, and in 2/26 TFRs. Aseptic loosening occurred in 22 distal femoral and 3 proximal tibia replacement stems for an overall incidence of 7.9 percent (25/314) at a mean of 46 months. Fatigue fracture occurred in 13 DFRs and 2 TFRs for an incidence of 4.7 percent (15/314) at a mean of 96 months. Bushing failures were uncommon and occurred in 7 DFRs and 7 PTRs for an overall incidence of 4.5 percent (14/314) at a mean time of 84 months. The overall endoprosthesis failure rate was 11 percent and 35 percent at 5 and 10 years, respectively. While overall survivorship of the DFR, PTR, and TFR were similar at 5 years, the overall survivorship at 10 years differed. At 10 years, the survivorship of the DFR was 74 percent, the PTR was 52 percent, and the TFR was 91 percent. The relatively lower survivorship of the PTR was due to the original design that used folded tabs to capture and hold the polyethylene component. This has been revised to a press fit design and no new failures have been observed. All of the mechanical failures were revised without incident. The overall function of the patients after surgery were uniformly good to excellent as measured by the Musculoskeletal Tumor Society rating. The average range of motion at the knee was 112 degrees for the DFR, 115 for the PTR, and 115 degrees for the TFR. CONCLUSIONS: Over the years there has been an evolution of endoprosthetic design to include forged rather than casted stems. Extramedullary porous in-growth surfaces were applied to help prevent aseptic loosening and a design modification in the late 80's has eliminated all polyethylene failures in the proximal tibia replacements. Selected cross-pin stem fixation also enhances fixation and prevents aseptic loosening. The only thing that has remained the same over the past 22 years has been the rotating hinge knee, which has become the gold standard for large endoprosthetic reconstructions involving the knee.

POSTER NO. P177

Perioperative Complications with Cemented Long Stem Femoral Components in Metastatic Bone Disease

Robert Lor Randall, MD, *Salt Lake City, UT (a – Biomet)*
Stephen Aoki, MD, Salt Lake City, UT (*)
Patrick Olson, MBBS,MRCS, Salt Lake City, UT (*)
Steve Bott, Salt Lake City, UT (n)

Introduction: Perioperative complications including hypotension and cardiopulmonary arrest have been associated with the use of long stem cemented femoral components in hip arthroplasty. We hypothesize that early cure stage deployment of PMMA with concurrent utilization of long endoscopic suction reduces morbidity to that of cementing conventional short stem femoral components in a similar patient population with metastatic bone disease. Methods:A retrospective chart review was performed of the first twenty-two consecutive cases undergoing either hemi- or total hip arthroplasty using the same long stem (300mm) femoral component for impending or realized fractures secondary to metastatic bone disease. Long laparoscopic suction of the femoral canal was performed concurrent with deployment of early stage PMMA down the entire length of the canal. No distal venting was performed. We assessed age at time of surgery, sex, disease type, Mirel's score, Harrington class when applicable, cement associated desaturation (CAD; defined as a drop below 90% O2 sat), cement associated hypotension (CAH; defined as a drop of 30% SBP), need for sympathomimetics, extubation in the O.R., postoperative desaturation, postoperative hypotension as well as MSTS functional score. Results:Twenty-two femoral components were placed in twenty patients. Zero CADs were experienced. Two CAHs occurred which were readily reversible. Both of these patients were extubated in the operating room. Two patients required delayed extubation in the SICU on the same day of surgery. No immediate perioperative hemodynamic sequelae resulted. While two patients died within three weeks of surgery (d 14, 21), neither death was related directly to surgery. Discussion & Conclusion:Although not a controlled study, we feel that with careful attention to early deployment of PMMA and venting via a long laparoscopic sucker, cemented long stem femoral component hip arthroplasty is a viable option in the patient with advanced metastatic bone disease.

POSTER NO. P178

Coexisting Findings Associated with Solitary Enchondromas of the Proximal Humerus

Jonathan C Levy, MD, *Miami Beach, FL (n)*
H Thomas Temple, MD, Miami, FL (n)
Allaaddin Mollabashy, MD, Miami, FL (n)
Jason B Sanders, MD, Miami, FL (*)
Mark J Kransdorf, MD, Jacksonville, FL (n)

Introduction: Patients with enchondroma of the proximal humerus frequently present to the general orthopaedist with shoulder pain. We reviewed our experience with this subgroup of patients to identify those that presented with pain, and the most likely causes of that pain. Methods: A retrospective review of clinical records and radiographic studies (radiographs, MRI, and bone scan) was performed for all patients presenting to an orthopaedic oncology unit with shoulder pain and a solitary enchondroma of the proximal humerus. Attention was focused on diagnostic evidence of additional pathology such as glenohumeral and acromioclavicular arthrosis, labral pathology, joint effusion, rotator cuff tendinopathy as well as complete and partial tears, bicipital tendonitis, subacromial and subdeltoid bursitis and trauma. Patients were excluded from the cohort if an MRI or report of MRI findings was absent. Results: Fifty-seven patients with proximal humerus enchondromas were identified with a mean age of 53.6 years. There were 41 females and 16 males. By clinical examination, impingement syndrome was most commonly diagnosed (17/57, 30 percent) condition. MRI analysis found 81 percent (46/57) to have additional shoulder pathology with the most common MRI finding being rotator cuff tendinopathy (51 percent, 25/46). 64 percent of the MRI findings (58/90) had correlation by clinical examination and 82 percent (47/57) of clinical examination diagnoses were confirmed by MRI. Discussion and Conclusion: Solitary enchondromas of the proximal humerus are often found incidentally during the evaluation of patients with shoulder pain. This study demonstrated that additional pathology is usually present in patients referred with enchondromas of the proximal humerus.

POSTER NO. P179

Prevention of Post-Laminectomy Spinal Deformity in Children with Intramedullary Spinal Cord Tumors

Sumeet Garg, *Brookline, MA (n)*
Scott S Simon, MD, Philadelphia, PA (n)
Leslie N Sutton, MD, Philadelphia, PA (n)
John P Dormans, MD, Philadelphia, PA (*)

Introduction: This study examines the effectiveness of single-stage tumor excision and spinal instrumentation in preventing post-laminectomy spinal deformity in children with intramedullary spinal cord tumors. Methods: 129 children with spinal cord tumors have been treated at our institution since 1970. Of these, 47 had intramedullary tumors and were retrospectively reviewed. 15 were excluded due to: death within two years of diagnosis (8), diagnosis within the last two years (4), or lack of follow-up (3). Results: 32 children with mean age at presentation of 9 years (range 2.5-14.9) and mean follow-up of 6.5 years (range 2-22.7) were reviewed. An average of 6.7 laminae per patient were removed (range 2-15). Initial surgical treatment consisted of laminectomy only in 16, laminoplasty in four, and laminectomy plus spinal fusion in 12. 5 of 12 children with spinal fusion at time of tumor decompression developed significant post-laminectomy deformity, however, four of these five had progressive neurologic defecits due to tumor progression or recurrence. 12 of 20 children without spinal fusion at time of tumor excision developed significant spinal deformity; of those developing deformity, 5 of 12 had progressive neurologic defecits due to tumor progression or recurrence. Excluding those with progressive neurologic defecits following tumor excision, only 1 of 8 children with spinal fusion developed a deformity while 7 of 15 children without spinal fusion developed a deformity, a siginificant finding ($p<0.05$). Conclusions: •In the absence of neurologic defecits due to tumor progression or recurrence, instrumented spinal fusion at the time of tumor excision is usually effective in preventing post-laminectomy deformity and should be considered in all children with intramedullary spinal cord tumors.

POSTER NO. P180

The use of Calcium Sulfate Pellets in the Treatment of Benign Skeletal Lesions

Jack Chen, MD, *Topanga, CA (e – Wright Medical)*
Lawrence R Menendez, MD, Los Angeles, CA (*)
Charalampos Zalavras, MD, Arcadis, CA (n)

Purpose: The purpose of the current study is to assess the efficacy of medical-grade calcium sulfate per se as a bone graft substitute in the treatment of benign skeletal lesions. Material and Methods: This is a retrospective review of all patients operated on by the senior author from July 1999 to February 2001. We included any patient with a histologically confirmed benign lesion that was treated with calcium sulfate pellets. The exclusion criteria were follow-up less than six months (unless the lesion healed within six months), the addition of any other bone graft substitute, and diagnosis of infection. The resorption of calcium sulfate and the progress of bone healing were monitored in all postoperative plain radiographs. The size of each bony defect was approximated by measuring its length and width on the single radiograph that best demonstrated the defect. Healing was strictly defined as absence of any lucency at the affected site, indicating complete filling of the bone defect with newly formed bone. Partially healed lesions were classified as not healed. Results: 53 patients met our inclusion criteria. There were 28 males and 25 females with a mean age of 39.8 years. The most common diagnosis was enchondroma; the most common site was the proximal humerus. The median size of the lesions measured 805 mm2 (range 12 to 4200 mm2). Mean follow up is 32.5 weeks (range 4 to 104 weeks). The calcium sulfate completely resorbed at a median time of 8 weeks. Healing of the bone defect with no lucency was evident in 38% of the defects by 6 months postoperatively. The healing rate increased to 92% at 18 months. Factors associated with healing were lesion size smaller than 1000 mm2 ($p = 0.03$) and metaphyseal location ($p = 0.009$). Complications in this series included 2 fractures and 1 case of deep infection. Conclusions: The current study is the largest to date on patients treated with calcium sulfate pellets. It is distinguished from other studies in that our patients were treated with calcium sulfate alone. Our study also indicates differences in the early healing rate based on the size and location of the lesion.

POSTER NO. P181

The Definition of Target Sign and Its Utility for the Diagnosis of Schwannomas

Hideyuki Koga, MD, *Fukuoka, Japan (n)*
Noriyoshi Kawaguchi, MD, Tokyo, Japan (*)
Seiichi Matsumoto, MD, Kobe, Japan (*)
Jun Manabe, MD, Tokyo, Japan (*)
Taisuke Tanizawa, MD, Tokyo, Japan (*)
Makoto Hirata, Tokyo, Japan (*)

Introduction: It is essential to differentiate schwannomas from other soft tissue tumors. We clearly defined characteristic Target sign and evaluated its utility for the diagnosis of schwannomas. Methods: We retrospectively reviewed radiological, macroscopic and histopathological findings of 310 schwannomas and studied the correlation among them. Results: 254 tumors showed biphasic pattern of central Antoni A and peripheral Antoni B macroscopically and histopathologically. 73 percent of those also showed biphasic pattern on MRI. Gadolinium (Gd)-enhanced T1-weighted images (T1WIs) showed central high intensity and peripheral low intensity while T2-weighted images (T2WIs) showed peripheral high intensity and central low intensity inversely. 87 cases had cystic, hemorrhagic, or necrotic degeneration, which corresponded to high intensity on T2WIs and low intensity on Gd-enhanced T1WIs. Such degeneration was only in Antoni A, and nine cases in which degenerative area was only in central portion of Antoni A showed tri-phasic pattern. The biphasic pattern was absent when degenerative area was larger or peripheral Antoni B was thin, even if biphasic pattern was present macroscopically. Discussion and Conclusion: This study showed that schwannomas basically consisted of the two areas of central Antoni A and peripheral Antoni B, if degenerative change didn_ft occur. We clearly defined that Target sign was the biphasic or tri-phasic pattern shown above, and it showed that those findings were extremely correlated to macroscopic and histopathological findings. Target sign was a characteristic of schwannomas and was absent in any other soft tissue tumors, so it was quite useful for the diagnosis of schwannomas.

POSTER NO. P182

The Clinical Significance of TGF-beta Isoform and VEGF Expression in Osteosarcoma

Sung Taek Jung, MD, *Gwangju, Korea, Republic of (n)*
Eun-Sun Moon, Prof, Kwangju-City, Korea, Republic of (n)
Eun Kyoo Song, MD, Kwangju, Korea, Republic of (n)
Kye-Jin Kim, MD, Kwangju, Korea, Republic of (n)
Yang-Kyung Kim, MD, Kwangju, Korea, Republic of (n)
Yong-uk Kim, MD, Kwangju, Korea, Republic of (*)

Introduction: Osteosarcoma was examined to determine firstly, if VEGF and the TGF-beta isoform were overexpressed in this sarcoma, and secondly, if the degree of expression might represent a significant biologic predictor for disease-specific survival. Material and Methods: Selected paraffin-embedded tissues of surgical specimens from 25 patients of prechemotherapy case with osteosarcoma, were stained with rabbit polyclonal anti-VEGF and TGF-beta isoform antibodies. The degrees and patterns of the TGF-beta isoform and VEGF expression were evaluated using SPSS 10.0 software by analyzing the correlation between age, sex, tumor size and the growth factors using the Spearman's correlation coefficient. A Mann-Whitney u test was performed to analyze the correlation between the degree of growth factor expression according to histological grade and death, and the presence of metastasis. The Kaplan-Meier method was used to analyze survival and to investigate the survival curve of each growth factor. The log rank test was performed to investigate the prognostic factors that were significantly correlated with survival. A p value < 0.05 was considered significant. Results: The survival rate of the 25 patients was 80%, and there were no clinical prognostic factors affecting the survival rate. All 5 patients who died of the osteosarcoma exhibited strong VEGF expression (p=0.023). Tumor grade correlated significantly with TGF-beta 2, -beta 3 and VEGF expression. According to the Kaplan-Meier method, no statistically significant difference between the degrees of TGF-beta 1,-beta 2 and -beta 3 expression and the survival rate was observed. The survival rate decreased with increasing VEGF expression level.

POSTER NO. P183

Anhydrous Alcohol as an Adjuvant to Curettage and Bone Graft or Cementing in Giant Cell Tumors

Joo Han Oh, MD, *Seongnam, Korea, Republic of (n)*
Sang-Hoon Lee, MD, Seoul, Korea, Republic of (n)
Han-Soo Kim, MD PhD, Seoul, Korea, Republic of (n)
Moon Sang Chung, MD, Seoul, Korea, Republic of (n)
Goo Hyun Baek, MD, Seoul, Korea, Republic of (n)
Hwan-Seong Cho, MD, Seoul, Korea, Republic of (n)
Pil Whan Yoon, MD, Seoul, Korea, Republic of (n)
Sung Wook Suh, MD, Goyang, Korea, Republic of (n)

Introduction: Curettage followed by local adjuvant therapy and reconstruction with bone graft or cementing is generally accepted treatment for giant cell tumors (GCT) of long bone. Although several adjuvant modalities had been used, anhydrous alcohol was applied in our institution due to such potential carcinogenic or pollution risks of phenol. So, we evaluated the feasibility and effectiveness of anhydrous alcohol for the adjuvant treatment of GCT. Methods: One hundred and three GCTs were treated and followed up for 6 years (range, 2 - 29.3 years) with the mean age of 33 years (range, 16 - 67 years). Wide resection only or wide resection with prosthetic reconstruction was performed in 34 patients. Curettage, an additional high-speed burring, and reconstruction with bone graft or cementing were performed in 69 patients. Among them, anhydrous alcohol was used as an adjuvant in 38 patients. Results: Four (10.5%) patients of anhydrous alcohol treatment had local recurrence, whereas 15 recurrences (48.4%) developed in 31 patients treated without anhydrous alcohol (p=0.001). There were no anhydrous alcohol-related complications. For the reconstruction of bone defect, there were no significant differences between the uses of bone graft and cementing. Discussion and Conclusion: Anhydrous alcohol can alter the structure of proteins, and cause distortion of nuclear detail and shrinkage of cytoplasm in cells. Our data suggested that anhydrous alcohol could be used as an effective adjuvant without potential risks for the treatment of GCT of long bone.

POSTER NO. P184

Reconstruction with Extra-corporeal Radiation Bone after Resection of Musculoskeletal Tumors

Tetsuo Hotta, MD, *Niigata City, Japan (n)*
Naoto Endo, MD, Niigata City, Japan (n)
Akira Ogose, MD, Niigata City, Japan (*)
Hiroyuki Kawashima, MD, Niigata City, Japan (n)
Tetsuro Morita, MD, Niigata City, Japan (n)
Hiroshi Hatano, Niigata City, Japan (n)
Yoshiya Inoue, MD, Shizuoka, Japan (n)
Hidehiko Saito, MD, Shizuoka, Japan (n)

INTRODUCTION In Japan, recycled bone, such as pasteurized, autoclaved, or irradiated bone, is popular for the tumor reconstruction, because massive allograft is hardly available. This study was performed to clarify the destiny of the grafted radiation (Rx) bone. METHODS From 1994, Rx bone has been used in the reconstruction after resection of musculoskeletal tumor. Fourteen bone tumor and 4 soft tissue tumor cases were included in this study. The average age was 49 year-old. Mean follow-up period was 51 months. Osteoarticular graft (OAG) was performed in 7 cases, intercalary graft (ICG) in 8 cases, and hemi-cortical graft (HCG) in 3 cases. Union rate, survival rate of the graft, and complication was examined. Histological examination of the graft was also available in 7 cases. RESULTS Union rate was 83.3 per cent. Non-union occurred in one hip OAG case and 2 ICG cases. Delayed union and infection were observed in each one OAG case. Survival rate of ICG, OAG, and HCG was 83.3, 28.6, and 100 per cent, respectively. All OAGs in the lower extremity failed into collapse, destruction, or osteolysis. Complication rate was 44.4 per cent. Histological examination revealed intramedullary revascularization of the graft with osteonecrosis, new bone formation in the junction area, and a small numbers of viable cartilage cells. DISCUSSION AND CONCLUSION Rx bone was quite helpful for the intercalary reconstruction of the bone defect. OAG in the lower extremity never survived longer, however it could provide a sufficient bone stock for the secondary total arthroplasty.

POSTER NO. P185

Fertility in Young Adults Following Chemotherapy for High Grade Bone Sarcomas

Richard D Lackman, MD, *Philadelphia, PA*
(a,e – Stryker Howmedica Osteonics)
Kathy Henderson, BSN, CRNP, Philadelphia, PA (*)
Susan Stonehouse Lee, MSN, CRNP, Philadelphia, PA (n)
Rakesh Donthineni-Rao, MD, Sacramento, CA (*)

Introduction: Chemotherapy improves long term survival and limb salvage for patients with high grade bone sarcomas but also raises concerns for longterm fertility problems. We hypothesized that while concerns for infertility are common, the occurrence of infertility is rare. Methods: Between 1985 and 1994, 36 adolescents were treated for high grade bone sarcoma (26 osteosarcoma, 8 Ewing's and 2 other). Typical multidrug pre and post surgical chemotherapy regimines were administered. Surviving patients were surveyed for attempts at child bearing and pretreatment fertility counseling. Results: 21 of 28 spindle cell and 5 of 8 Ewings's patients were long term survivors. 10 of the spindle cell and 3 of the Ewing's survivors (9 males and 4 females) had attempted childbearing. All reported 1 to 3 births. All reported full pregnancies, no fertility drugs given and no birth defects. The majority of patients conceived their children within 3 months with a maximum time to conception of 9 months. The mean time to conception from cessation of chemotherapy was 6 years with a range of 1 to 11 years. In regard to pretreatment fertility counseling, 4 recalled a prognosis for probable infertility, 3 did not anticipate problems and 6 did not recall specific information but were aware of possible infertility problems. Discussion: In our series no fertility problems were seen in 13 patients who attempted childbearing following treatment for high grade bone sarcoma. In light of this we counsel our patients that they will probably not have fertility problems following such treatment. This removes the anger and frustration associated with the spector of probable infertility so often associated with sarcoma treatment.

POSTER NO. P186

En Bloc Resection of the Lateral Malleolus and Ankle Reconstruction for Malignant Tumors of the Distal Fibula

Panayiotis J Papagelopoulos, MD, *Athens, Greece (n)*
Olga D Savvidou, MD, Athens, Greece (*)
George Sotirios Themistocleous, Athens, Greece (*)
Krishnan K Unni, MD, Rochester, MN (*)
Franklin H Sim, MD, Rochester, MN (*)

INTRODUCTION:The aim of this study was to analyze the oncologic and functional outcome of en bloc resection of the lateral malleolus for malignant tumors of the distal fibula. MATERIAL-METHODS:There were 10 patients (4 children of mean age, 7.5 yrs and 6 adults of mean age, 42 yrs).The tumors included 4 osteosarcomas, 3 chondrosarcomas, 2 Ewing sarcomas, and 1 adamantinoma.Extraarticular resection was performed in 6 patients and intraarticular resection was performed in 4.A primary ankle arthrodesis was performed in 4 adults and postoperative bracing without any reconstruction in 4 children and 2 adults. RESULTS:Within a mean follow up time of 14.4 years, a local recurrence occurred in 2 patients.Reoperation was performed in 6 patients including a below knee amputation in 3. Five patients with arthrodesis had an International Society of Limb Salvage (ISOLS) functional score of 27.6(92%) and 2 adolescents with no primary soft tissue reconstruction had an ISOLS score of 24(80%).All 10 patients were disease free at the last follow up. CONCLUSION:Limb salvage surgery for malignant tumors of the distal fibula can be done through a wide extra-articular or intra-articular resection.Primary ankle arthrodesis is indicated for adults after extra-articular resection.In children, repair of the lateral soft tissues and reconstruction of the tibiofibular mortise is necessary after tumor resection to avoid late ankle deformity or instability.Adjuvant radiotherapy may preclude late reconstructive procedures.

POSTER NO. P187

Primary Synovial Sarcoma of the Hand

Mark James Herr, MD, *Rochester, MN (n)*
Sean P Scully, MD, PhD, Rochester, MN (n)

Introduction: Our goal was to review the experience evaluating and treating soft tissue sarcomas (STS) about the hand. Methods: Seventy-eight consecutive patients, diagnosed with and treated for a primary STS of the hand, were identified. Eleven of the 78 patients were diagnosed with primary Synovial Cell Sarcoma of the hand Results: There were 5 males and 6 females. The average age was 31.4 years. The average follow-up was 111 months. Treatment included wide excision, hemi-amputation, radiation, and ray amputation. Adjuvant therapy was utilized in seven patients. One patient died secondary to disease at 57 months. One patient had pulmonary metastasis at 36 months, treated with surgery, radiation, and chemotherapy. This patient was alive with

no evidence of disease at 135 months. Conclusion: Ninety-one percent of patients treated had no evidence of disease at last follow-up after aggressive use of surgery and or adjuvant therapies.

POSTER NO. P188

Long-Term Follow-up of 67 Patients Treated for Pigmented Villonodular Synovitis (PVNS)

Catharina Chiari, MD, *Vienna, Austria (n)*
Christian Pirich, MD, Vienna, Austria (n)
Franz Kainberger, MD, Vienna, Austria (n)
Klemens Trieb, MD, Vienna, Austria (n)

Introduction: PVNS is a rare, benign lesion characterised by locally aggressive growth. Despite of radical surgery and adjuvant theapies recurrence rates are high. Methods: 67 consecutive patients (42 male, 25 female, average age 45.9 years, range 6.7-78.8) treated surgically at our center were evaluated retrospectively. Results: Locations of disease: 26 hands, 20 knees, 11 feet, 4 ankles, 4 hips, 2 shoulders. Types of surgery: 43 resections, 19 synovectomies of joints, 3 toe amputations, 2 arthroplasties. 56 patients were followed clinically, 4 patients had died (89.6% follow-up rate). Preoperative duration of symptoms was 48.5 months (range, 0.5 –360.7). 13 of 29 preoperative MRIs led to the correct diagnosis of PVNS. 12 patients were reoperated for recurrent disease after previous surgery elsewhere. At the point of follow-up 9 patients had been operated meanwhile because of recurrence. After an average follow-up of 79.8 months (range 6.9-293.8) there were 4 cases of recurrence (7.1%). 39 patients had a follow-up MRI , in the remaining cases clinical examination revealed no sign of recurrence. Adjuvant radiosynovioorthesis was performed in 9 knee joints 7.4 weeks postoperatively (range, 3,4-13,8). Clinical results were very satisfying among the patients without recurrence, in the group of knee joints the average Lysholm Score was 95.7 points (range, 81-100). Conclusion: The review of our data shows, that early perfomance of MRI (typically decreased signal in T1 and T2, caused by hemosederin deposits), radical surgery, adjuvant radiosynovioorthesis in large joints and MRI follow-up lead to accurate diagnosis and acceptable rates of local recurrence.

POSTER NO. P189

Long-term Follow-up After Surgical Treatment for Enchondroma of the Proximal Humerus

Joshua D Auerbach, MD, *Philadelphia, PA (n)*
Gregory Gillman Klingenstein, BA, New York, NY (*)
Edmond Cleeman, MD, New York, NY (n)
Dempsey S Springfield, MD, New York, NY (n)

Introduction: Enchondromas are benign cartilage tumors which commonly occur in the proximal humerus. Although uncommon, the potential for malignant transformation into chondrosarcoma mandates close observation and occasionally, surgical management. Methods: This is a retrospective review of all patients referred to the senior author with an enchondroma of the proximal humerus, taken from a population of 1649 new patients between 1996-2000. Lesions with characteristic radiographic findings of a cartilaginous tumor without cortical penetration were diagnosed as enchondroma. There were 43 patients, 15 males and 28 females with an average age of 52(range 29-85). Patients were operated if they had anxiety with the specific diagnosis, continuous unexplained pain, or a large lesion with cortical scalloping. Results: Thirty-two patients(74%) presented with shoulder pain, of which 18(56%) had other shoulder pathology, most commonly rotator cuff disease(8/32). Eleven patients(26%) were diagnosed incidentally on plain X-ray. Twelve patients(28%) underwent surgery (e.g. biopsy, curettage, and allograft/cement). The most common indications for surgery included patient anxiety(9/12), large lesion with cortical scalloping(5/12), and continuous unexplained pain(4/12). Mean follow-up was 51 months(range: 33-68 months). Four patients(33%) reported improved pain, while 8 patients(67%) reported no change. No patient had evidence of recurrent disease, and all grafts were adequately incorporated. The 31 patients not operated on have been followed for an average of 50 months(range: 29-76) with none progressing to chondrosarcoma. Conclusions: Patient anxiety, large lesions, and unexplained pain are the most common indications for surgery of enchondroma in the proximal humerus. Surgical treatment has demonstrated adequate results at long-term follow up.

POSTER NO. P190

Importance of Particle Size on Healing of Bone Allografts

Theodore Malinin, MD, *Miami, FL (a,d,e – Biomet)*
H Thomas Temple, MD, Miami, FL (a – Biomet)

Introduction: Ideal properties of bone allografts used to fill osseous defects are ill-defined. Heterotopic bone formation in rodents is often used as an index of osteoinductivity. We employed a primate model to study osseous defects filled with bone allografts of various particle sizes. Methods: Study was performed on 28 baboons with 12 x 14 mm defects in the metaphyses of the femur and tibia. Aseptically processed, freeze-dried particulate cortical and cancellous bone 1-2 mm, 500-800µ and less than 350µ in size was tested. Control defects were either unfilled or filled with autografts. Results: Consistent and complete filling occurred with particles less than 350µ. These incorporated and produced new bone directly without endochondral ossification. Decalcified bone induced new bone formation around the defect, with incomplete incorporation. Discussion and Conclusions: Allograft particle size is important in determining the rate healing and replacement of host bone. Undecalcified particles transform directly into trabecular bone. Decalcified particles induce endochondral ossification. In patients cortical bone grafts with particle sizes less than 350µ appear to behave as they do in experimental animals. .

POSTER NO. P191

◆Massive Custom Made Unicompartmental Knee Arthroplasty for Tumours

Tushar R Jimulia, MBBS, *Stanmore Middlesex, United Kingdom (n)*
Steve R Cannon, FRCS, Stanmore Middlesex, United Kingdom (*)
Paul Unwin, PhD, Middlesex, United Kingdom (*)

INTRODUCTION: The purpose of this study is to present our experience of custom made massive unicompartmental knee replacements for tumours. The problem we face occasionally is partial bony involvement of the distal femur, and it would be ideal not to sacrifice the uninvolved half of the distal femur. The design of this new prosthesis does just that. METHODS: Between 1989 and 1999, 14 cases of massive custom made unicompartmental knee arthroplasties were done for a variety of tumours, both low grade aggressive as well as benign. There were 4 males and 10 females. The average age was 45.5years. The follow- up was between 2 and 12 years (average 8.1 years). We used rigorous criteria prior to selection of a patient for this surgery. Special custom-made prosthesis was made for each patient. RESULTS: The post-operative range of motion was excellent.One patient

died from metastatic liver disease. None has been revised to date. All these patients did well on the knee scores and mobilised full weight bearing. DISCUSSION: This is new concept and design. These patients would have otherwise needed an allograft, with its due risks, or a massive distal femoral replacement. We have avoided the risks of allograft surgery, and sacrificed less bone as compared to a massive distal femoral replacement, and retained some proprioception. We have achieved good results, and feel that as long as the rigorous indications are met, this prosthesis is justified.

POSTER NO. P192

Immunologic and Radiographic Assessment of Large Bony Allografts

Carter D Kiesau, MS-IV, *Seattle, WA (n)*
Timothy Rapp, MD, Maywood, IL (n)
James D Bruckner, MD, Seattle, WA (n)
Karen A Nelson, PhD, Seattle, WA (n)
Ernest U Conrad III, MD, Seattle, WA (a – Northwest Tissue Center)

INTRODUCTION: Allografts were evaluated to assess the relationship between osseous union and the development of HLA Class I and Class II antibodies. METHODS: We evaluated 80 patients who had been treated surgically with a large bony allograft for a malignant bone tumor. Patients were assigned to a union or non-union group based on radiographic and clinical assessments. All patients were evaluated for antibodies to HLA Class I and Class II antigens at regular intervals and HLA antibody results were correlated with clinical outcome. RESULTS: Forty-six patients were assigned to the union group and 34 to the non-union group, with an overall average age of 28.4 years and a male to female ratio of 48 to 32. The rate of nonunion for this cohort was 38.8 percent. Bony union occurred in 57.5 percent of patients, with an average time to union of 14.6 months. Graft removal was required in 41.3 percent of patients. Serologic data revealed the development of Class I HLA antibodies in 66.3 percent of patients overall; 61.8 percent of non-union and 69.6 percent of union patients. Class II antibodies developed in 83.8 percent of patients overall; 85.3 percent of non-union and 82.6 percent of union patients. Chi-square analysis comparing clinical outcome to the production of Class I or Class II HLA antibodies was not significant. DISCUSSION AND CONCLUSION: The osseous healing of massive allografts remains a challenging clinical problem. This study demonstrates a positive correlation between Class II HLA antibody production and poor clinical outcome, however not of statistical significance. Analysis of specific HLA subtypes in these patients may be of some benefit in demonstrating how host/graft reactions might be minimized with the hope of improving osseous healing.INTRODUCTION: Allografts were evaluated to assess the relationship between osseous union and the development of HLA Class I and Class II antibodies. METHODS: We evaluated 80 patients who had been treated surgically with a large bony allograft for a malignant bone tumor. Patients were assigned to a union or non-union group based on radiographic and clinical assessments. All patients were evaluated for antibodies to HLA Class I and Class II antigens at regular intervals and HLA antibody results were correlated with clinical outcome. RESULTS: Forty-six patients were assigned to the union group and 34 to the non-union group, with an overall average age of 28.4 years and a male to female ratio of 48 to 32. The rate of nonunion for this cohort was 38.8 percent. Bony union occurred in 57.5 percent of patients, with an average time to union of 14.6 months. Graft removal was required in 41.3 percent of patients. Serologic data revealed the development of Class I HLA antibodies in 66.3 percent of patients overall; 61.8 percent of non-union and 69.6 percent of union patients. Class II antibodies developed in 83.8 percent of patients overall; 85.3 percent of non-union and 82.6 percent of union patients. Chi-square analysis comparing clinical outcome to the production of Class I or Class II HLA antibodies was not significant. DISCUSSION AND CONCLUSION: The osseous healing of massive allografts remains a challenging clinical problem. This study demonstrates a positive correlation between Class II HLA antibody production and poor clinical outcome, however not of statistical significance. Analysis of specific HLA subtypes in these patients may be of some benefit in demonstrating how host/graft reactions might be minimized with the hope of improving osseous healing.

POSTER NO. P193 – ORS

Hedgehog Signaling Regulates Proliferation In Chondrosarcoma: Implication For Novel Therapy

Tri D Tiet, MD, Toronto, Canada (*)
Sevan Hopyan, MD, Toronto, Canada (*)
Puviindran Nadesan, MD, Toronto, Canada (*)
Robert S Bell, MD, Tullahoma, TN (*)
Jay S Wunder, MD, Toronto, Canada (*)
Benjamin A Alman, MD, Toronto, Canada (n)

Chondrosarcoma is a malignant cartilage tumor, which may arise from benign precursor lesions, such as enchondromas. Some cases of multiple enchondromas are caused by a mutation in the parathyroid hormone related protein receptor, resulting in constitutive activation of Hedgehog mediated signaling. Indian Hedgehog (IHH) and Parathyroid hormone related protein (PTHrP) play crucial roles regulating growth plate chondrocyte differentiation. Primary chondrosarcomas were investigated, and found to exhibit a high level of expression of the hedgehog target genes, PTC1 and GLI1. In contrast to normal growth plates, we found that PTHrP was unable to downregulate IHH expression in chondrosarcoma organ cultures, suggesting constitutive hedgehog activation. 120 chondrosarcoma xenografts from twelve different tumors were established in NOD-SCID mice. Half of the mice were treated with the hedgehog inhibitory agent, triparanol, resulting in a decreased level of expression of the hedgehog target genes, PTC1 and GLI1 in the xenografts, demonstrating effective IHH blockade. Triparanol treatment showed a 60% decrease in volume and 40% decrease in cellularity in the xenografts. In addition, there was a 25% lower rate of proliferation as measured by the incorporation of BrdU in the treated xenografts. These results show that hedgehog signaling is activated in chondrosarcoma, and that this signaling pathway regulates proliferation of the tumor cells. Our data raises the possibility that hedgehog blockade could be used as an effective treatment for chondrosarcoma, a tumor for which there are currently no effective non-surgical management options.

POSTER NO. P194 – WITHDRAWN

SCIENTIFIC EXHIBIT NO. SE062

FDG PET Scan Imaging for Soft-Tissue Sarcomas

***Ernest U. Conrad III, MD**, Seattle, WA (n)*
Janet F. Eary, MD, Seattle, WA (n)
Scott M. Schuetze, MD, Seattle, WA (n)
James Bruckner, MD, Seattle, WA (n)
Brian P. Rubin, MD, Seattle, WA (n)
Cheryl B. Vernon, MSW, Seattle, WA (n)
Douglas Hawkins, MD, Seattle, WA (n)
Winfried Brenner, MD, Seattle, WA (n)

Anatomic imaging modalities do not accurately assess response of soft-tissue sarcomas to preoperative radiotherapy and/or chemotherapy. [F-18]-fluorodeoxy-D-glucose (FDG) positron emission tomography (PET) predicts histopathologic response to therapy in these patients. We determined the correlation between change in FDG uptake and histopathologic response to preoperative doxorubicin-based chemotherapy, risk of disease recurrence and overall survival for patients with intermediate- or high-grade, localized soft-tissue sarcomas in a retrospective analysis of 38 patients. The maximum standard uptake values (SUVmax) of tumors were measured prior to treatment with doxorubicin-based chemotherapy and prior to surgery. Resected specimens were examined for residual viable tumor using standard pathologic methods for soft-tissue sarcomas. The association between change in SUVmax and residual viable sarcoma was determined by the Spearman rank correlation. Patients were followed at least annually for evidence of recurrent disease and survival. Kaplan-Meier analyses were performed to determine whether the change in SUVmax to chemotherapy correlated with risk of disease recurrence after surgery and survival.The change in the SUVmax of FDG inversely correlates with the degree of residual viable tumor after preoperative chemotherapy. Patients whose tumors have a 40% or greater decline in the SUVmax to chemotherapy are at a significantly lower risk of recurrent disease after complete resection, and in these patients there is a trend toward improved overall survival. FDG PET is a useful, noninvasive measure of chemotherapy sensitivity of intermediate and high-grade soft-tissue sarcomas. Soft-tissue sarcomas that show a response to doxorubicin-based chemotherapy by FDG PET imaging have a lower risk of disease recurrence.

SCIENTIFIC EXHIBIT NO. SE063

Radiographic Evaluation of Pathological Bone Lesions: Current Spectrum of Disease and Approach to Diagnosis

***Benjamin G. Domb, MD**, New York, NY (n)*
Scott Ellis, MD, New York, NY (*)
Wakenda Tyler, MD, New York, NY (*)
Michael Gardner, MD, New York, NY (n)
Joshua Dines, MD, New York, NY (n)
Edward F. McCarthy, MD, Baltimore, MD (n)

The radiographic evaluation of pathological bone lesions is an extremely powerful tool in the diagnosis of such lesions. However, it is a complicated subject which must be approached in a methodical fashion in order arrive at the correct diagnosis. The purpose of this study is to educate and update orthopedic surgeons on the current spectrum of pathological bone lesions and algorithm for radiographic evaluation of these lesions. Using the combined experience of orthopedic surgeons and bone pathologists at two institutions, the specific radiographic characteristics of a wide spectrum of lesions were analyzed. Included amongst these were benign and malignant osseous and cartilaginous tumors, osteomyelitis, lymphoma, fibrous dysplasia, multiple myeloma, and metastatic carcinoma. The lesions were categorized according to shared radiographic characteristics, and a comprehensive approach was developed for diagnosis. The results of the analysis were used to design a step by step algorithm for the orthopedic surgeon to evaluate bone lesions seen on radiograph. This algorithm allows the surgeon to categorize bone lesions by their radiographic appearance and ultimately arrive at a diagnosis or narrow differential diagnosis.

Abalo, Eduardo . . . . . .Paper 088
Abboud, Joseph Albert . . . . . .Paper 151, 160
Abdelkerim, Ashraf . . . . . .Scientific Exhibit SE075
Abdu, William A . . . . . .Symposia U
Abe, Muneaki . . . . . .Poster P280
Abumi, Kuniyoshi . . . . . .Paper 185
Adams, Angela . . . . . .Poster P142
Adams, Joanne B . . . . . .Paper 290, Poster P098, ...Scientific Exhibit SE010, SE034
Adams, Julie E . . . . . .Scientific Exhibit SE051
Adams, Robert A . . . . . .Paper 079
Adey, Lauren P . . . . . .Poster P451
Aebi, Max . . . . . .Paper 188, Poster P384
Aglietti, Paolo . . . . . .Scientific Exhibit SE036
Aguilar, Julyn . . . . . .Paper 262
Ahmad, Christopher . . . . . .Poster P281
Ahmad, Yasrab . . . . . .Scientific Exhibit SE005
Ahmed, Mahmood . . . . . .Paper 265
Ahn, Jae-Sung . . . . . .Poster P402
Ahn, Nicholas . . . . . .Paper 259
Ahn, Uri . . . . . .Paper 259
Ain, Michael Craig . . . . . .Poster P358
Ajoy, Shetty Prashad . . . . . .Paper 068
Akhavan, Sam . . . . . .Poster P236, P388
Akiyoshi, Yuichiro . . . . . .Paper 272
Albenzio, Pietro . . . . . .Poster P348
Alberta, Frank . . . . . .Poster P280
Albright, James A . . . . . .Paper 051, 081
Alcid, Jess . . . . . .Poster P281
Alexander, Charlotte B . . . . . .Scientific Exhibit SE091
Alexander, Jerry W . . . . . .Paper 250
Alford, John . . . . . .Poster P211
Ali, Ahmad Mohamad . . . . . .Poster P215
Ali, Hesham H . . . . . .Scientific Exhibit SE042
Ali, Naseema Mehboob . . . . . .Paper 265
Aligizakis, Agisilaos . . . . . .Poster P392
Allan, D Gordon . . . . . .Poster P168
Allen, Answorth Anthony . . . . . .Paper 074, 102
Allen, Christina . . . . . .Poster P327
Allen, Matthew . . . . . .Paper 221
Allen, Todd R . . . . . .Poster P349, P351
Allen, Wayne . . . . . .Scientific Exhibit SE014
Allende, Christian . . . . . .Poster P449
Alonso, Jorge . . . . . .Paper 192, 195
Altchek, David W . . . . . .Paper 074, 102
Alvine, Franklin G . . . . . .Paper 115
Amelio, Ernesto . . . . . .Poster P203
Amendola, Annunziato . . . . . .Symposia CC
Amiel, David . . . . . .Poster P349, P351
Amir, Hagai . . . . . .Paper 011
Amrami, Kimberly K . . . . . .Scientific Exhibit SE049
Amro, Rena R . . . . . .Paper 019
Amstutz, Harlan C . . . . . .Paper 278, Scientific Exhibit SE021
Amundson, Glenn M . . . . . .Paper 259
An, Howard S . . . . . .Poster P418
Anderson, Allen F . . . . . .Paper 022
Anderson, Edward R . . . . . .Paper 192, 195
Anderson, John T . . . . . .Poster P074
Anderson, John . . . . . .Paper 139
Anderson, Kyle . . . . . .Poster P324
Anderson, Richard Coveney . . . . . .Poster P434
Anderson, Tracy L . . . . . .Poster P237
Andersson, Gunnar B J . . . . . .Poster P418, ...Scientific Exhibit SE090, Symposia A
Andrews, Carol . . . . . .Poster P325
Anekstein, Yoram . . . . . .Paper 122
Anker, Christopher . . . . . .Paper 221
Antoci, Valentine Sr. . . . . .Poster P225
Antoci, Valentine Jr. . . . . .Poster P225
Antounian, Francois S . . . . . .Paper 052
Aoki, Stephen . . . . . .Poster P177
Aono, Hiroyuki . . . . . .Poster P414
Aponte-Tinao, Louis Alberto . . . . . .Paper 087, 088
Appleby, David M . . . . . .Poster P021
Appleyard, Richard Charles . . . . . .Poster P355, P432
Apreleva, Maria . . . . . .Poster P266, P286
Araghi, Arash . . . . . .Paper 079
Aragona, James . . . . . .Scientific Exhibit SE090
Arbel, Ron . . . . . .Paper 011
Arciero, Robert A . . . . . .Paper 022
Arendt, Elizabeth A . . . . . .Symposia CC
Arlet, Vincent . . . . . .Paper 188
Armstrong, Douglas G . . . . . .Paper 198
Arnoczky, Steven P . . . . . .Symposia P
Arora, Arvind . . . . . .Paper 097, 098
Arreola, Manuel . . . . . .Poster P245
Arriaga-Florez, Maria Jesus . . . . . .Poster P364
Arrington, Edward D . . . . . .Poster P299, Symposia M
Asato, Hideki . . . . . .Paper 077
Asayama, Isao . . . . . .Paper 208, Poster P167
Aschenbrener, Daniel . . . . . .Poster P324
Aschenbrenner, John . . . . . .Poster P235, P248
Ash, Nahman . . . . . .Paper 011
Asher, Marc Addason . . . . . .Paper 255
Askew, Michael . . . . . .Poster P155
Aso, Yoshinori . . . . . .Poster P032
Asprinio, David E . . . . . .Poster P367
Atsuta, Yuji . . . . . .Poster P400
Attias, Naftaly . . . . . .Paper 069
Auerbach, Joshua D . . . . . .Poster P189
Awad, John . . . . . .Poster P423
Axe, Michael J . . . . . .Poster P353
Ayerza, Miguel Angel . . . . . .Paper 087, 088
Bach, Bernard R . . . . . .Poster P338
Bachmann, Georg . . . . . .Poster P331
Bachus, Kent N . . . . . .Paper 062, 063
Badley, Elizabeth . . . . . .Paper 154
Badman, Brian . . . . . .Poster P245
Badrul, Shah . . . . . .Paper 202
Badylak, Steve . . . . . .Symposia ORS1
Bae, Dae Kyung . . . . . .Paper 283
Bae, Hyun W . . . . . .Paper 189, Poster P407, P412
Bae, Sung Chul . . . . . .Paper 283
Bae, Tae Soo . . . . . .Poster P309
Baek, Goo Hyun . . . . . .Paper 047, Poster P183, P294
Bagg, Mark R . . . . . .Symposia M
Bailey, Aaron M . . . . . .Poster P081
Bailey, Alexander S . . . . . .Paper 259
Baird, Robert . . . . . .Paper 017, Poster P346
Baker, Champ L . . . . . .Paper 052
Baker, Dale . . . . . .Poster P025, P133, P145
Balasa, Vinod . . . . . .Paper 136
Baldini, Andrea . . . . . .Scientific Exhibit SE036
Baleani, Massimiliano . . . . . .Scientific Exhibit SE023
Balint, Chris . . . . . .Poster P308
Ball, Scott T . . . . . .Poster P349, P351
Banan, Hamayoon . . . . . .Scientific Exhibit SE005
Bandyk, D . . . . . .Paper 036
Banes, Albert . . . . . .Symposia ORS1
Bang, Annie . . . . . .Poster P238
Bang, Hoang . . . . . .Poster P088
Banks, Anne . . . . . .Poster P121

Banks, Scott A .....Poster P099, P121, Scientific Exhibit SE045
Bansal, Vijay K .....Poster P339
Banwart, J Christopher .....Poster P151
Barber-Westin, Sue .....Paper 107
Barca, Paolo .....Paper 128
Barden, Regina M .....Poster P112
Bargar, William Lamont .....Poster P022, P198, Symposia AA
Barnes, C Lowry .....Poster P121, P145
Barnes, Douglas A .....Poster P375
Baron, John A .....Paper 001, 004, 033
Barrack, Robert L .....Paper 174, 206, Scientific Exhibit SE014
Barrance, Peter .....Poster P353
Barrera, O Andres .....Scientific Exhibit SE042
Barrett, Gene R .....Paper 016, 237
Barrett, Jane .....Paper 001, 004, 033
Barron, Lonner .....Poster P416
Barry, Elizabeth M .....Paper 059, Poster P128
Basad, Erhan .....Poster P331
Basamania, Carl J .....Poster P298
Bashyal, Ravi K .....Paper 029
Basmania, Carl .....Scientific Exhibit SE054
Basobas, Leonard .....Poster P420, P421
Basran, Harpreet Singh .....Paper 259
Basu, Manoj .....Poster P436
Batista, Fabio .....Paper 070
Bauer, Thomas W .....Paper 186, Poster P394, P396
Bavage, Rudrani .....Poster P148
Bawa, Maneesh .....Poster P402
Bay, R Curtis .....Paper 069
Bayrakci, Kenan .....Poster P164
Beaty, James H .....Symposia J
Beaule, Paul E .....Paper 278, Scientific Exhibit SE021
Beaupre, Lauren .....Poster P012
Beckenbaugh, Robert D .....Poster P456
Becker, Ann .....Paper 136
Beckman, Lorne .....Poster P384
Beebe, Kathleen .....Poster P228
Beekman, Ryan .....Poster P212
Behrens, Fred F .....Poster P228
Belanger, Theodore Andrew .....Poster P411
Beldner, Steven .....Paper 044
Bell, Gordon R .....Paper 256
Bell, M S .....Poster P436
Bell, Michael .....Symposia F
Bell, Robert S .....Paper 084
Bellew, James William .....Paper 081
Bellezza, Anthony .....Poster P422
Ben-Galim, Peleg .....Paper 011
Benevenia, Joseph .....Symposia K
Benhaim, Prosper .....Poster P320
Benirschke, Stephen K .....Paper 117, 119
Benjamin, Michael .....Poster P437
Bennett, Anna .....Poster P126
Bennett, Derek M .....Poster P040
Bennett, Miho .....Poster P359
Benoit, Paul .....Paper 028
Bensahel, Henri .....Symposia X
Benson, Leon S .....Paper 049, Poster P455, P457
Beredjiklian, Pedro K .....Paper 050, 151
Berend, Keith R .....Paper 290, Poster P098, Scientific Exhibit SE010, SE034
Berger, Richard A .....Paper 048
Berger, Richard A .....Paper 205, 207, 210, Poster P112
Bergula, Arnie .....Paper 105
Berkowitz, Scott D .....Paper 060
Berkson, Eric Matthew .....Poster P322
Berland, Kimberly A .....Poster P018
Berman, Arnold Theodore .....Scientific Exhibit SE091
Bernasek, Thomas L .....Paper 036, 244
Bernstein, Joseph .....Paper 200, Poster P366
Bernstein, Robert .....Poster P372
Berry, Daniel J .....Paper 096, 165, Symposia I, L, W
Bert, Jack M .....Scientific Exhibit SE009, SE029, SE047
Bertone, Celeste .....Poster P268
Bertoni, Franco .....Paper 085
Bertot, Alexander J .....Paper 174
Berven, Sigurd H .....Paper 123
Besjakov, Jack .....Paper 197
Bess, Robert Shay .....Poster P391
Bessette, Benoit J .....Poster P323
Betz, Randal R .....Poster P387
Bevoni, Roberto .....Scientific Exhibit SE024
Beynnon, Bruce .....Poster P121, P154
Bezwada, Hari .....Poster P165
Bhandari, Mohit .....Poster P204, P216, P220, P227, P239, P329, P362, P363
Bhargava, Tarun .....Paper 069
Bhatia, Nitin .....Poster P378
Bhave, Anil .....Paper 262, Poster P148, P376, P377, Scientific Exhibit SE043
Bickels, Jacob .....Paper 228
Bierbaum, Benjamin E .....Paper 099, 100, 176, Poster P009
Biermann, Janet Sybil .....Scientific Exhibit SE091
Bigos, Stanley James .....Scientific Exhibit SE090
Binazzi, Roberto .....Poster P070
Bindreiter, Ullreich .....Paper 103
Binski, James C .....Poster P251
Birch, John G .....Poster P251
Bird, Justin .....Paper 216
Bishay, Michael .....Scientific Exhibit SE005
Bishop, Allen T .....Poster P267, P461
Bishop, Julie .....Paper 216, 217, Poster P273
Biviji, Ayaz A .....Poster P051
Bizzini, Mario .....Scientific Exhibit SE027
Blackwell, Angel .....Paper 169
Blagev, Denitza .....Poster P079
Blaha, J David .....Poster P004, P171, Symposia W
Blair, Pat .....Poster P198
Blakemore, Laurel C .....Scientific Exhibit SE071
Blankstein, Michael .....Poster P227, P238
Blum, Steven .....Scientific Exhibit SE032
Blum, Yossef C .....Poster P223
Blumenfeld, Thomas J .....Poster P022
Blumenthal, Scott L .....Paper 252
Boberg, Carol J. .....Poster P068
Bobyn, J Dennis .....Scientific Exhibit SE013
Boden, Scott D .....Symposia A, K
Boehm, Cynthia A .....Poster P426
Boerger, T O .....Poster P213
Boeri, Cyril .....Paper 061, Poster P127
Boes, Matthew .....Poster P329
Boettner, Friedrich .....Poster P147
Boettner, Fritz .....Poster P031
Bohlen, Barry .....Poster P139
Bohlman, Henry H .....Poster P391, P411
Boileau, Pascal .....Paper 147, 215
Boland, Patrick J .....Paper 227
Boldt, Jens G .....Scientific Exhibit SE027
Bolognesi, Michael P .....Scientific Exhibit SE017, SE028, SE038
Bond, Thomas K .....Paper 007
Bone, Lawrence B .....Poster P231
Bong, Matthew R .....Poster P079, P219, P352

Bongiovanni, Santiago . . . . . .Paper 088
Bonnin, Michel . . . . . .Paper 113
Bono, Christopher . . . . . .Paper 129, Poster P389
Bono, James V . . . . . .Scientific Exhibit SE022
Bono, Peter . . . . . .Paper 182
Bonutti, Peter M . . . . . .Paper 284, Poster P036, P287, ...Scientific Exhibit SE041, Symposia C
Booth, Robert Emrey . . . . . .Poster P008, P055, P114, P119, ...P135, P165, Symposia W
Borden, Lester Stuart . . . . . .Symposia I
Born, Christopher T . . . . . .Poster P247
Borrelli, Joseph . . . . . .Poster P246
Boscainos, Petros J . . . . . .Poster P226
Bosch, Ulrich . . . . . .Paper 104
Bosse, Michael J . . . . . .Paper 164, Symposia R
Bostrom, Mathias P G . . . . . .Poster P031
Bott, Steve . . . . . .Poster P177
Bottner, Friedrich . . . . . .Scientific Exhibit SE006
Bouhalia, Aziz . . . . . .Poster P263
Boulahia, Aziz . . . . . .Paper 141
Bourne, Robert Barry . . . . . .Paper 010, 179, 203, 241, ...Poster P006, P015, P047, P087, P104, Symposia DD, U
Bouvier, Daniel P . . . . . .Poster P260
Bowen, Richard E . . . . . .Symposia X
Boyan, Barbara D . . . . . .Scientific Exhibit SE087
Boyle, James . . . . . .Poster P110
Bozentka, David J . . . . . .Paper 050, 151
Bradley, Gloria . . . . . .Scientific Exhibit SE064
Bragdon, Charles R . . . . . .Poster P019, P075, P096, ...Scientific Exhibit SE004
Brage, Michael E . . . . . .Paper 110, Poster P446
Brander, Victoria Anne . . . . . .Poster P142
Brandsson, Sveinbjorn . . . . . .Poster P330
Brandt, Jan Mels B . . . . . .Poster P104
Brandt, Kenneth D . . . . . .Poster P196
Branovacki, George . . . . . .Poster P278
Branson, Jill . . . . . .Poster P018
Brassart, Nicholas . . . . . .Paper 215
Brennan, Murray . . . . . .Paper 227
Brenner, Winfried . . . . . .Scientific Exhibit SE062
Bridwell, Keith H . . . . . .Paper 123, 126, 127, 254, Poster P424
Briggs, Karen K . . . . . .Paper 014, 018, Poster P197, P282, P343
Brinson, Martha . . . . . .Paper 201
Brintzenhofeszoc, Karlynn . . . . . .Paper 131
Brodke, Darrel S . . . . . .Poster P394
Brodsky, Adam R . . . . . .Poster P444
Brooks, Daria Laureen . . . . . .Paper 228
Brown, Carla . . . . . .Scientific Exhibit SE043
Brown, Edward Charles . . . . . .Poster P125
Brown, Michael H . . . . . .Poster P139
Brown, Stephen L . . . . . .Paper 017, Poster P346
Brown, Thomas E . . . . . .Poster P083
Browne, Jon E . . . . . .Paper 022
Bruce, Bonnie . . . . . .Paper 158, 159, Poster P359
Bruckner, James D . . . . . .Poster P192, Scientific Exhibit SE062
Bruehl, Stephen . . . . . .Poster P142
Bryant, Cari R . . . . . .Poster P163
Bryk, Eli . . . . . .Poster P438
Buchanan, Thomas S . . . . . .Poster P353
Buchel, Edward W . . . . . .Poster P461
Bucholz, Mary . . . . . .Poster P345
Bucholz, Robert William . . . . . .Paper 064
Buchowski, Jacob . . . . . .Poster P390
Buckley, Kathleen . . . . . .Paper 018
Buckwalter, Joseph A . . . . . .Scientific Exhibit SE087
Buckwalter, Kathleen C . . . . . .Scientific Exhibit SE088
Bugbee, William . . . . . .Paper 108, 110, ...Poster P349, P351, P354, P446
Bullock, Daniel . . . . . .Paper 003
Bullough, Peter G . . . . . .Poster P218
Burchette, Raoul . . . . . .Paper 261
Burd, Timothy A . . . . . .Paper 251
Burgess, Scott David . . . . . .Poster P232
Burgess, Wilson H . . . . . .Paper 106
Burnett, Robert Stephen . . . . . .Paper 010, 203, ...Poster P006, P087, P112
Burr, David B . . . . . .Symposia ORS2
Burroughs, Brian . . . . . .Poster P042, P075, P096
Burton, Douglas C . . . . . .Paper 255
Busato, Andre . . . . . .Paper 096, Poster P073
Buscayret, Florent . . . . . .Paper 113
Busse, Jason W . . . . . .Poster P220
Bustillo, Jorge . . . . . .Poster P231
Butcher, William . . . . . .Poster P354, P439
Butkovich, Bradley . . . . . .Poster P245
Butler, David L . . . . . .Symposia ORS1
Butler, Jay Brad . . . . . .Poster P296
Byrick, Robert J . . . . . .Poster P238
Cabanela, Miguel E . . . . . .Paper 206, Symposia I, L
Cahill, Janet . . . . . .Poster P147
Cain, Eric Lee . . . . . .Paper 026
Caldwell, Paul E . . . . . .Poster P139
Calhoun, Jason H . . . . . .Scientific Exhibit SE089
Callaghan, John J . . . . . .Paper 115, Poster P014, P090, ...Symposia G, L, W
Callahan, Leigh . . . . . .Scientific Exhibit SE087
Calmes, Janine . . . . . .Paper 263, Poster P375
Caltoum, Christine B . . . . . .Poster P267
Camargo, Marcelo P . . . . .Scientific Exhibit SE017, SE018, SE028
Campbell, Barbara Jean . . . . . .Scientific Exhibit SE087
Campbell, Patricia A . . . . . .Paper 278, Scientific Exhibit SE021
Cannon, Steve R . . . . . .Poster P191
Cantu, Robert . . . . . .Poster P200
Capello, William N . . . . . .Paper 100, Poster P020
Capen, Daniel Alexander . . . . . .Poster P386
Carandang, Gerard . . . . . .Poster P301
Carlson, Grace A . . . . . .Poster P320
Carlson, Tom C . . . . . .Poster P198
Carmack, David B . . . . . .Symposia M
Carmichael, Stephen W . . . . . .Scientific Exhibit SE049
Carragee, Eugene . . . . . .Symposia A
Carreon, Leah Yacat . . . . . .Paper 122, Poster P382
Carrigan, Robert B . . . . . .Paper 026, Poster P247
Carter, Sam . . . . . .Poster P382
Cascio, Brett . . . . . .Poster P271, P358
Casey, Brett Edward . . . . . .Paper 132
Casper, Julie . . . . . .Scientific Exhibit SE075
Casto, Steve R . . . . . .Poster P111, P167
Catani, Fabio . . . . . .Paper 288
Catledge, Shane Aaron . . . . . .Poster P003
Cawley, Patrick . . . . . .Paper 235
Ceccarelli, Francesco . . . . . .Scientific Exhibit SE024
Cech, Jennifer A . . . . . .Poster P345
Celli, Andrea . . . . . .Paper 079, 142
Celli, Luigi . . . . . .Paper 142
Chalnick, David Lee . . . . . .Scientific Exhibit SE036
Chaminade, Bruno . . . . . .Paper 118
Chamnongkich, Samatchai . . . . . .Poster P111
Chang, Benjamin . . . . . .Poster P464
Chang, Bong-Soon . . . . . .Poster P413
Chang, Dennis H . . . . . .Paper 248
Chang, Eric . . . . . .Poster P037, P206

Chang, Wei Ning .....Paper 135, Poster P404, ...Scientific Exhibit SE066
Chanos, Michalis .....Poster P292
Chao, David J .....Paper 235
Chao, Jerome Donald .....Poster P463
Chapman, S .....Poster P403
Charity, John Anthony Forsyth .....Paper 204
Chaudhury, Asif .....Poster P213
Chavers, Laura .....Poster P386
Chawda, Mayur .....Paper 194
Chebli, Caroline M .....Poster P259
Chen, Albert C .....Poster P349
Chen, Chih-Hwa .....Poster P318
Chen, Chih-Tung .....Paper 109
Chen, Han-Shiang .....Poster P153
Chen, Jack .....Poster P180
Chen, Sheng-Tsung .....Paper 282
Chen, Shih-Hao .....Poster P440
Chen, Shu-Ya .....Poster P195
Chen, Wen-Jer .....Poster P307, P318
Chen, Yeung-Jen .....Poster P440
Cherrick, Irene .....Paper 221
Chiang, Alexis .....Poster P452
Chiang, Peter P .....Poster P045
Chiari, Catharina .....Poster P188
Chicoine, Brian .....Poster P420
Chih-Hwa, Chen .....Poster P307
Chin, Patrick .....Paper 144, 146, 212
Chiron, Philippe .....Paper 118
Cho, Hwan-Seong .....Poster P183
Cho, Keihan .....Poster P118
Cho, Stephanie .....Paper 109
Cho, Yang-Bum .....Poster P294
Cho, Yoon-Je .....Paper 092, 206
Choi, Chang Hyuk .....Poster P201
Choi, Kellen .....Poster P308, Scientific Exhibit SE068
Choi, Kuiwon .....Poster P309
Chou, Wen-Ying .....Poster P140
Chou, Ying-Chao .....Paper 041
Christensen, David Mark .....Poster P224
Christensen, Steve .....Poster P042
Christie, Michael J .....Paper 201, Poster P048, ...Scientific Exhibit SE013, Symposia L
Chuang, Tai-Yuan .....Poster P307, P318
Chung, Jae Yoon .....Paper 183, Poster P397, P410
Chung, Moon Sang .....Paper 047, Poster P183, P294
Chung, Yung Khee .....Paper 047, Poster P294
Ciccone, William J .....Poster P345
Ciotola, Joseph Anthony .....Poster P259
Clabeaux, John .....Poster P257
Clare, Michael Patrick .....Paper 120
Clark, Lindsey .....Poster P110
Clark, Marcia .....Poster P012
Clark, Nicole .....Poster P489
Clarke, Henry D .....Poster P149
Clarke, Ian C .....Poster P029, Scientific Exhibit SE007
Clarke, Michael T .....Paper 097, 098
Clavert, Philippe .....Poster P266
Claytor, Brian S .....Poster P379
Cleeman, Edmond .....Poster P189
Clements, David H .....Poster P387
Clohisy, John C .....Paper 092
Clough, Timothy M .....Paper 114
Codsi, Michael J .....Paper 176
Cofield, Robert H ...Paper 076, 144, 146, 148, 212, Poster P258, Symposia BB
Cohen, David A .....Poster P390, P423
Cohen, David B .....Paper 102
Cohen, Mark S .....Symposia D, Q
Cohen, Peter Z .....Scientific Exhibit SE088
Cohen, Steven B .....Poster P312
Colby, Scott .....Paper 260
Cole, Brian J .....Poster P322, P338
Cole, Peter A .....Symposia R
Coleman, Struan H .....Paper 102
Coley, Edward .....Poster P300
Collier, Matthew B .....Poster P095, P107, P116
Collinge, Cory Alan .....Poster P235, P248
Colombier, Jean .....Paper 113
Colwell, Clifford W ....Paper 060, 105, Poster P051, P086, P113, ...P138, Scientific Exhibit SE080, Symposia EE
Comfort, Thomas Krebs .....Paper 280, Poster P028
Comp, Phillip C. .....Paper 060
Conditt, Michael A .....Paper 286
Conlin, Michael .....Poster P243
Connor, Patrick Michael .....Poster P300
Conrad, Bryan P .....Poster P429
Conrad, Ernest U .....Poster P192, Scientific Exhibit SE062
Conrad, Stephen E .....Scientific Exhibit SE091
Conti, Stephen F .....Symposia H
Conway, Janet Donohue .....Poster P148
Cook, Monique .....Poster P003
Cook, Stephen D .....Poster P334, Scientific Exhibit SE052
Cook, Thomas .....Scientific Exhibit SE018, SE028, SE038
Cooney, William P .....Paper 048
Cooney, William Patrick .....Paper 180
Coons, David A .....Poster P235, P248
Cooper, Andrew .....Paper 255
Cordasco, Frank A .....Poster P317
Cordista, Andrew .....Poster P429
Cornell, Charles N .....Paper 064
Corrado, Ezio Maria .....Poster P203
Coughlin, Kathryn M .....Poster P121, P154
Coupe, Kevin .....Paper 169
Cowart, Jerry .....Paper 125
Cox, G .....Poster P403
Crawford, Alvin Howell .....Paper 136, Poster P405
Crawford, Charles .....Poster P035
Creevy, William R .....Poster P447
Crichlow, Renn J .....Poster P221, P222
Cripton, Peter .....Poster P422
Crisco, Joseph .....Poster P211
Crosby, Lynn A .....Paper 218
Cross, Mervyn J .....Paper 008
Crowninshield, Roy D .....Poster P134
Cugola, Landino .....Poster P203
Cummings, Robert Jay .....Symposia J
Cummins, Craig .....Paper 214
Curia, Emiliano .....Poster P078
Cushner, Fred D .....Paper 172, Poster P125
D'Alessandro, Donald F .....Poster P300
D'Andrea, Linda P .....Poster P387
D'Antonio, James A .....Paper 100
D'Lima, Darryl D .....Paper 105, Poster P086, P138, P354
Da Silva, Yong Sing .....Poster P463
Dabney, Kirk W .Paper 135, Poster P404, Scientific Exhibit SE066
Dahners, Laurence E .....Poster P232
Dalton, John F .....Poster P453
Dalury, David F .....Poster P156
Damron, Timothy A .....Paper 221, Symposia T
Dapuzzo, Michele R .....Poster P026, P072
David, Tal S .....Paper 235

Davidson, Richard S . . . . . .Paper 030
Davis, Aileen M . . . . . .Paper 154
Davis, John P . . . . . .Paper 285, Poster P150
Davis, John T . . . . . .Poster P334
Davison, Brian L . . . . . .Poster P200
Dawson, Edgar G . . . . . .Poster P395, P407
Dawson, Patrick . . . . . .Poster P243
Day, Susan M . . . . . .Scientific Exhibit SE088
DeAngelis, Joseph . . . . . .Poster P434
DeAngelis, Nicola . . . . . .Paper 065, Poster P250, P434
DeBoer, David Kent . . . . . .Paper 201
DeConciliis, Gregory P . . . . . .Poster P308
DeCoster, Thomas A . . . . . .Paper 066
DeOrio, James Keith . . . . . .Poster P445
DeVicente-Rodriguez, Juan Carlos . . . . . .Poster P364
Dearborn, John T . . . . . .Paper 281
Debi, Ronen . . . . . .Poster P046
Deie, Masataka . . . . . .Poster P316
Del Regno, Antonio . . . . . .Poster P240
DelBrio-Leon, Maria Angeles . . . . . .Poster P364
Dela Rosa, Mylene A . . . . . .Paper 095
Delamarter, Rick B . . . . . .Paper 189, Poster P407, P412
Deland, Jonathan T . . . . . .Poster P444
Dell, Richard M . . . . . .Paper 152
Della Valle, Craig . . . . . .Paper 248, Poster P037, P112
Delp, Scott L . . . . . .Scientific Exhibit SE084
Demos, Harry A . . . . . .Poster P047
Deng, Xiang-Hua . . . . . .Poster P315
Dennett, Chris . . . . . .Paper 014
Dennis, Douglas A . . . . . .Scientific Exhibit SE039, ...SE050, Symposia G, W
Deschamps, Gerard . . . . . .Paper 057
Devereaux, PJ . . . . . .Poster P220
Devinney, Scott . . . . . .Poster P279
Dheenadhayalan, Jayarama Raju . . . . . .Paper 068
Dhert, W.J.A. . . . . .Paper 276
Dhmitri, Kenneth . . . . . .Poster P065
Di Cesare, Paul E . . . . . .Poster P037, P079
DiBella, Claudia . . . . . .Paper 085
DiGioia, Anthony M . . . . .Scientific Exhibit SE084, Symposia AA
Diamantakis, Georgios . . . . . .Poster P292
Diaz, Rodrigo M . . . . . .Poster P026, P072
Dickey, Ian . . . . . .Paper 086, Scientific Exhibit SE051
Dimaano, Fred . . . . . .Poster P086
Dimakopoulos, Panayotis . . . . . .Poster P292
Dimar, John R . . . . . .Paper 121, 123
Dines, David M . . . . . .Scientific Exhibit SE077, Symposia BB
Dines, Joshua . . . . . .Scientific Exhibit SE063
Dirschl, Douglas R . . . . . .Paper 066, Poster P234, P243
Disch, Alexander . . . . . .Paper 199
Djurasovic, Mladen . . . . . .Paper 121
Do, Twee T . . . . . .Poster P403
Dobbs, Matthew Barrett . . . . . .Paper 139, 264, 268, 270
Dodds, Kathleen . . . . . .Paper 290, Poster P098, ...Scientific Exhibit SE010, SE034
Doherty, Arin . . . . . .Poster P075
Dohm, Michael P . . . . . .Symposia U
Dom, Karl . . . . . .Paper 211, Poster P435
Domb, Benjamin . . . . . .Scientific Exhibit SE063
Dominati, Simon-Paul . . . . . .Scientific Exhibit SE038
Donaldson, Michelle Lee . . . . . .Poster P343
Donaldson, Thomas Kent . . . . . .Poster P029
Donati, Davide . . . . . .Paper 085
Donigan, Jonathan . . . . . .Poster P423
Donthineni-Rao, Rakesh . . . . . .Paper 160, Poster P175, P185
Doornberg, Job . . . . . .Poster P253
Dorey, Frederick .Paper 278, Poster P176, Scientific Exhibit SE021
Dormans, John P . . . . . .Paper 090, 267, Poster P179
Dorotka, Ronald . . . . . .Paper 103
Dorr, Lawrence D . . . . . .Poster P016, Symposia B
Dosch, Jean-Claude . . . . . .Paper 061
Douglas, Keith . . . . . .Paper 162
Doukas, William C . . . . . .Symposia M
Dowd, James E . . . . . .Paper 178
Downey, Kevin . . . . . .Scientific Exhibit SE052
Dragoo, Jason L . . . . . .Poster P320
Drakos, Mark . . . . . .Paper 102
Droge, John . . . . . .Paper 063
Drogt, Jack A . . . . . .Scientific Exhibit SE047
Drohan, William N. . . . . .Paper 106
Drummond, Denis S . . . . . .Poster P409
Du, Bin . . . . . .Paper 250
Ducker, Thomas . . . . . .Poster P428
Dulchavsky, Scott . . . . . .Poster P030
Duncan, Clive P . . . . . .Poster P005
Duncan, Scott F M . . . . . .Paper 042, Poster P461
Dunham, Rory . . . . . .Poster P272
Dunn, Warren . . . . . .Paper 238
Dupuis, Michel . . . . . .Paper 061
Dye, Scott F . . . . . .Paper 020, Poster P347, Symposia P
Dyer, Paul . . . . . .Scientific Exhibit SE030
Eary, Janet F . . . . . .Scientific Exhibit SE062
Eastell, Richard . . . . . .Poster P215
Eastwood, Gillian . . . . . .Poster P205
Eberle, Robert W . . . . . .Paper 249, Poster P046, P066, ...Scientific Exhibit SE015, SE016, SE025
Ebramzadeh, Edward . . . . . .Paper 116
Eckardt, Jeffrey John . . . . . .Poster P176
Eckhardt, Christina . . . . . .Poster P415
Edgerton, Bradford . . . . . .Paper 261
Edidin, Avram A . . . . . .Poster P062, P422
Edmonds, Harvey L. . . . . .Paper 121
Edwards, Charles Cannon . . . . . .Paper 126
Edwards, Charles . . . . . .Poster P424
Edwards, John Z . . . . . .Poster P155
Edwards, Sara . . . . . .Poster P455
Edwards, Thomas Bradley . . . . . .Paper 141, 147, Poster P263
Eggli, Stefan . . . . . .Paper 096, Poster P073
Egol, Kenneth A . . . . . .Paper 166, 196, Poster P206, P219, P223, ...P229, P241, P361, Scientific Exhibit SE055
Ehrlich, Michael G . . . . . .Poster P211
Eidelman, Mark . . . . . .Paper 140
Einhorn, Thomas A . . . . . .Symposia K
Eismont, Frank J . . . . . .Poster P406, Symposia A
Ejerhed, Lars . . . . . .Poster P306
El Amrani, Hakima . . . . . .Paper 06
El Ghoneimy, Ahmed . . . . . .Paper 085
ElAttrache, Neal S . . . . . .Poster P281
Elerson, Emily . . . . . .Paper 131, 253
Elias, Hyams S . . . . . .Poster P366
Elias, John J . . . . . .Poster P345
Elkassem, Husam . . . . . .Paper 010, 241
Ellerman, Andree . . . . . .Symposia AA
Elliott, Michael Johnathon . . . . . .Poster P427
Ellis, Scott . . . . . .Scientific Exhibit SE063
Ellis, Thomas J . . . . . .Poster P243
Elrashidy, Hany . . . . . .Paper 205
Emans, John B . . . . . .Paper 028
Emerson, Roger H . . . . . .Paper 056
Emery, Sanford E . . . . . .Poster P411
Emery, Shawn Clark . . . . . .Poster P351
Endo, Naoto . . . . . .Poster P184

Engelhardt, Peter .....Symposia F
Engh, C Anderson .....Paper 032, 039, Poster P002, P013, P059, P107, P116,
Engh, Charles A .....Paper 039, Poster P013, P059
Engh, Gerard Anderson .....Poster P095, P116
Enright, Timothy .....Poster P106
Ensini, Andrea .....Paper 288
Epinette, Jean-Alain .....Paper 055
Erggelet, Christoph .....Paper 022
Erickson, Jill .....Poster P007
Eriksson, Bengt I .....Paper 040, Poster P330
Erol, Bulent .....Paper 267
Eslava, Michael A .....Paper 233
Esler, Colin .....Poster P126
Estin, Mira .....Paper 115
Estok, Daniel M .....Poster P019
Etienne, Gracia .....Poster P040, P130, P161, Scientific Exhibit SE052
Evans, Peter J .....Paper 266
Ewert, Andreas .....Scientific Exhibit SE058
Ezzet, Kace A .....Poster P051, P113, P138
Fabbri, Nicola .....Paper 229
Fadale, Paul .....Poster P211
Faldini, Cesare .....Paper 167, Scientific Exhibit SE024, SE056
Falicov, Alexis .....Paper 191
Fantozzi, Silvia .....Paper 288
Farley, Timothy D .....Paper 014, Poster P340
Farmer, Kevin W .....Paper 131, Poster P271
Farnsworth, Christine L .....Poster P402
Faro, Frances .....Paper 124, Poster P387, P402
Farr, Jack .....Poster P322
Farrell, Christopher Michael .....Paper 034, 076
Farritor, Shane M .....Poster P169
Favorito, Paul J .....Poster P339
Faxen, Eva C .....Poster P330
Fehring, Thomas K .....Paper 173, 177, 242
Feinberg, Judy .....Poster P020
Feldman, David S .....Paper 269, Poster P374
Felmlee, Joel P .....Scientific Exhibit SE049
Femino, Frank P .....Poster P055
Ferguson, Peter .....Paper 084
Ferrara, Michael S .....Poster P109, P111
Fineberg, Marc S .....Poster P288, P339
Fisher, Richard C .....Scientific Exhibit SE088
Fisher, Zac .....Poster P224
Fishkin, Zair .....Poster P159
Fithian, Donald C .....Paper 035
Fitzgerald, Mark S .....Poster P310
Fitzpatrick, Mary Kate .....Poster P247
Flanigan, David .....Paper 049
Flanum, Mark .....Poster P049
Flatow, Evan L .....Paper 216, 217, Poster P273, Symposia BB
Fleming, James E .....Poster P426
Fluhme, Derrick .....Paper 236
Flynn, John MPaper 019, 029, Scientific Exhibit SE071, Symposia J
Foad, Susan .....Poster P403
Fontbote, Christian A .....Poster P327
Ford, Kevin Ray .....Paper 012
Forng, Ren-Yo .....Paper 106
Forthman, Christopher L .....Poster P276, P277
Foster, Timothy E .....Poster P329
Fowble, Vincent A .....Poster P438
Fowler, Peter J .....Symposia CC
France, John C .....Poster P428
Francis, Charles W .....Paper 060
Francis, Kimberly A .....Paper 236
Frankle, Mark A .....Poster P279
Frassica, Frank J .....Paper 229, Poster P358
Freeborn, Mark A. .....Paper 164
Freedman, Brett .....Paper 125
Freedman, John .....Poster P238
Freedman, Kevin Blake .....Poster P338
Freeman, Michael A R .....Poster P305
Fregley, Benjamin .....Poster P322
Freiberg, Andrew A .....Poster P075, P108, P152
Freitas, Alex .....Poster P224
French, Bruce Green .....Paper 065, Poster P250
Fribourg, David M .....Paper 189
Frick, Steven L .....Paper 268
Friedlaender, Gary E .....Scientific Exhibit SE052
Friedman, Richard J .....Symposia EE
Friedman, Samara .....Poster P371
Frondoza, Carmelita .....Poster P117
Fu, Freddie H .....Paper 022, 236
Fuchs, Bruno .....Paper 224
Fuente-Martin, Eduardo Luis .....Poster P364
Fujii, Hiroshi .....Paper 089
Fujimoto, Eisaku .....Poster P316
Fumich, Frank E .....Poster P428
Funayama, Atsushi .....Poster P120
Furey, Christopher George .....Poster P388
Furman, Bridgette D .....Paper 287, Poster P038
Gaffey, John .....Poster P014
Gaines, Robert W .....Poster P380, P381
Galano, Greg J. .....Paper 021, 024
Galante, Jorge O .....Paper 093, 205, Poster P045
Galasso, Olimpio .....Paper 128, Poster P203, P240
Galloway, Howard .....Paper 231, 232
Galpin, Robert D .....Paper 198
Gandaifis, Nicolaos .....Poster P226, P392
Ganley, Theodore J .....Paper 019, 026
Garbuz, Donald S .....Poster P005
Garcia, Barry .....Poster P337
Gardner, Michael J .....Poster P393, Scientific Exhibit SE063
Garellick, Goran .....Paper 168
Garfin, Steven R .....Poster P402
Garg, Sumeet .....Paper 019, 090, Poster P179
Garino, Jonathan P .....Paper 099, Poster P024, P030, P052
Garretson, Ralph B .....Poster P322
Garrett, William E .....Paper 013
Garvey, M B .....Poster P238
Garvin, Kevin L .....Poster P064, P103, P169, Scientific Exhibit SE042
Gausepohl, Thomas .....Scientific Exhibit SE053
Gaynor, Tracey P .....Paper 124
Gebhardt, Mark C .....Paper 222, 223
Gedroyc, Wady .....Poster P305
Gehrig, George .....Paper 081
Gehrig, Laura M .....Paper 081
Geissler, William Bennett .....Symposia Q
Gejo, Ryuichi .....Poster P131
Gelber, Jonathan .....Poster P273
Gellman, Harris .....Scientific Exhibit SE081
Georgoulis, Anastasios .....Poster P336
Gerber, Ariane .....Poster P266
Gerber, Christian .....Paper 149, 150, 219, 220, Poster P265, P293, Symposia BB, E, N
Gerbino, Peter G .....Paper 025
Gerstenfeld, Louis C .....Symposia ORS2
Getty, Patrick John .....Symposia T
Ghiselli, Gary .....Poster P372, P395
Giakas, Giannis .....Poster P336

Giannini, Sandro . . . . . .Paper 167, 288, Poster P207, ...Scientific Exhibit SE024, SE056
Giannoudis, Peter . . . . . .Paper 161, 163, 194
Gibbs, Eric . . . . . .Symposia T
Gie, Graham Allan . . . . . .Paper 204
Gigliotti, Sergio . . . . . .Poster P203
Gilbart, Michael . . . . . .Paper 149, 150, Poster P262, P293
Gilbert, Jeremy . . . . . .Paper 093
Giles, Steve . . . . . .Poster P071
Gill, Gurdev S . . . . . .Poster P123, P146
Gill, Harinderjit . . . . . .Paper 058
Gill, Thomas James . . . . . .Paper 018, 073
Ginn, Thomas Adam . . . . . .Paper 046
Ginsberg, G . . . . . .Paper 060
Gioe, Terence J . . . . . .Paper 002, 006, Scientific Exhibit SE029
Gladstone, James N . . . . . .Poster P273
Glassman, Andrew H . . . . . .Symposia L
Glassman, Steven D . . . . . .Paper 121, 122, 123, Poster P382
Glattes, R Christopher . . . . . .Paper 126
Gleason, Thomas F . . . . . .Poster P018, Scientific Exhibit SE065
Glees, Markus . . . . . .Paper 181
Glutting, Joseph . . . . . .Poster P404
Gobezie, Reuben . . . . . .Poster P108, P221, P222
Goetz, Devon D . . . . . .Poster P014, P090
Goldberg, Benjamin . . . . . .Poster P278
Goldberg, Michael J . . . . . .Symposia U
Goldberg, Tyler D . . . . . .Scientific Exhibit SE017, SE018, SE038
Goldberg, Victor . . . . . .Poster P088
Goldfarb, Charles A . . . . . .Paper 045
Goldstein, Neal . . . . . .Scientific Exhibit SE065
Goldstein, Wayne M . . . . . .Poster P018, ...Scientific Exhibit SE032, SE065
Gollogly, Sohrab . . . . . .Poster P489
Gonzalez Della Valle, Alejandro M . . . . . .Paper 091
Goode, Barry . . . . . .Poster P375
Goodman, Stuart Barry . . . . . .Poster P058
Goradia, Vipool K . . . . . .Poster P312
Gorczyca, John T . . . . . .Poster P214
Gordon, J Eric . . . . . .Paper 139, 264, 270
Gordon, Michael D . . . . . .Poster P260
Gordon, Noah . . . . . .Poster P130
Gorin, Michel . . . . . .Poster P041
Gottschalk, Frank A B . . . . . .Paper 070, Poster P132
Gotze, Christian . . . . . .Scientific Exhibit SE006
Goulet, James A . . . . . .Paper 064, 164
Gradisar, Ivan A . . . . . .Poster P155
Gramstad, Gregory . . . . . .Poster P301
Grana, William A . . . . . .Symposia CC
Grande, Daniel A . . . . . .Poster P416, Scientific Exhibit SE077
Grandi, Gian Luca . . . . . .Poster P207, Scientific Exhibit SE024
Graney, Kristen Kellar . . . . . .Paper 228
Grant, William . . . . . .Paper 221
Granville, Robert R . . . . . .Symposia M
Grappiolo, Guido . . . . . .Poster P004
Graveleau, Nicolas . . . . . .Paper 113
Gray, Tinker . . . . . .Paper 240
Green, Andrew . . . . . .Paper 213
Green, Steven Marshall . . . . . .Poster P452, P459
Greenleaf, Jonathan . . . . . .Paper 052
Greenwald, A Seth . . . . . .Scientific Exhibit SE003, SE026, ...SE040, SE082, SE086
Gregg, John R . . . . . .Paper 019, 026
Grewal, Ruby . . . . . .Poster P256
Grieb, Teri A. . . . . .Paper 106
Griffin, Anthony M . . . . . .Paper 084
Griffin, William L . . . . . .Paper 173, 177, 242
Grimer, Robert John . . . . . .Paper 082
Grimm, Katherine . . . . . .Paper 002, 006, 280, Poster P028
Gross, Allan E . . . . . .Symposia L
Gruen, Thomas A . . . . . .Paper 249, 278, Poster P048, ...Scientific Exhibit SE015, SE021
Gruppo, Ralph . . . . . .Paper 136
Guedes deSouza Pinto, Marco Antonio . . . . . .Paper 070
Guelich, David . . . . . .Poster P457
Guettler, Joseph . . . . . .Poster P298
Guilak, Farshid . . . . . .Symposia O
Guller, Ulrich . . . . . .Paper 007
Gupta, Ranjan . . . . . .Poster P283
Gupta, Salil . . . . . .Poster P229
Gurkan, Ilksen N . . . . . .Poster P164, P360
Gurnett, Christina Ann . . . . . .Paper 270
Gurske, Jennifer . . . . . .Poster P288
Gustafson, G Allen . . . . . .Scientific Exhibit SE007
Gustke, Kenneth A . . . . . .Paper 036, 244
Gutow, Andrew P . . . . . .Poster P453
Guyatt, Gordon . . . . . .Poster P204
Guyer, Richard D . . . . . .Paper 252
Guyton, Gregory P . . . . . .Poster P435
Ha, Chul Won . . . . . .Paper 101
Ha, Jeong Hyun . . . . . .Poster P413
Ha, Jinny . . . . . .Poster P117
Ha, Sang-Ho . . . . . .Poster P458
Haaker, Rolf Georg . . . . . .Paper 031, Symposia AA
Haas, Steven B . . . . . .Scientific Exhibit SE079
Haber, Daniel F . . . . . .Poster P058
Haddad, Fares Sami . . . . . .Poster P056, Scientific Exhibit SE014
Haden, Lisa . . . . . .Poster P085, P115
Hadjikouti-Dyer, Christina . . . . . .Paper 161
Hadjipauvlou, Alecos . . . . . .Poster P392
Haemmerle, Marcus . . . . . .Poster P327
Haft, Geoffrey F . . . . . .Poster P234
Hagenauer, Mary Ellen . . . . . .Poster P106
Haghighi, Parviz . . . . . .Poster P351
Haher, Thomas Richard . . . . . .Poster P387
Haider, Hani . . . . . .Poster P169, Scientific Exhibit SE042
Haidukewych, George John . . . . . .Paper 023, 034, 148, 165, 171, ...Poster P068, P162, Symposia Z
Hak, David J . . . . . .Poster P491
Hall, Janette M . . . . . .Paper 164
Hall, John E . . . . . .Paper 028
Hallab, Nadim . . . . . .Paper 093
Halpern, Michael T . . . . . .Poster P033
Hame, Sharon Lee . . . . . .Poster P325, Scientific Exhibit SE075
Hammond, Jason . . . . . .Poster P271
Hanada, Hirofumi . . . . . .Scientific Exhibit SE030
Handelsman, John Ellis . . . . . .Poster P371
Hanks, Steve . . . . . .Poster P411
Hanley, Edward N . . . . . .Symposia A
Hanna, Mark Wesley . . . . . .Poster P230
Hannafin, Jo A . . . . . .Poster P317
Hannouche, Didier . . . . . .Poster P254
Hanssen, Arlen D . . . . . .Poster P048, P162, ...Scientific Exhibit SE013, SE086, Symposia G, W
Hara, Michiya . . . . . .Poster P118, P326
Harada, Toshihiko . . . . . .Poster P417
Harada, Yoshitada . . . . . .Poster P077
Haralson, Robert H . . . . . .Scientific Exhibit SE090
Harden, R Norman . . . . . .Poster P142
Harder, Valerie S . . . . . .Poster P044, P439
Hardwick, Mary . . . . . .Poster P051
Harlan, Cody Stephen . . . . . .Paper 259
Harman, Melinda K . . . . . .Poster P099, Scientific Exhibit SE045

Harner, Christopher D . . . . . .Paper 236, Poster P327
Harness, Neil G . . . . . .Poster P450
Harper, William . . . . . .Poster P126
Harris, Barton . . . . . .Poster P139
Harris, Nicholas J . . . . . .Poster P431
Harris, Timothy E . . . . . .Poster P422
Harris, William H . . . . . .Poster P019, P042, P045, P075, P096, ...Scientific Exhibit SE004
Harrold, Fraser . . . . . .Poster P266
Hartigan, Brian J . . . . . .Poster P457
Harvey, Edward J . . . . . .Paper 188
Hashimoto, Tomoyuki . . . . . .Poster P396
Haskell, Andrew . . . . . .Poster P441
Hasler, Carol-Claus . . . . . .Symposia F
Hassaballa, Mo . . . . . .Poster P010
Hassenpflug, J . . . . . .Symposia AA
Hasserius, Ralph . . . . . .Paper 197
Hatakeyama, Yuji . . . . . .Paper 071
Hatano, Hiroshi . . . . . .Poster P184
Hatzidakis, Armodios Miltiadis . . . . . .Paper 215
Haverkamp, Daniel . . . . . .Paper 274
Hawker, Gillian . . . . . .Paper 154
Hawkins, Douglas . . . . . .Scientific Exhibit SE062
Hawkins, Monica . . . . . .Poster P086
Hawkins, Richard J . . . . . .Poster P282
Hawkins, Robert H . . . . . .Poster P256
Haydon, Chris . . . . . .Paper 010, 203, 241, Poster P104
Hayes, T David . . . . . .Paper 173
Hayes, Victor . . . . . .Paper 258, Poster P416
Haynes, Richard Justis . . . . . .Paper 132, 263
Hazelwood, Scott J . . . . . .Poster P491
He, David Y . . . . . .Poster P170
Healey, John H . . . . . .Paper 227
Healy, Kevin . . . . . .Symposia ORS2
Healy, William L . . . . . .Poster P021, P065
Hecht, Suzanne . . . . . .Scientific Exhibit SE075
Hedegaard, Holy . . . . . .Poster P210
Heels-Andsell, Diane . . . . . .Poster P204
Hegyi, Gyorgy . . . . . .Poster P082
Hein, Werner . . . . . .Poster P311
Heiner, John P . . . . . .Poster P049, P106
Heinrich, Eric Matthew . . . . . .Paper 209
Heisel, Christian . . . . . .Paper 095
Helfet, David Leonard . . . . . .Poster P199, P255
Henderson, Kathy . . . . . .Poster P185
Henn, R. Frank . . . . . .Paper 213
Hennrikus, William L . . . . . .Poster P321
Henshaw, Robert Mikael . . . . . .Paper 083, 228
Heper, L . . . . . .Poster P403
Herbenick, Michael . . . . . .Poster P217
Herberts, Peter . . . . . .Paper 168, 276
Herbertsson, Par . . . . . .Paper 197
Herkowitz, Harry N . . . . . .Symposia A
Herman, Martin Joseph . . . . . .Poster P202
Hermida, Juan C . . . . . .Poster P086, P138
Hernandez, Arnaldo Jose . . . . . .Poster P377
Hernandez, Jon David . . . . . .Poster P244
Hernandez, Victor Hugo . . . . . .Poster P026, P072, P078
Hernigou, Philippe . . . . . .Paper 057
Herr, Mark James . . . . . .Poster P187
Herrera-Soto, Jose A . . . . . .Poster P405
Herring, John Anthony . . . . . .Paper 137
Hertel, Ralph . . . . . .Symposia N, Y
Herzenberg, John E . . . . . .Paper 140, 262, Poster P376, P377
Hewett, Timothy E . . . . . .Paper 012
Heyworth, Benton E. . . . . .Paper 024, 043, 133, 134
Hickman, Joshua M . . . . . .Paper 205
Hiebert, Rudi . . . . . .Poster P223
Higgins, Deanna . . . . . .Poster P261
Higgins, Linda . . . . . .Paper 056
Higgins, Thomas F . . . . . .Paper 062, 063
Hildebrand, Frank . . . . . .Paper 193, 194, Poster P249
Hilibrand, Alan Sander . . . . . .Symposia S
Hillmeier, Joachim Siegfried . . . . . .Paper 187
Hines, Jerod . . . . . .Paper 062
Hirata, Makoto . . . . . .Poster P181
Ho, Charles . . . . . .Paper 018
Ho, Yvette . . . . . .Paper 228
Hoang, David . . . . . .Paper 235
Hochschuler, Stephen Howard . . . . . .Paper 252
Hodge, W Andrew . . . . . .Scientific Exhibit SE045
Hodge, William Andrew . . . . . .Poster P099
Hoenecke, Heinz R . . . . . .Poster P354
Hoff, William A . . . . . .Scientific Exhibit SE050
Hoffman, Kent C . . . . . .Poster P170
Hofmann, Aaron Adam . . . . . .Scientific Exhibit SE017, SE018, ...SE028, SE038, Symposia W
Hokama, Jorge . . . . . .Poster P369
Holdridge, Sean . . . . . .Paper 221
Holdsworth, David W . . . . . .Poster P015
Holman, Mark L. . . . . .Poster P321
Holmes, George B . . . . . .Scientific Exhibit SE090
Holt, Sara K . . . . . .Paper 117, 119, 191
Holtom, Paul D . . . . . .Scientific Exhibit SE089
Holzhauser, Markus . . . . . .Poster P344
Hong, Richard . . . . . .Poster P393
Hooker, Michael Sean . . . . . .Poster P224
Hopgood, Philip . . . . . .Poster P166
Hoppeler, Hans . . . . . .Paper 219, 220
Hopper, Robert . . . . . .Paper 032, 094, Poster P002
Horan, Marilee P . . . . . .Poster P282
Horibe, Shuji . . . . . .Poster P313
Hornicek, Francis J . . . . .Paper 222, 223, Scientific Exhibit SE070
Horodyski, Mary Beth . . . . . .Poster P429
Horton, William C . . . . . .Paper 123
Hosalkar, Harish Sadanand . . . . . .Poster P409
Hotta, Tetsuo . . . . . .Poster P184
Hou, Chun-han . . . . . .Poster P357
Hou, Sheng-Mou . . . . . .Poster P357
House, C Ken . . . . . .Poster P296
House, Homer C . . . . . .Scientific Exhibit SE025
House, Hugh . . . . . .Scientific Exhibit SE025
Howard, Craig . . . . . .Poster P231
Howard, James . . . . . .Poster P015, P047
Howie, Donald . . . . . .Paper 202,
Hozack, William J . . . . . .Poster P017, P033, P062, P070, ...Scientific Exhibit SE019, Symposia B, I, L
Hreska, Timothy . . . . . .Paper 028
Hsu, Chia-Chen . . . . . .Poster P136, P153, P433
Hsu, Chien-Jen . . . . . .Poster P140
Hsu, Horng-Chaung . . . . . .Poster P195
Hsu, Wellington . . . . . .Poster P395
Huang, Anna . . . . . .Poster P042, P096
Huang, Chun-Shun . . . . . .Poster P433
Huang, Robert . . . . . .Paper 132
Hugate, Ronald R . . . . . .Paper 111
Hui, Andrew . . . . . .Poster P015, P047
Hulen, Christopher A . . . . . .Poster P406
Hume, Eric L . . . . . .Paper 099
Hungerford, David S . . . . . .Poster P117, P130, P170
Hungerford, Marc Wilson . . . . . .Symposia C
Hunt, Thomas R . . . . . .Scientific Exhibit SE026

Hurwitz, Shepard R . . . . . .Paper 066
Hussein, Mohammed . . . . . .Paper 190
Hutter, Andrew . . . . . .Scientific Exhibit SE081
Hutton, William C . . . . . .Poster P230
Hyman, Joshua E . . . . . .Paper 021
Iannotti, Joseph P . . . . . .Symposia BB, ORS1
Ibrahim, Kamal N. . . . . .Symposia F
Iesaka, Kazuho . . . . . .Poster P079
Ihn, Joo Chul . . . . . .Paper 273
Ikawa, Motoya . . . . . .Poster P400
Illgen, Richard Lynn . . . . . .Poster P049, P106
Imai, Yoshiyuki . . . . . .Poster P418
Imrie, Susanna N . . . . . .Poster P058
Incavo, Stephen J . . . . . .Poster P035, P121, P154
Infante, Anthony Frank . . . . . .Poster P460
Inoue, Masayuki . . . . . .Scientific Exhibit SE035
Inoue, Yoshiya . . . . . .Poster P184
Insall, John N . . . . . .Poster P125, Scientific Exhibit SE036
Inwards, Carrie . . . . . .Paper 224
Iorio, Richard . . . . . .Poster P021, P065
Ip, Tze C . . . . . .Poster P373
Iqbal, Perwiaz . . . . . .Paper 265
Irrgang, James J . . . . . .Paper 236
Isberg, Jonas L . . . . . .Poster P330
Iseka, Kazuho . . . . . .Scientific Exhibit SE055
Ishida, Yoichiro . . . . . .Paper 089
Ishikawa, Takuji . . . . . .Poster P333
Ishimoto, Katsuhiko . . . . . .Poster P160
Iskander, John M . . . . . .Paper 032, Poster P002
Islinger, Richard B . . . . . .Symposia M
Ismaily, Sabir . . . . . .Paper 209, 286
Isu, Kazuo . . . . . .Poster P173
Itamura, John Minoru . . . . . .Poster P295
Ito, Hiroshi . . . . . .Poster P050, P080
Ito, Manabu . . . . . .Paper 185
Itoi, Eiji . . . . . .Paper 071, Symposia E
Ivaldo, Nicola . . . . . .Poster P268
Iwamoto, Yukihide . . . . . .Paper 271, Poster P069, P097, P218
Iwasaki, Motoki . . . . . .Poster P414
Iwasaki, Yasunobu . . . . . .Paper 234
Iwase, Miho . . . . . .Scientific Exhibit SE048
Izaki, Teruaki . . . . . .Poster P454
Jackowski, Dianne . . . . . .Poster P220
Jacob, Hilaire . . . . . .Scientific Exhibit SE037
Jacobs, Joshua J . . . . . .Paper 093, 205, Poster P112, P134
Jacofsky, David J . . . . . .Paper 086, 165, 171, Poster P162
Jafarnia, Kourosh . . . . . .Poster P449
Jahr, Jonathan S . . . . . .Poster P030
Jain, Nitin . . . . . .Paper 007
Jain, Ritu . . . . . .Paper 075
Janoff, Daniel . . . . . .Poster P243
Jaramaz, Branislav . . . . . .Scientific Exhibit SE084
Jarrett, S David . . . . . .Poster P057
Jaseniuk, Jonathan . . . . . .Paper 235
Jasty, Murali . . . . . .Scientific Exhibit SE004
Jazrawi, Laith M . . . . . .Poster P352
Jenny, Jean-Yves . . . . . .Paper 061, Poster P127
Jeong, Gerard . . . . . .Paper 182
Jeys, Lee . . . . . .Paper 082, Poster P431
Jibodh, Stefan R . . . . . .Poster P360
Jimenez, Matthew L . .Poster P018, P237, Scientific Exhibit SE065
Jimulia, Tushar R . . . . . .Poster P191
Jingushi, Seiya S . . . . . .Paper 271, Poster P069
Jinno, Tetsuya . . . . . .Poster P032
Jiranek, William A . . . . . .Poster P139, Scientific Exhibit SE083, ...SE086, Symposia L
Jo, Hyunchul . . . . . .Poster P328, P342
Johnell, Olof . . . . . .Paper 153
Johnson, B. . . . . .Paper 036
Johnson, Brian . . . . . .Paper 263
Johnson, Darren L . . . . . .Poster P344
Johnson, Donald Hugh . . . . . .Poster P323
Johnson, Jeffrey Einer . . . . . .Symposia H
Johnson, Karin A . . . . . .Poster P299
Johnson, Lloyd . . . . . .Paper 092
Johnson, Robert J . . . . . .Symposia P
Johnson, Timothy S . . . . . .Paper 109
Johnston, James D . . . . . .Paper 250
Johnston, Richard C . . . . . .Poster P014, P090
Jones, Bob . . . . . .Scientific Exhibit SE014
Jones, Lynne C . . . . . .Poster P130, P170
Jones, Richard Edward . . . . . .Paper 099
Jordan, Louis CM . . . . . .Poster P083
Jordan, Louis R . . . . . .Paper 178
Josefsson, Per Olof . . . . . .Paper 197
Joseph, Thomas A. . . . . .Paper 059
Joshi, Atul B . . . . . .Poster P023, P027, P123, P146
Joyce, Michael J . . . . . .Scientific Exhibit SE082
Judet, Thierry . . . . . .Paper 113
Juliano, Paul J . . . . . .Paper 111
Jung, Hong-Geun . . . . . .Poster P435
Jung, Sung Taek . . . . . .Paper 183, Poster P182, P410
Junkelis, Dainius . . . . . .Paper 070
Jupiter, Jesse B . . . . . .Poster P199, P254, P255, P449, ...P450, P451, Symposia D, Q, Y
Kabo, Michael . . . . . .Poster P176
Kadrmas, Michael Wayne . . . . . .Poster P244
Kadzielski, John . . . . . .Poster P199
Kagan, Abbott . . . . . .Scientific Exhibit SE088
Kahler, David M . . . . . .Scientific Exhibit SE084
Kahn, Richard L . . . . . .Poster P147
Kainberger, Franz . . . . . .Poster P188
Kajino, Tomomichi . . . . . .Poster P408
Kalantzis, George . . . . . .Poster P010
Kalfas, Iain H . . . . . .Paper 256
Kamrin, Majid . . . . . .Poster P114
Kanamiya, Takeshi . . . . . .Poster P118
Kanaya, Fuminori . . . . . .Paper 077
Kanayama, Masahiro . . . . . .Poster P396
Kaneda, Kiyoshi . . . . . .Paper 185, Poster P408
Kaneko, Kenji . . . . . .Scientific Exhibit SE048
Kang, James . . . . . .Poster P411
Kang, Lana . . . . . .Paper 213
Kang, Seung Baik . . . . . .Poster P113
Kanim, Linda E A . . . . . .Poster P407
Kankane, Manoj Kumar . . . . . .Paper 068
Kantor, Stephen R . . . . . .Poster P082
Kaplan, David . . . . . .Symposia ORS1
Karamat, Lukas . . . . . .Poster P443
Karandikar, Ninad S . . . . . .Poster P133
Karlsson, Jon . . . . . .Poster P304, P306, P330
Karlsson, Magnus . . . . . .Paper 197
Karol, Lori A . . . . . .Paper 131
Karpman, Robert R . . . . . .Scientific Exhibit SE088
Karr, Donna . . . . . .Paper 192
Karrholm, Johan Nils . . . . . .Poster P019, P330
Kartus, Juri . . . . . .Poster P304, P306
Karunakar, Madhav A . . . . . .Paper 164
Kasperk, Hans Christian . . . . . .Paper 187
Kasser, James R . . . . . .Symposia J
Katonis, Paul . . . . . .Poster P392
Katz, Donald E . . . . . .Paper 131

Katz, Jeffrey N . . . . . .Paper 001, 004, 033, Symposia DD
Katzer, Alexander . . . . . .Paper 277
Kauffman, Jeffrey I . . . . . .Poster P261
Kaufman, John D . . . . . .Scientific Exhibit SE087
Kavanagh, Brian F . . . . . .Paper 037
Kawaguchi, Noriyoshi . . . . . .Poster P181
Kawaguchi, Satoshi . . . . . .Poster P173
Kawahara, Norio . . . . . .Poster P383
Kawai, Shinya . . . . . .Paper 089
Kawamura, Sumito . . . . . .Poster P315
Kawashima, Hiroyuki . . . . . .Poster P184
Kay, Robert Michael . . . . . .Symposia X
Kaya, Mitsunori . . . . . .Poster P173
Kazaglis, Jeffrey A . . . . . .Poster P442
Kazani, Shamsah . . . . . .Paper 007
Kazimiroff, Paul . . . . . .Paper 261
Kazmareck, Colleen . . . . . .Poster P036, P287
Keaveny, Tony . . . . . .Scientific Exhibit SE076
Kebaish, Khaled M- . . . . . .Poster P390, P423
Keblish, Peter A . . . . . .Scientific Exhibit SE027
Keggi, John M . . . . . .Scientific Exhibit SE012
Keggi, Kristaps J . . . . . .Paper 099, Scientific Exhibit SE012
Kelikian, Armen S . . . . . .Poster P439
Kellam, James F . . . . . .Paper 164
Kellar-Graney, Kristen . . . . . .Paper 083
Kellett, Catherine . . . . . .Paper 058
Kelley, Scott S . . . . . .Poster P085, P115
Kelly, Cynthia M . . . . . .Poster P176
Kelly, Jennifer . . . . . .Paper 221
Kennedy, John . . . . . .Poster P444
Kennedy, William R . . . .Paper 099, 249, Scientific Exhibit SE015
Kennon, Robert Edward . . . . . .Scientific Exhibit SE012
Kenny, Patrick Joseph . . . . . .Paper 204
Kervildis, Michael . . . . . .Scientific Exhibit SE074
Khadivi, Bahram . . . . . .Paper 108
Khan, Zafar S . . . . . .Poster P278
Khanna, A Jay . . . . . .Scientific Exhibit SE060
Khanna, G . . . . . .Scientific Exhibit SE061
Khanuja, Harpal S . . . . . .Poster P117
Khatod, Monti . . . . . .Paper 176
Khoury, Amal . . . . . .Poster P208
Kido, Tadato . . . . . .Paper 071
Kiesau, Carter D . . . . . .Poster P192
Kikugawa, Kazuhiko . . . . . .Poster P270
Killeen, Kathleen . . . . . .Paper 002, 006, 280, Poster P028, ...Scientific Exhibit SE029
Kim, Han-Soo . . . . . .Poster P183
Kim, Hee Sun . . . . . .Paper 283
Kim, Hui Taek . . . . . .Paper 137
Kim, Jane . . . . . .Paper 005, 175
Kim, Kang Jung . . . . . .Scientific Exhibit SE048
Kim, Kye-Jin . . . . . .Paper 183
Kim, Kye-Jin . . . . . .Poster P182
Kim, Seung-Ho . . . . . .Paper 072, Poster P309, P314
Kim, Shin Yoon . . . . . .Paper 273
Kim, Shin-Yoon . . . . . .Poster P061
Kim, Yang-Kyung . . . . . .Paper 183
Kim, Yang-Kyung . . . . . .Poster P182
Kim, Yeon-Sung . . . . . .Paper 183
Kim, Yong Jung . . . . . .Paper 254
Kim, Yong Sik . . . . . .Poster P061
Kim, Yong-Goo . . . . . .Paper 273
Kim, Yong-uk . . . . . .Poster P182
Kimura, Tomoatsu . . . . . .Poster P131
King, David J . . . . . .Paper 264
King, Warren D . . . . . .Paper 106
Kinsey, Tracy . . . . . .Paper 208, Poster P109, P111, P143, P167
Kirkendall, Donald T . . . . . .Paper 013
Kirkpatrick, Delores K . . . . . .Scientific Exhibit SE090
Kirkpatrick, John S . . . . . .Poster P379
Kish, Benjamin . . . . . .Paper 156, 157
Kish, Vincent L. . . . . .Poster P171
Kishida, Shunji . . . . . .Poster P077
Kita, Masataka . . . . . .Poster P069
Kitaoka, Kenichi . . . . . .Paper 184
Klatt, Joshua . . . . . .Paper 063
Klauser, Wolfgang . . . . . .Poster P066
Klein, Scott . . . . . .Poster P382
Klepps, Steve . . . . . .Paper 216
Kligman, Mordechai . . . . . .Poster P038
Klingenstein, Gregory Gillman . . . . . .Poster P189
Kloen, Peter . . . . . .Poster P199, P255
Knahr, Karl . . . . . .Poster P443
Knecht, Stephen L . . . . . .Paper 115
Knight, Tania . . . . . .Paper 202
Knoller, Stefan . . . . . .Poster P415
Ko, Jih-Yang . . . . . .Poster P440
Ko, Sang-Bong . . . . . .Poster P201
Kobayash, Kenji . . . . . .Poster P316
Kobayashi, Moto . . . . . .Paper 071
Kobayashi, Tetsuya . . . . . .Poster P400
Kocher, Mininder S . . . . . .Paper 025, Poster P282
Koga, Daisuke . . . . . .Poster P032
Koga, Hideyuki . . . . . .Poster P181
Koga, Takamasa . . . . . .Poster P454
Koh, Jason L . . . . . .Poster P350
Koikawa, Natue . . . . . .Poster P333
Kolb, Edward H . . . . . .Poster P322
Kolomytkin, Oleg V . . . . . .Paper 051
Koman, L Andrew . . . . . .Paper 046, 266
Kominski, Gerald . . . . . .Paper 155
Komistek, Richard D . . .Paper 289, Scientific Exhibit SE039, SE050
Kondo, Makoto . . . . . .Poster P120
Kondrachov, Dimitry . . . . . .Paper 258, Poster P416
Konermann, Werner . . . . . .Symposia AA
Korrosis, Sortiris . . . . . .Poster P431
Koslowsky, Thomas Christian . . . . . .Scientific Exhibit SE053
Kostopoulos, Dimitrios . . . . . .Poster P226
Kostuik, John P . . . . . .Poster P390, P423
Kotani, Yoshihisa . . . . . .Paper 185
Koulouvaris, Panaviotis S. . . . . .Paper 275
Kovacic, Jeffrey J . . . . . .Poster P394
Kovacik, Mark W . . . . . .Poster P155
Koval, Kenneth J . . . . . .Paper 166, 196, ...Poster P206, P219, P223, P229, P241, P361, ...Scientific Exhibit SE055, SE088, Symposia Z
Kowalski, Adam . . . . . .Poster P350
Koyoma, Tsuyoshi . . . . . .Poster P076, P084
Kozaki, Naoto . . . . . .Poster P454
Krackow, Kenneth A . . . . . .Poster P101, P110, P144, P159
Kragh, John F . . . . . .Poster P442
Kransdorf, Mark J . . . . . .Poster P178
Krause, William . . . . . .Scientific Exhibit SE057
Kregor, Philip James . . . . . .Paper 162, Symposia R
Kremenic, Ian . . . . . .Poster P462
Kress, Kenneth J . . . . . .Paper 099
Krettek, Christian . . . . . .Paper 104, 193, 194, Poster P249
Krevolin, Janet L . . . . . .Poster P081
Krikler, Stephen J. . . . . .Scientific Exhibit SE005
Krishnan, Sumant . . . . . .Paper 215
Krol, Marina . . . . . .Poster P273
Krupp, Ryan . . . . . .Poster P035

Kubiak, Erik . . . . . .Poster P079, P219, P223, P352, P361, ...Scientific Exhibit SE055
Kudrna, James Charles . . . . . .Poster P044
Kuiper, Jan Herman . . . . . .Poster P071
Kuklo, Timothy R . . . . . .Paper 125
Kullberg, Ragnar . . . . . .Poster P306
Kumai, Tsukasa . . . . . .Poster P437
Kumar, Sanjay . . . . . .Paper 148
Kummer, Fredrick J . . . . . .Poster P079, P206, P219, P223, ...P229, P352, Scientific Exhibit SE055
Kuroda, Ryosuke . . .Paper 234, Poster P319, Scientific Exhibit SE039
Kurosaka, Masahiro . . . . . .Paper 234, Poster P160, P319, P417, ...Scientific Exhibit SE039
Kurosawa, Hisashi . . . . . .Poster P333
Kurtin, Stephen M . . . . . .Scientific Exhibit SE028, SE038
Kurtz, Steven M . . . . . .Poster P033, P062, P422
Kwak, Christine . . . . . .Paper 110
Kwon, Soon Yong . . . . . .Poster P061
Kwong, Louis M . . . . . .Paper 040
Kyle, Richard F . . . . . .Symposia Z
LaPorte, Dawn . . . . . .Paper 080
Lachiewicz, Paul F . . . .Poster P057, P115, P124, Symposia EE, I, W
Lackman, Richard D . . . . . .Paper 160, Poster P175, P185
Lafosse, Laurent . . . . . .Poster P291, Symposia N
Lai, Sue Min . . . . . .Paper 255
Laing, P W . . . . . .Paper 112
Lamberton, Tony . . . . . .Paper 204
Lambiris, Elias . . . . . .Poster P292
Lampropulos, Mario . . . . . .Poster P369
Lander, Philip . . . . . .Paper 188
Landgraf, Peter . . . . . .Scientific Exhibit SE058
Lane, Joseph M . . . . . .Poster P393, Scientific Exhibit SE087, ...Symposia K, ORS2
Langerman, Richard J . . . . . .Poster P272
Larsen, John M . . . . . .Poster P386
Laskin, Richard Sheldon . . . . . .Paper 285, Poster P150, ...Scientific Exhibit SE079
Lassen, Michael Rud . . . . . .Paper 040
Latta, Loren L . . . . . .Paper 067
Lauder, Anthony J . . . . . .Poster P103
Laudner, Kevin G . . . . . .Poster P327
Launay, Franck . . . . . .Paper 027, 029
Laurencin, Cato T . . . . . .Scientific Exhibit SE083, Symposia K
Lautenschlager, Eugene . . . . . .Poster P350
Lavernia, Carlos J . . . . . .Poster P026, P072, P078, ...Scientific Exhibit SE080
Lavoie, Guy John . . . . . .Poster P012
Lawler, Ericka Ann . . . . . .Poster P452
Lawless, Matthew . . . . . .Poster P217
Lazennec, Jean Yves . . . . . .Poster P041
Le, Theodore Toan . . . . . .Paper 164
LeDuff, Michael J . . . . . .Paper 278, Scientific Exhibit SE021
Lea, Randall David . . . . . .Scientific Exhibit SE090
Learmonth, Ian D . . . . . .Poster P010
Lebeck, Lauralynn . . . . . .Paper 110
Lee, Casey K . . . . . .Paper 129, Poster P389
Lee, Cathy . . . . . .Poster P273
Lee, Chang Yang . . . . . .Poster P309
Lee, Choon-Ki . . . . . .Poster P413
Lee, David . . . . . .Poster P072
Lee, Greg . . . . . .Poster P439
Lee, Gwo-Chin . . . . . .Poster P162
Lee, Jae Hak . . . . . .Poster P413
Lee, Jae Hyup . . . . . .Poster P413
Lee, Jun Young . . . . . .Poster P380, P458
Lee, Keun Bae . . . . . .Poster P397
Lee, Myung Chul . . . . . .Poster P328, P342
Lee, Paul T H . . . . . .Paper 097, 098
Lee, Samuel . . . . . .Poster P257
Lee, Sang Wook . . . . . .Poster P201
Lee, Sang Yang . . . . . .Scientific Exhibit SE039
Lee, Sang-Hong . . . . . .Poster P458
Lee, Sang-Hoon . . . . . .Poster P183, P328, P342
Lee, Sang-Min . . . . . .Paper 092
Lee, Seung-Bak . . . . . .Poster P060
Lee, Steve K . . . . . .Poster P452
Lee, Steven . . . . . .Poster P290, P462
Lee, Thay Q . . . . . .Poster P280, P281, P283
Lee, YeonSoo . . . . . .Poster P281, P283
Lee, Yu-Po . . . . . .Poster P176
Leece, Pamela . . . . . .Poster P239
Leet, Arabella I . . . . . .Paper 027, Poster P370
Lehman, Ronald . . . . . .Paper 125
Lehman, Wallace B . . . . . .Paper 269, Poster P374, Symposia X
Lehtinen, Janne Tapani . . . . . .Poster P286
Leighton, Ross K . . . . . .Paper 064
Lemons, Jack E . . . . . .Poster P003
Lenke, Lawrence G . . . . .Paper 126, 127, 254, Poster P387, P424
Leopold, Seth S . . . . . .Poster P112
Lephardt, Scott M . . . . . .Poster P327
Lett, Patrick W . . . . . .Poster P034
Levin, Anna . . . . . .Poster P376
Levin, Daniel . . . . . .Paper 093
Levin, L Scott . . . . . .Scientific Exhibit SE089
Levine, Pamela M . . . . . .Poster P459
Levitz, Seth . . . . . .Poster P451
Levy, Andrew Stuart . . . . . .Poster P289
Levy, Jonathan C . . . . . .Poster P178
Lewallen, David G . . . . . .Poster P048, Scientific Exhibit SE013, ...SE051, Symposia L
Lewis, Randall J . . . . . .Scientific Exhibit SE013
Lewis, Randall . . . . . .Poster P048
Lewis, Valerae O . . . . . .Paper 230
Lewonowski, Kris . . . . . .Poster P419
Li, Guoan . . . . . .Poster P152, Scientific Exhibit SE044
Liebergall, Meir . . . . . .Poster P208
Lieberman, Isador H . . . . . .Paper 186, 190, Poster P394
Lieberman, Jay R . . . . . .Paper 060, Symposia EE, K
Liebman, Matthew . . . . . .Paper 196
Lin, Hsiu-Chen . . . . . .Poster P195
Lin, Jack . . . . . .Paper 106
Lin, Patrick P . . . . . .Paper 230
Lindahl, Hans . . . . . .Paper 168
Lindgren, Bruce . . . . . .Paper 141, Poster P263
Linke, Berend . . . . . .Poster P415
Liporace, Frank . . . . . .Paper 182, Poster P229, P241
Lipton, Carter B . . . . . .Paper 043, 134
Liu, Hwa-Chang . . . . . .Paper 282
Liu, Steve S . . . . . .Poster P014
Livnigstone, Brian . . . . . .Poster P436
Lo, Ian . . . . . .Paper 216, 217
Lo, Ngai-Nung . . . . . .Poster P093
Loehr, Joachim F . . . . . .Paper 277
Lofvendahl, Sofia . . . . . .Paper 153
Logan, Martin Charles . . . . . .Poster P305
Lombardi, Adolph V . . . . . .Paper 290, Poster P098, ...Scientific Exhibit SE010, SE034
Lombardo, Stephen J . . . . . .Paper 015
Long, Michael J . . . . . .Poster P151
Long, William T . . . . . .Poster P063
Lonner, Baron . . . . . .Paper 258
Lonner, Jess H . . . . . .Paper 005, Poster P119, P135

Lopez, Robert . . . . . .Paper 192
Losert, Udo . . . . . .Paper 103
Losina, Elena . . . . . .Paper 001, 004, 033
Lotke, Paul A . . . . . .Paper 005, 175, Poster P135, Symposia G
Lotz, Martin . . . . . .Paper 105
Lou, Julia E . . . . . .Paper 267
Lowe, Thomas G . . . . . .Poster P387
Lowry, Jason . . . . . .Poster P064
Lozynsky, Andrew J . . . . . .Poster P042
Lu, Tong-wu . . . . . .Paper 282
Lubicky, John Peter . . . . . .Poster P421
Lubinus, Philipp . . . . . .Poster P066
Luck, Stefan . . . . . .Paper 277
Luhmann, Scott J . . . . . .Paper 139, 264
Lyons, Steven Thomas . . . . . .Paper 244
Lyons, Steven . . . . . .Scientific Exhibit SE018
Ma, C Benjamin . . . . . .Poster P257, P315
Maale, Gerhard E . . . . . .Poster P297
Maalouf, Ghassan . . . . . .Paper 118
MacDonald, Steven J . . . . . .Paper 179, 203, 241, ...Poster P006, P015, P047, P087, P104
MacGillivray, John Dougald . . . . . .Poster P257
MacKenzie, D Allan . . . . . .Scientific Exhibit SE090
MacLennan, Paul . . . . . .Poster P379
Madan, Sanjeev . . . . . .Poster P374
Mader, Konrad . . . . . .Scientific Exhibit SE053
Maeno, Shinichi . . . . . .Poster P120
Maenza, Ruben . . . . . .Poster P369
Maguire, Gerald . . . . . .Poster P039
Mahajan, Varun . . . . . .Poster P388
Mahar, Andrew . . . . . .Poster P402
Maheshwer, Conjeevaram . . . . . .Paper 068, Poster P088
Mahfouz, Mohamed . . .Paper 289, Scientific Exhibit SE039, SE050
Mahomed, Nizar . . . . . .Paper 001, 004, 033, 154
Mahoney, Ormonde M . . . .Paper 208, Poster P109, P111, P143, P167
Mairot, Fabrice . . . . . .Paper 061
Majima, Tokifumi . . . . . .Scientific Exhibit SE035
Makhsous, Mohsen . . . . . .Poster P439
Makwana, Nilesh . . . . . .Paper 112
Malawer, Martin M . . . . . .Paper 083, 228
Malcarney, Hilary . . . . . .Poster P264
Malchau, Henrik . . . . . .Paper 168, 276, Symposia DD
Malinin, Theodore . . . . . .Poster P190
Malkani, Arthur L . . . . . .Poster P025, P035, P133, P145
Mallen, Jonathan R . . . . . .Poster P367
Mallory, Thomas H . . . . . .Paper 290, Poster P098, ...Scientific Exhibit SE010, SE034
Malmqvist, Bengt . . . . . .Paper 153
Maloney, William J . . . .Paper 092, 093, 206, Symposia DD, I, L, W
Malvarez, Hector R . . . . . .Poster P369
Manabe, Jun . . . . . .Poster P181
Mandelbaum, Bert . . . . . .Paper 022
Mandiga, Rahul . . . . . .Paper 025
Manfrini, Marco . . . . . .Paper 229
Mankin, Carole . . . . . .Scientific Exhibit SE070
Mankin, Henry J . . . . . .Paper 222, 223, Scientific Exhibit SE070
Manley, Michael T . . . . . .Paper 055, 100
Mann, Gideon . . . . . .Paper 156, 157
Mann, Roger A . . . . . .Poster P441
Manna, Barbara . . . . . .Paper 255
Manning, David W . . . . . .Poster P045
Marchesi, Dante . . . . . .Paper 188
Marcolongo, Michelle . . . . . .Poster P062
Marcus, Randall Evan . . . . . .Poster P236
Mardjetko, Steven M . . . . . .Poster P420, P421
Margheritini, Fabrizio . . . . . .Poster P327
Mariconda, Massimo . . . . . .Paper 128
Marino, Andrew A . . . . . .Paper 051
Markel, David C . . . . . .Poster P212
Markovic, LJubisa . . . . . .Poster P023, P027
Markovich, George David . . . .Poster P099, Scientific Exhibit SE045
Marks, David S . . . . . .Poster P381
Marks, Reema . . . . . .Poster P052
Marongiu, Maria Carmen . . . . . .Paper 142
Marra, Guido . . . . . .Poster P301
Marsh, John Lawrence . . . . . .Paper 066, Poster P234
Marshall, Jeanette . . . . . .Paper 214
Martell, John M . . . . . .Poster P019, P033, P045
Marti, Rene K . . . . . .Paper 274
Martin, Scott David . . . . . .Paper 143, 145
Martins, Cesar Antonio de Quadros . . . . . .Poster P377
Mashru, Rakesh Pravinkumar . . . . . .Poster P202
Mason, J Bohannon . . . . . .Paper 177, 242
Mason, James . . . . . .Scientific Exhibit SE077
Masonis, John Leander . . . . . .Poster P047
Masri, Bassam A . . . . . .Poster P005
Masson, Edward . . . . . .Poster P012
Masuda, Koichi . . . . . .Poster P418
Math, Kevin . . . . . .Paper 172
Mathews, Vasilios . . . . . .Paper 243
Mathis, Kenneth B . . . . . .Paper 209
Matsen, Frederick A . . . . . .Poster P274, Symposia E
Matsuda, Shuichi . . . . . .Poster P097
Matsui, N . . . . . .Scientific Exhibit SE039
Matsui, Nobuzo . . . . . .Paper 234, Poster P319
Matsumoto, Akio . . . . . .Paper 234
Matsumoto, Hideo . . . . . .Poster P120
Matsumoto, Seiichi . . . . . .Poster P181
Matsumoto, Tomoyuki . . . . . .Poster P160
Matsuno, Takeo . . . . . .Poster P050, P080, P400
Matsushita, Isao . . . . . .Poster P131
Matsuzaki, Akio . . . . . .Poster P454
Matthews, Sacha D . . . . . .Poster P452
Matziolis, Georg . . . . . .Paper 199
Mavrodontidis, Alexandros . . . . . .Paper 275
Mawatari, Taro . . . . . .Poster P097
May, Charles B . . . . . .Poster P132
Mazahery, Behrang . . . . . .Poster P044
Mazzuca, Steven A . . . . . .Poster P196
McAfee, Paul C . . . . . .Symposia A
McAllister, David R . . . . . .Poster P325
McAuley, James P . . . . . .Paper 094, Poster P095, P107, P116,
McBeath, Andrew A . . . . . .Poster P106
McCalden, Richard W . . . . . .Paper 179, 203, 241, ...Poster P006, P015, P047, P087, P104
McCall, Brian Richard . . . . . .Poster P275
McCallister, Wren V . . . . . .Poster P274
McCarthy, Edward F . . . . . .Scientific Exhibit SE063
McCarthy, Joseph C . . . . . .Symposia B
McClenny, Michelle D . . . . . .Poster P003
McConnell, Alison . . . . . .Poster P216, P284
McCormick, Jeremy J . . . . . .Poster P301
McCoy, Leslie . . . . . .Poster P051
McCoy, Thomas H . . . . . .Paper 177, 242
McDonald-McGinn, Donna M . . . . . .Poster P409
McFarland, Beth . . . . . .Poster P246
McFarland, Edward G . . . . . .Poster P271
McFarlin, Sarah . . . . . .Poster P446
McGarry, Michelle H . . . . . .Poster P280, P281, P283
McGee, Margaret A . . . . . .Paper 202
McGillivary, Gary R . . . . . .Poster P453
McGrath, Timothy V . . . . . .Poster P339

McGuire, Kevin J .....Paper 200
McGwin, Gerald .....Paper 017, 192, 195, Poster P346, P379
McHugh, Malachy P .....Poster P290, P462
McKee, Andrew .....Paper 257
McKee, Michael D .....Poster P242, P284, P285, Symposia D, Y
McKenzie, Colin .....Poster P030
McKinley, Todd Owen .....Poster P234
McLain, Robert F .....Paper 256, Poster P426
McMahon, Margot .....Paper 284, Poster P036, P287, ...Scientific Exhibit SE041
McQueen, David A .....Poster P151
McQueen, Margaret M .....Symposia Y
Medige, John .....Poster P231
Medley, John B .....Poster P104
Meeder, Peter Jurgen .....Paper 187
Meehan, Robert E .....Poster P446
Mehendale, Sanchit .....Poster P010
Mehbod, Amir A .....Scientific Exhibit SE061
Mehin, Ramin .....Paper 203, 241, Poster P006
Mehle, Susan Clay .....Paper 002, 006, 280, Poster P028
Mehlman, Charles T .....Paper 136
Mehta, Samir .....Paper 090, Poster P135, P366
Meier, Jeffrey D .....Poster P289
Meier, Steven W .....Poster P289
Meislin, Robert J .....Poster P352
Meissner, Mark H .....Paper 191
Meldrum, Russell D .....Poster P020, P196
Melhorn, J Mark .....Scientific Exhibit SE090
Melone, Charles P .....Paper 044
Menendez, Lawrence R .....Poster P180
Menendez-Rodriguez, Primitiva .....Poster P364
Mercuri, Mario .....Paper 085, 229
Merola, Andrew A .....Poster P387
Merten, Sheri M .....Poster P267
Messer, Terry M .....Poster P232
Meyer, Dominik Christoph .....Paper 219, 220
Meyer, Georg .....Poster P415
Micheli, Lyle J .....Paper 022, 025
Middleton, Robert Gordon .....Poster P368
Mighell, Mark A .....Poster P279
Mihalko, William Michael .....Poster P101, P110, P144, ...P159, P231, P288, P339
Mihata, Teruhisa .....Poster P280
Miki, Hidenobu .....Poster P001, P060, P076, P084
Milano, Carlo .....Paper 128
Miles, Anthony William .....Poster P205
Mileti, Joseph .....Poster P258
Miller, Bruce .....Paper 059, Poster P163
Miller, Freeman .Paper 135, Poster P404, Scientific Exhibit SE066
Miller, Mark D .....Poster P312
Miller, Suzanne .....Paper 236
Millett, Peter J .....Paper 073, Poster P262
Millstein, Eric S .....Poster P335
Min, Kan .....Poster P381
Minagawa, Hiroshi .....Paper 071, Scientific Exhibit SE051
Minami, Akio .....Paper 185, Poster P050, P080, ...Scientific Exhibit SE035
Miranda, A .....Paper 036
Mitchell, Philip .....Poster P005
Mitchell, Steven R .....Poster P166
Mitsionis, Grigoris .....Paper 275
Mitsuoka, Tomoki .....Poster P313
Mittlmeier, Thomas W F .....Scientific Exhibit SE058
Miura, Hiromasa .....Poster P097
Miyauchi, Akira .....Poster P414
Mizobuchi, Hiroo .....Paper 184
Mizuno, Kiyonori .....Poster P319
Mochizuki, Yu .....Poster P270
Moed, Berton R .....Poster P212
Mohan, Avinash .....Poster P367
Mohan, Vivek .....Paper 039
Mole, Daniel .....Paper 141, 147, Symposia N
Mollabashy, Allaaddin .....Poster P178, P406
Moller, Hans .....Poster P381
Mont, Michael A .....Paper 284, Poster P040, P130, P161, P170, ...Scientific Exhibit SE041, SE043, SE052, Symposia B, C
Montori, Victor M .....Poster P220
Moon, Eun-Sun .....Poster P182, P397
Moon, Young Lae .....Poster P458
Moon, Young-Wan .....Poster P061
Moore, Douglas C .....Poster P211
Moore, J Russell .....Paper 080
Moore, K David .....Poster P003
Moorthy, Murali .....Paper 116
Moraiti, Tina .....Poster P336
Moran, Steven .....Paper 048
Morcuende, Jose A .....Paper 268
Morelli, Christine .....Poster P147
Moreyra, Carlos E .....Poster P078
Morgan, Craig D .....Poster P310
Morita, Sadao .....Poster P032
Morita, Tetsuro .....Poster P184
Morita, Yuji .....Poster P131
Moritani, Masahiro .....Poster P414
Moriya, Hideshige .....Poster P077
Moroni, Antonio .....Paper 167, Poster P207, ...Scientific Exhibit SE056
Moroz, Paul J .....Paper 028
Morra, Edward .....Scientific Exhibit SE040
Morrey, Bernard F .....Paper 034, 078, 079, Poster P068
Morris, Carol D .....Paper 227
Morris, Hugh B .....Poster P035
Morrison, J Craig .....Paper 201
Moseley, Bruce .....Paper 022
Mosheiff, Rami .....Poster P208
Moshirfar, Ali .....Scientific Exhibit SE060
Moskal, Joseph T .....Poster P083, P100, Scientific Exhibit SE031
Moskovich, Ronald .....Paper 182
Moskowitz, Norman .....Scientific Exhibit SE090
Most, Ephrat .....Scientific Exhibit SE044
Motamed, Soheil .....Poster P295
Motamedi, Kambiz .....Poster P325
Motomura, Goro .....Paper 271
Moussaoui, Akli .....Paper 061
Movin, Tomas .....Poster P304
Muehleman, Carol .....Poster P418
Muehling, Valerie .....Paper 066
Mueller, Urs .....Poster P073
Mullins, Eric Ronald .....Poster P121
Muneta, Takeshi .....Poster P032
Munzinger, Urs .....Scientific Exhibit SE027
Murakami, Hideki .....Poster P383
Muratoglu, Orhun K .....Poster P042, P075, P096
Muratsu, Hirotsugu .....Poster P160, P319, P417, ...Scientific Exhibit SE039
Murcia-Mazon, Antonio .....Poster P364
Murphy, Jeffrey A .....Paper 173, Poster P158
Murphy, John .....Poster P023, P027
Murphy, Michael S .....Paper 080
Murphy, Stephen B .....Paper 099, Poster P009
Murray, David W .....Paper 058
Murrell, George A C .....Paper 214, Poster P264, P355, P432

Murthi, Anand M .....Poster P259
Muschler, George F .....Poster P426, Symposia O
Muscolo, D Luis .....Paper 087, 088
Muthukaruppan, Yegappan A L .....Paper 239
Myer, Gregory Donald .....Paper 012
Nadaud, Matthew C .....Poster P155
Nagda, Sameer .....Poster P175
Nagowski, Jarrod .....Paper 039
Nagoya, Satoshi .....Poster P173
Naito, Masatoshi .....Paper 272, Poster P118, P326, ...Scientific Exhibit SE030
Najibi, Soheil .....Poster P021
Nakagawa, Koichi .....Poster P418
Nakamura, Norimasa .....Poster P313
Nakamura, Shawn J .....Paper 174
Nakane, Masaki .....Poster P227, P238
Nakashima, Yasuharu .....Paper 271, Poster P069
Nakayama, Koichi .....Poster P097
Namba, Robert S .....Paper 035
Naresh Babu, J .....Paper 068
Nasser, Sam .....Poster P102, Scientific Exhibit SE013
Nattiv, Aurelia .....Scientific Exhibit SE075
Naudie, Doug .....Paper 096
Nauhgton, Michelle .....Paper 266
Nazarian, David George .....Poster P008, P055, P114, P165
Negishi, Takaoki .....Poster P332
Nehme, Alexander .....Paper 118
Nehrer, Stefan .....Paper 103
Nelson, Charles .....Paper 005, 175
Nelson, Janis .....Poster P355
Nelson, Joshua .....Poster P064
Nelson, Karen A .....Poster P192
Nelson, Russell W .....Poster P386
Nelson, Trudi .....Paper 253
Nepola, James V .....Poster P234
Nestor, Bryan J .....Poster P011
Nevelos, Jim .....Scientific Exhibit SE005
Newton, Peter O .....Paper 124, Poster P387, P402, Symposia A
Neyton, Lionel .....Paper 141, 147, Poster P263
Ng, Biing Yann .....Poster P436
Nguyen, Augustine .....Poster P435
Nguyen, Bob .....Poster P210
Nicholas, Stephen J .....Poster P290, P462
Niki, Yasuo .....Poster P120
Nikolopoulos, Konstantinos .....Poster P226
Nilsson, Ulf .....Poster P306
Nishii, Takashi .....Poster P001, P060, P076, P084
Noble, Philip .....Paper 209, 250, 286
Nogueira, Monica P .....Poster P377
Noh, Kyu-Cheol .....Poster P314
Nohara, Yutaka .....Poster P332
Nolan, Robert S .....Poster P288
Nork, Sean E .....Paper 117, 119, 191, Symposia R
Nousiainen, Markku .....Poster P216
Nove Josserand, Laurent .....Poster P263
Nove-Josserand, Laurent .....Paper 141
Noyes, Frank R .....Paper 107
Noz, Marilyn .....Poster P039
Nozaka, Koji .....Paper 071
Nung, Lo Ngai .....Poster P137
Nunley, James Albert .....Symposia H
Nyquist, Fredrik .....Paper 197
Nyska, Meir .....Paper 156, 157
O'Brien, Jeremy Joseph .....Poster P087
O'Brien, Michael F .....Poster P420
O'Brien, Stephen J .....Paper 102
O'Brien, Timothy .....Poster P141, P197
O'Connor, Gregory J .....Poster P012
O'Driscoll, Shawn W .....Paper 078, Symposia D
O'Holleran, James .....Paper 073, Poster P282
O'Keefe, Mary C .....Poster P019, Scientific Exhibit SE004
O'Keefe, Regis J .....Symposia ORS2
O'Keefe, Thomas Joseph .....Poster P048, Scientific Exhibit SE013
O'Malley, Martin J .....Poster P444
O'Neill, Patrick J .....Paper 131, Scientific Exhibit SE067
O'Rourke, Michael R .....Paper 246, 247, Scientific Exhibit SE008
O'Toole, Robert V .....Poster P108
Oberto, Daniel R .....Poster P321
Obremsky, William T .....Scientific Exhibit SE073
Ochi, Mitsuo .....Poster P270, P316
Oda, Juhachi .....Poster P383
Odum, Susan Marie .....Paper 177, 242
Ogilvie, Christian .....Paper 084
Ogose, Akira .....Poster P184
Oh, Chong .....Paper 166
Oh, Irvin .....Paper 072, Poster P314
Oh, Joo Han .....Poster P183
Ohlin, Acke .....Poster P381
Ohnmeiss, Donna D .....Paper 251, 252
Ohzono, Kenji .....Poster P001, P060
Oinuma, Kazuhiro .....Poster P077
Okamoto, Meguru .....Poster P050, P080
Okuda, Shin'ya .....Poster P414
Okuma, Masahiko .....Poster P418
Olivecrona, Henrik .....Poster P039
Olivecrona, Lotta .....Poster P039
Oliver, Matthew .....Paper 257
Olivo, Jane .....Paper 178
Olson, Patrick .....Poster P177
Olson, Steven A .....Poster P244
Omine, Akira .....Paper 077
Onozawa, Tsukasa .....Poster P400
Orishimo, Karl F .....Paper 094, Poster P013
Osland, John Donald .....Poster P074
Osmani, Omar N .....Poster P025
Osmon, Douglas R .....Poster P162
Ostendorf, Marieke .....Paper 276
Ostrum, Robert F .....Paper 064
Otani, Toshiro .....Poster P120
Otis, James .....Poster P257
Otsuka, Norman Yoshinobu .....Paper 138, Poster P373, P378, Symposia X
Ottersbach, Andreas .....Paper 031
Owen, John R. .....Poster P139
Ozeki, Satoru .....Poster P332
Padberg, Anne .....Paper 127
Padgett, Douglas E .....Poster P011, P038, P043
Page, Mark C .....Poster P196
Pagnano, Mark W .....Paper 171, 180, Symposia G
Paiement, Guy D .....Paper 060
Pak Lin, Chin .....Poster P137
Paley, Dror Paper 140, 262, Poster P377, Scientific Exhibit SE043, Symposia C
Paley, Jonathan J .....Paper 262
Paley, Jonathan .....Poster P376
Palmisano, Donald J .....Symposia V
Pan, Hui-Fen .....Poster P195
Panagopoulos, Andreas .....Poster P292
Pandit, Hemant G .....Paper 058
Panlilio, Adelisa L .....Scientific Exhibit SE089
Paoloni, Justin .....Poster P355
Papadogiannakis, Nikos .....Poster P304

Papagelopoulos, Panayiotis J . . . . . .Poster P186, P226
Papannagari, Ramprasad . . . . . .Scientific Exhibit SE044
Papas, Sam . . . . . .Scientific Exhibit SE074
Pape, Hans Christopher . . . . . .Paper 193, 194, Poster P249
Paprosky, Wayne Gregory . . . . . .Paper 038, 205, 206, 245, ...246, 247, 248, Poster P112, ...Scientific Exhibit SE008, Symposia L
Parameswaran, Angelo D . . . . . .Poster P233
Parikh, Shital . . . . . .Poster P403, P405
Parise, Carol . . . . . .Poster P198
Park, Jae-Chul . . . . . .Paper 101
Park, Jin Soo . . . . . .Paper 047, Poster P294
Park, Jun-Sic . . . . . .Paper 072, Poster P314
Park, Jun-Sic . . . . . .Poster P413
Park, Samuel Sanghong . . . . . .Poster P219, P223, ...Scientific Exhibit SE055
Park, Sang Eun . . . . . .Poster P152
Park, Sang-Hyun . . . . . .Poster P209
Park, Thomas M . . . . . .Poster P380
Park, Yoon Keun . . . . . .Poster P328, P342
Park, Youn Soo . . . . . .Poster P061
Parks, Brent G . . . . . .Poster P435
Parrish, Erin Nicholas . . . . . .Paper 008
Parrish, William M . . . . . .Symposia K
Parsch, Klaus . . . . . .Symposia F
Parsons, Ira M . . . . . .Poster P274
Parvizi, Javad . . . . . .Paper 096, Poster P017, P034, P040, ...P070, P161, Scientific Exhibit SE019
Pateder, Dhruv . . . . . .Poster P271
Patel, Jig . . . . . .Poster P047
Patel, Mihir . . . . . .Poster P088, P236
Patel, Minoo Keki . . . . . .Paper 262
Patel, Rajesh Vitthal . . . . . .Paper 160
Patel, Tushar C . . . . . .Scientific Exhibit SE052
Pathare, Neil . . . . . .Paper 073
Patil, Shantanu . . . . . .Paper 105, Poster P086, P113, P138, P354
Patron, Laura P . . . . . .Poster P334
Patterson, Andrew H . . . . . .Paper 043
Patterson, Brendan M . . . . . .Poster P236
Paxton, Liz . . . . . .Paper 035
Payman, Khodam-Rad . . . . . .Paper 138
Payne, William D . . . . . .Poster P168
Peabody, Terrance D . . . . . .Symposia T
Pearl, Michael L . . . . . .Paper 261
Pedersen, Douglas R . . . . . .Poster P090
Pedersen, Elizabeth . . . . . .Poster P285
Peelle, Michael . . . . . .Poster P246
Pegreffi, Francesco . . . . . .Paper 167, Scientific Exhibit SE056
Peindl, Richard Dennis . . . . . .Poster P300
Pellicci, Paul M . . . . . .Poster P011, P043
Penenberg, Brad L . . . . . .Poster P004
Pennig, Dietmar . . . . . .Scientific Exhibit SE053
Pennypacker, Jason L . . . . . .Paper 111
Perka, Carsten . . . . . .Paper 199
Peters, Christopher L . . . . . .Poster P007
Peters, Gary R . . . . . .Paper 060
Petre, Dirk . . . . . .Paper 211
Petriccioli, Dario . . . . . .Poster P268
Pettrone, Frank A . . . . . .Paper 052, Poster P275
Petty-Saphon, Satham . . . . . .Poster P196
Pfeffer, Glenn B . . . . . .Symposia H
Phillips, Frank M . . . . . .Symposia A
Phillips, Matthew J . . . . . .Poster P144
Phipps, Michael J . . . . . .Symposia M
Phongkhunakorn, Anuwat . . . . . .Paper 285
Pierce, William . . . . . .Paper 260
Pietrobon, Ricardo . . . . . .Paper 007
Pillow, Ann . . . . . .Paper 136
Pinsky, Brian A . . . . . .Scientific Exhibit SE026
Pinzur, Michael S . . . . . .Paper 070
Piper, Terrence Lee . . . . . .Poster P419
Pirich, Christian . . . . . .Poster P188
Piriou, Philippe . . . . . .Paper 113
Pirkl, Christof . . . . . .Paper 149
Pittman, Gavin T . . . . . .Paper 062
Pizzutillo, Peter D . . . . . .Poster P202
Plakogiannis, Christos . . . . . .Poster P368
Plank, Gordon . . . . . .Poster P042, P096
Platt, Steve R . . . . . .Poster P169
Poggie, Robert A . . . . . .Poster P102
Polly, D R . . . . . .Scientific Exhibit SE061
Polotsky, Anna V . . . . . .Poster P117
Polsky, Dan . . . . . .Paper 200
Pomeroy, Donald L . . . . . .Paper 173
Ponce, Brent . . . . . .Poster P221, P222
Ponseti, Ignacio V . . . . . .Paper 268
Pope, Richard . . . . . .Symposia M
Posner, Martin A . . . . . .Poster P229, P452
Postak, Paul D . . . . . .Scientific Exhibit SE003, SE026, SE040
Potter, Hollis . . . . . .Poster P317
Pressman, Ari . . . . . .Poster P323
Price, Andrew . . . . . .Paper 058
Price, Charles Turner . . . . . .Symposia J
Priebat, Dennis . . . . . .Paper 228
Pring, David . . . . . .Scientific Exhibit SE005
Prokuski, Laura J . . . . . .Scientific Exhibit SE089
Puffer, James . . . . . .Scientific Exhibit SE075
Puget, Jean L . . . . . .Paper 118
Puigdevall, Miguel . . . . . .Poster P369
Pulido, Pamela . . . . . .Poster P051
Puno, Rolando M . . . . . .Paper 122
Pupello, Derek . . . . . .Poster P279
Purtill, James J . . . . . .Scientific Exhibit SE019
Qiu, Yong . . . . . .Poster P398, P401
Quarnstrom, Kim . . . . . .Scientific Exhibit SE032
Queale, William . . . . . .Poster P271
Quraishi, Nasir Ali . . . . . .Poster P213
Qureshi, Ford . . . . . .Paper 257
Rae, Paul . . . . . .Poster P166
Ragland, Phillip . . . . . .Poster P040
Rahilly, George T F . . . . . .Poster P459
Rajadhyaksha, Amar D . . . . . .Poster P367
Rajaratnam, Sam . . . . . .Paper 257
Rajasabapathy, S . . . . . .Paper 068
Rajasekaran, S . . . . . .Paper 068
Raman, Raghu . . . . . .Paper 161, 163
Ramappa, Arun J . . . . . .Paper 018, Poster P265
Rameto, Ali . . . . . .Poster P436
Rana, Maunak . . . . . .Paper 256
Ranalletta, Maximiliano . . . . . .Paper 087
Ranawat, Amar S . . . . . .Paper 279
Ranawat, Chitranjan S . . . . . .Paper 243, 279
Randall, Robert Lor . . . . . .Poster P177
Rankin, Marc E . . . . . .Paper 107
Rapp, Timothy . . . . . .Poster P192
Rapuri, Venkat . . . . . .Poster P161, Scientific Exhibit SE019
Raque, George H . . . . . .Paper 121
Rashbaum, Ralph F . . . . . .Paper 251
Raskin, Kevin A . . . . . .Paper 223
Rasquinha, Vijay J . . . . . .Paper 243, 279
Rathjen, Karl B . . . . . .Scientific Exhibit SE071
Ratzel, Adam . . . . . .Scientific Exhibit SE003, SE026

Ray, Rose M . . . . . .Poster P033
Raynor, Barry L . . . . . .Paper 127
Razzano, Pasquale . . . . . .Scientific Exhibit SE077
Reach, John S . . . . . .Scientific Exhibit SE049, SE051
Rechtine, Glenn R . . . . . .Poster P429
Reed, William O . . . . . .Paper 259
Refshauge, Kathryn Margaret . . . . . .Paper 231, 232
Reiland, Youri . . . . . .Poster P291
Reilly, Mark C . . . . . .Poster P228
Reilly, Patrick . . . . . .Poster P247
Reindl, Rudolph . . . . . .Poster P384
Reinhardt, Mary Kay . . . . . .Paper 186, 190, Poster P394
Reish, Timothy G . . . . . .Paper 172
Renard, Regis . . . . . .Poster P228
Renfree, Kevin J . . . . . .Paper 042
Resch, Sylvia . . . . . .Paper 153
Reynolds, Max . . . . . .Poster P365
Reynolds, Paul R . . . . . .Poster P114
Rhee, John JM . . . . . .Symposia S
Ricchetti, Eric T . . . . . .Poster P409
Ricci, William Michael . . . . . .Paper 169, Poster P246
Rich, Margaret Mary . . . . . .Paper 264
Rich, Valerie . . . . . .Paper 059, Poster P128
Richards, Robin R . . . . . .Poster P238
Richardson, James . . .Paper 112, Poster P071, Scientific Exhibit SE005
Richardson, Rachel . . . . . .Paper 266
Richmond, John C . . . . . .Poster P210
Ridgeway, Stephen R . . . . . .Poster P100, Scientific Exhibit SE031
Riera-Rovira, Pedro . . . . . .Poster P364
Ries, Michael D . . . . . .Scientific Exhibit SE014
Riew, K Daniel . . . . . .Paper 125, Poster P424, Symposia S
Rill, Lynn . . . . . .Poster P245
Rimnac, Clare M . . . . . .Poster P062
Rind, David . . . . . .Poster P449
Rinella, Anthony . . . . . .Paper 126, Poster P424
Ring, David . . . . . .Poster P199, P253, P254, P255, P276, ...P277, P449, P450, P451, Symposia D, Y
Rios, Antonio . . . . . .Poster P150
Ristanis, Stavros . . . . . .Poster P336
Rizk, Wagdy S . . . . . .Poster P151
Rizzo, Marco . . . . . .Poster P456
Robbin, Mark R . . . . . .Poster P391
Roberts, Craig S . . . . . .Paper 161, Poster P225, P233
Roberts, Donald W . . . . . .Paper 173
Robertsson, Otto . . . . . .Symposia DD
Robinson, James T . . . . . .Paper 017, 195, Poster P346
Rockwood, Charles A . . . . . .Scientific Exhibit SE054
Rodeo, Scott Alan . . . . . .Poster P315, P317
Rodkey, William G . . . . . .Poster P343
Rodriguez, Jose A . . . . . .Paper 243, 279
Roeder, Christoph . . . . . .Poster P073
Roeder, Christopher Paul . . . . . .Paper 096
Roessing, Sven . . . . . .Poster P129
Roh, Jeffrey . . . . . .Poster P411
Roh, Michael . . . . . .Poster P424
Roig, Enrique . . . . . .Poster P072
Romagnoli, Matteo . . . . . .Poster P207
Romano, Gaetano . . . . . .Poster P240
Romanus, Bertil . . . . . .Symposia F
Romeo, Anthony A . . . . . .Poster P338
Romero, Anthony . . . . . .Poster P352
Romero, Jose . . . . . .Scientific Exhibit SE037
Ronen, Debi . . . . . .Scientific Exhibit SE016
Rorabeck, Cecil H . . .Paper 010, 179, 203, 206, 241, Poster P006, P015, P047, P087, P104
Rose, Peter S . . . . . .Paper 086
Rosen, Jeffrey E . . . . . .Poster P352
Rosenberg, Aaron Glen . . . . . .Paper 205, 247, ...Poster P112, P134, Symposia W
Rosenwasser, Melvin Paul . . . . . .Paper 043, Poster P463
Rosier, Randy N . . . .Scientific Exhibit SE082, Symposia K, O, ORS2
Ross, Glen . . . . . .Poster P260, P308, Scientific Exhibit SE068
Rostgard-Christensen, Lars . . . . . .Poster P304
Roth, Anne W . . . . . .Paper 060
Rothman, Richard H . . . . . .Poster P017, P033
Rothwell, Walter S . . . . . .Paper 165
Rovesta, Claudio . . . . . .Paper 142
Rowe, Sung Man . . . . . .Poster P397, P410
Roye, David Price . . . . . .Paper 134
Rozental, Tamara D . . . . . .Paper 050
Rubash, Harry E . . . . . .Poster P075, P096, P152, ...Scientific Exhibit SE004, SE044, Symposia L
Rubenthaler, F . . . . . .Paper 031
Rubin, Brian P . . . . . .Scientific Exhibit SE062
Rubino, L Joseph . . . . . .Paper 218
Ruch, David Simms . . . . . .Symposia Q
Rudicel, Sally A . . . . . .Paper 116, Scientific Exhibit SE087
Rudman, David P . . . . . .Poster P290, P462
Rue, Loring W . . . . . .Poster P379
Rueger, David C . . . . . .Poster P334
Rufai, Arminu . . . . . .Poster P437
Ruland, Robert Thomas . . . . . .Poster P252
Russell, Jackie . . . . . .Poster P098
Russell, Thomas A . . . . . .Paper 064
Russo, Sergio . . . . . .Poster P203
Ryan, Michael George . . . . . .Poster P011
Ryd, Leif . . . . . .Poster P031
Ryder, Steven . . . . . .Poster P214
Ryu, Byung Dam . . . . . .Poster P314
Sabah, Dundar . . . . . .Paper 229
Sabatino, Chris . . . . . .Poster P228
Sachs, Barton L . . . . . .Paper 251
Sadasivan, Kalia K . . . . . .Paper 051
Saeki, Kazuhiko . . . . . .Poster P118, P326
Safier, Shannon David . . . . . .Poster P202
Sah, Robert L-Y . . . . . .Poster P349
Saillant, Gerard . . . . . .Poster P041
Saito, Hidehiko . . . . . .Poster P184
Saito, Hidetomo . . . . . .Paper 071
Sakai, Hiroshige . . . . . .Paper 186
Sakai, Takashi . . . . . .Poster P001, P060
Sakamoto, Jiro . . . . . .Poster P383
Sakuraba, Keishoku . . . . . .Poster P333
Sala, Debra Anne . . . . . .Paper 269
Saleh, Khaled J . . . . . .Paper 009, Poster P040, P161, Symposia U
Saleh, Micheal . . . . . .Poster P215
Salehi, Abraham . . . . . .Scientific Exhibit SE014
Salsbury, Thomas L . . . . . .Poster P064
Saltzman, Charles L . . . . . .Paper 115
Saltzman, Matthew . . . . . .Paper 070
Saluja, Rajit . . . . . .Symposia Z
Salvati, Eduardo Agustin . . .Paper 091, Poster P011, Symposia EE
Sambale, Rafael Donatus . . . . . .Paper 130
Sanders, Jason B . . . . . .Poster P178
Sanders, Jay . . . . . .Scientific Exhibit SE065
Sanders, Roy W . . . . . .Paper 120, 169, Symposia Z
Sandhu, Harvinder S . . . . . .Symposia K
Sandow, Michael J . . . . . .Scientific Exhibit SE074
Sands, Andrew K . . . . . .Poster P438
Sangeorzan, Bruce J . . . . . .Paper 117, 119, 191
Sankar, Wudbhav N . . . . . .Paper 267
Santore, Richard F . . . . . .Symposia B

Santos, Erick M . . . . . .Poster P003
Santpure, Sagheih . . . . . .Paper 262
Sapkas, Georgios . . . . . .Poster P392
Sarmiento, Augusto . . . . . .Paper 067
Saroff, Donald . . . . . .Paper 152
Sartori, Mark . . . . . .Poster P301
Sarwahi, Vishal . . . . . .Poster P463
Sasso, Rick C . . . . . .Symposia S
Sato, Reiko . . . . . .Paper 158, 159, Poster P359
Sato, Takeshi . . . . . .Paper 071
Saunders, Marnie . . . . . .Paper 111
Saur, Marion Andrea . . . . . .Paper 130
Savvidou, Olga D . . . . . .Poster P186
Sawaki, Keisuke . . . . . .Poster P333
Sayyadd, Mohammed . . . . . .Poster P405
Scarborough, Mark Thomas . . . . . .Symposia T
Scarborough, Nancy . . . . . .Paper 263, Poster P375
Scarvell, Jennifer Mary . . . . . .Paper 231, 232
Scharf, Hanns-Peter . . . . . .Poster P129
Scharfenberger, Angela . . . . . .Poster P012
Scheller, Arnold D . . .Poster P260, P308, Scientific Exhibit SE068
Scheltema, Karen . . . . . .Paper 002, 006
Schemitsch, Emil H . . . . . .Poster P204, P216, P220, P227, ...P238, P242, P284, P285, Symposia R
Schepsis, Anthony Alberto . . . . . .Poster P310, P329
Scher, David M . . . . . .Paper 269, Poster P374
Scherl, Susan . . . . . .Poster P356, Scientific Exhibit SE071
Schiff, Adam . . . . . .Poster P455
Schlatterer, Daniel R . . . . . .Paper 198, Poster P231
Schmalzried, Thomas P . . . . . .Paper 095, Symposia B, I
Schmidt, R . . . . . .Poster P403
Schmidt, Tracy . . . . . .Scientific Exhibit SE087
Schmitt, Sabine . . . . . .Poster P129
Schneeberger, Alberto G . . . . . .Paper 220
Schneider, Erich . . . . . .Poster P415
Schneider, Wolfgang . . . . . .Poster P443
Schneiderbauer, Michaela Maria . . . . . .Paper 225
Schoenecker, Perry L . . . . . .Paper 139, 264, 270
Schon, Lew C . . . . . .Poster P435, Symposia H
Schroeder, Allison . . . . . .Scientific Exhibit SE032
Schuetze, Scott M . . . . . .Scientific Exhibit SE062
Schunemann, Holger . . . . . .Poster P220
Schurman, John R . . . . . .Poster P151
Schwappach, John R . . . . . .Paper 169
Schwartz, Kristin A . . . . . .Paper 009
Schwartz, Victor E . . . . . .Symposia V
Scott, Allison C . . . . . .Poster P375
Scott, W Norman . . . . . .Paper 172, Poster P125
Scuderi, Giles R . . . . . .Paper 172, Poster P125, P149, ...Scientific Exhibit SE036
Sculco, Thomas P . . . . . .Poster P011, P031, P147, ...Scientific Exhibit SE091, Symposia I
Scully, Sean P . . . . . .Paper 225, Poster P187, ...Scientific Exhibit SE051, Symposia O
Searle, Clark P . . . . . .Symposia M
Seebauer, Ludwig . . . . . .Scientific Exhibit SE054
Seitz, William H . . . . . .Poster P465, Scientific Exhibit SE026
Sekel, Ronald . . . . . .Poster P046, Scientific Exhibit SE016
Sekundiak, Todd . . . . . .Poster P053, P103, P105, ...Scientific Exhibit SE042
Seligson, David . . . . . .Poster P233
Sell, Timothy C . . . . . .Poster P327
Seltzer, Dana G . . . . . .Paper 069
Sen, Milan . . . . . .Poster P384
Seng Jin, Yeo . . . . . .Poster P137
Seo, Hyoung Yeon . . . . . .Paper 183, Poster P397, P410
Seon, Jong-Keun . . . . . .Poster P410
Seong, Sang Cheol . . . . . .Poster P328, P342
Sethi, Paul . . . . . .Paper 015
Sexton, Shaun Alan . . . . . .Poster P056
Shabat, Shay . . . . . .Paper 156, 157
Shah, Rahul V . . . . . .Scientific Exhibit SE012
Shah, Suken A . . . . . .Paper 135, Scientific Exhibit SE066
Shahrdar, Cambize . . . . . .Poster P016
Shankar, Anoop . . . . . .Paper 007
Shapiro, Todd . . . . . .Poster P283
Sharkey, Peter F . . . . . .Poster P017, Symposia C
Sharp, Chris . . . . . .Paper 106
Sharrock, Nigel E . . . . . .Poster P147
Shaughnessy, William J . . . . . .Paper 023
Shaw, Susan . . . . . .Paper 221
Shea, Raymond G . . . . . .Poster P133
Shegog, Mychelle Lorrayne . . . . . .Poster P058
Shelbourne, K Donald . . . . . .Paper 239, 240
Shelton, Julia . . . . . .Scientific Exhibit SE005
Shen, Ming . . . . . .Poster P081
Shepperd, John . . . . . .Paper 257
Sherman, Orrin H . . . . . .Poster P352
Sherry, Eugene . . . . . .Poster P365
Shiba, Ryoichi . . . . . .Poster P160
Shigenobu, Keiichi . . . . . .Poster P396
Shih, Chun-Hsiung . . . . . .Poster P318
Shimmin, Andrew . . . . . .Scientific Exhibit SE052
Shin, Alexander Yong Shik . . . . . .Poster P461
Shin, Dong-Kyu . . . . . .Poster P201
Shindle, Michael K . . . . . .Paper 131
Shino, Konsei . . . . . .Poster P313
Shinomiya, Kenichi . . . . . .Poster P032
Shiota, Etsuji . . . . . .Poster P454
Shiozaki, Yoshiki . . . . . .Poster P313
Shirai, Chikashi . . . . . .Poster P077
Shiramizu, Kei . . . . . .Paper 272
Shireffs, Thomas G . . . . . .Paper 003
Shishido, Takaakishi . . . . . .Scientific Exhibit SE007
Short, Andrew Liam . . . . . .Paper 058
Shourbaji, Nader . . . . . .Paper 162
Shrader, Michael Wade . . . . . .Paper 023
Shubin Stein, Beth E . . . . . .Poster P317
Shufflebarger, Harry L . . . . . .Symposia A
Shuto, Toshihide . . . . . .Paper 271, Poster P069
Siddiqi, Farhan . . . . . .Paper 258, Poster P416
Sieniawska, Christine Elizabeth . . . . . .Poster P071
Sierra, Rafael J . . . . . .Paper 180, Poster P026
Silber, Jeff Scott . . . . . .Poster P416
Silber, Jeffrey H . . . . . .Paper 200
Silva, Mauricio . . . . . .Paper 095, Poster P209
Sim, Franklin H . . . . . .Paper 086, 224, 229, Poster P186
Simmons, Barry P . . . . . .Scientific Exhibit SE090
Simmons, Kristy . . . . . .Paper 227
Simon, Michael A . . . . . .Scientific Exhibit SE070
Simon, Scott S . . . . . .Poster P179
Simons, Williams S. . . . . .Poster P171
Simpson, Kathy J . . . . . .Poster P109, P111
Sims, Stephen H . . . . . .Paper 164
Singh, Gurkirtal . . . . . .Paper 158, 159, Poster P359
Singh, Hardayal . . . . . .Poster P298
Singh, Navpreet . . . . . .Poster P284
Sink, Ernest L . . . . . .Paper 170
Sinkov, Vladimir . . . . . .Poster P390
Sirianni, Leigh E . . . . . .Poster P063
Sirkin, Michael Saul . . . . . .Poster P228
Sirveaux, Francois . . . . . .Paper 147

Sisto, Domenick J . . . . . .Paper 053
Skaggs, David Lee . . . . . .Paper 133, 134, Scientific Exhibit SE071
Skutek, Michael . . . . . .Paper 104
Slakey, Joseph B . . . . . .Poster P427
Slauterbeck, James R . . . . . .Scientific Exhibit SE087
Smith, Adam M . . . . . .Paper 046
Smith, Adam . . . . . .Poster P338
Smith, Anthony . . . . . .Paper 042, Poster P461
Smith, Beth P . . . . . .Paper 266
Smith, Evert . . . . . .Poster P010
Smith, John Taylor . . . . . .Poster P489
Smith, Malcolm . . . . . .Poster P108
Smith, Paul N . . . . . .Paper 231, 232
Smith, Richard R . . . . . .Scientific Exhibit SE009, SE047
Smith, Scott T . . . . . .Paper 066
Smith, Stephanie . . . . . .Poster P356
Smucker, Joseph . . . . . .Poster P388
Smythe, George A . . . . . .Poster P432
Snyder, Jonathan . . . . . .Paper 046
Snyder, Stephen J . . . . . .Poster P335
Snyder-Mackler, Lynn . . . . . .Poster P353
Sochart, David H . . . . . .Poster P166
Sodha, Samir C . . . . . .Poster P464
Sohn, Hong-Moon . . . . . .Poster P458
Soileau, Elizabeth S . . . . . .Poster P057, P124
Song, Eun Kyoo . . . . . .Poster P182, P397, P410
Song, Sang Jun . . . . . .Paper 283
SooHoo, Nelson Fong . . . . . .Paper 155
Sorrells, R Barry . . . . . .Poster P158
Soucacos, Panayotis N . . . . . .Poster P336
Souhami, Louis . . . . . .Poster P082
Spadaro, Joseph A . . . . . .Paper 221
Spencer, Eric . . . . . .Poster P459
Spencer, Robert . . . . . .Scientific Exhibit SE005
Spencer, Upshur M . . . . . .Paper 127
Sperling, John William . . . . . .Paper 076, 144, 146, 148, 212, ...Poster P258
Spinner, Robert Jay . . . . . .Poster P267
Sponseller, Paul D . . . . . .Paper 027, 029, 131, ...Scientific Exhibit SE060, SE067
Sporer, Scott M . . . . . .Paper 003, 245, 246, 248, ...Scientific Exhibit SE008
Spotorno, Lorenzo . . . . . .Poster P004
Sprague, Sheila . . . . . .Poster P204, P220, P239
Springer, Bryan Donald . . . . . .Paper 034, Poster P162
Springfield, Dempsey S . . . . . .Poster P189
Sprott, Dominic . . . . . .Paper 218, Poster P217
Squire, Matthew W . . . . . .Poster P049
Squire, Matthew . . . . . .Paper 177
Stafilas, Kosmas . . . . . .Paper 275
Stanich, Pete . . . . . .Poster P106
Stanley, David W . . . . . .Scientific Exhibit SE049
Stannard, James P . . . . . .Paper 017, 192, 195, Poster P346
Stanos, Steve . . . . . .Poster P142
Stans, Anthony A . . . . . .Paper 023
Stark, Erik . . . . . .Poster P447
Starkey, Chad . . . . . .Paper 015
Starr, Roland . . . . . .Poster P148
States, Lisa J . . . . . .Poster P409
Stauff, Amy . . . . . .Poster P325
Steadman, J Richard . . . . . .Paper 014, 018, ...Poster P141, P197, P340, P343
Stedtfeld, Hans-Werner . . . . . .Scientific Exhibit SE058
Steffen, Thomas . . . . . .Poster P384
Steffensmeier, Scott . . . . . .Poster P152
Stegemann, Philip M . . . . . .Poster P288
Steiger, Jerry A. . . . . .Scientific Exhibit SE030
Stein, V . . . . . .Poster P066
Steinbeck, Joern . . . . . .Scientific Exhibit SE006
Steinberg, Ely . . . . . .Paper 011
Steinitz, Daniel . . . . . .Paper 188
Steinmann, Patrick . . . . . .Paper 150
Steinmann, Scott P . . . . . .Poster P260, P267
Steinmeyer, Juergen . . . . . .Poster P331
Steklov, Nick . . . . . .Poster P354
Sterett, William I . . . . . .Paper 014, 059, Poster P128, P141, P340
Stergiou, Nick . . . . . .Poster P336
Stern, Avinoam . . . . . .Paper 156, 157
Stern, Laura D . . . . . .Paper 049
Stern, Peter D . . . . . .Paper 045
Stewart, Rena . . . . . .Poster P491
Stewart, Todd . . . . . .Poster P431
Stiehl, James B . . . . . .Paper 031, Symposia AA
Stills, Harold F . . . . . .Paper 218
Stills, Harold . . . . . .Poster P217
Stindel, Eric . . . . . .Symposia AA
Stirland, Katy M . . . . . .Scientific Exhibit SE017, SE028
Stockheim, Martin . . . . . .Paper 031
Stokes, David A . . . . . .Paper 237
Stone, Mary Lou . . . . . .Paper 035
Stonehouse Lee, Susan . . . . . .Poster P185
Stossel, Clifford . . . . . .Poster P056
Stover, Michael David . . . . . .Poster P228
Strain, Richard E . . . . . .Scientific Exhibit SE090
Strauch, Robert J . . . . . .Poster P463
Strauss, Elton . . . . . .Scientific Exhibit SE088
Strickland, Sabrina . . . . . .Paper 074
Stroop, Davis . . . . . .Paper 136
Stuart, Michael J . . . . . .Poster P034
Stubbs, Allston Julius . . . . . .Poster P298
Stuchin, Steven Andrew . . . . . .Symposia C
Stuerz, Henning . . . . . .Poster P331
Stulberg, S David . . . . . .Poster P048, P122, P142, ...Scientific Exhibit SE084, Symposia AA
Stull, Douglass . . . . . .Poster P300
Su, Brian W . . . . . .Paper 043
Su, Edwin P . . . . . .Paper 091, Poster P031
Suarez, Miguel Angel . . . . . .Poster P364
Sucato, Daniel J . . . . . .Paper 253, 260
Suda, Kota . . . . . .Poster P408
Sudkamp, Norbert . . . . . .Symposia Y
Sugano, Nobuhiko . . . . . .Poster P001, P060, P076, P084
Suggs, Jeremy F . . . . . .Poster P152
Sugimoto, Kazuya . . . . . .Poster P437
Sugioka, Yoichi . . . . . .Paper 271
Suh, Sung Wook . . . . . .Poster P183
Sullivan, Elroy . . . . . .Paper 132, 263, Poster P375
Sullivan, Patrick M . . . . . .Poster P014, P090
Sultan, Peter G . . . . . .Poster P152
Sumen, Yoshio . . . . . .Poster P316
Sumner, Rick . . . . . .Symposia ORS2
Sun, Edward C . . . . . .Poster P373
Sun, Jong-Il . . . . . .Paper 072
Suneja, Rajeev . . . . . .Paper 082
Susarla, Anand . . . . . .Poster P241
Sutherland, Charles J . . . . . .Poster P048
Sutton, Leslie N . . . . . .Poster P179
Sutton, Mark . . . . . .Poster P029
Suzuki, Kou . . . . . .Poster P332
Svensson, Michael . . . . . .Poster P304
Swanson, Scott A . . . . . .Poster P103
Swiontkowski, Marc F . . . . . .Poster P204, Symposia R

Swords, Michael .....Poster P460
Sychterz, Christi .....Poster P013, P059
Syed, Khalid .....Poster P227
Szabo, Istvan .....Paper 141, Poster P263
Szymanski, Deborah .....Paper 139
Tabor, Owen B .....Paper 054
Takada, Junichi .....Poster P173
Takahashi, Tomoki .....Poster P071
Takakura, Yoshinori .....Poster P437
Takao, Masaki .....Poster P001, P076, P084
Takasugi, Shinichiro .....Poster P069
Takayama, Hiroyuki .....Poster P417
Takeda, Naoki .....Poster P400
Takedani, Hideyuki .....Poster P094
Takemasa, Ryuchi .....Paper 184
Takemitsu, Masakazu .....Poster P400
Talac, Robert .....Scientific Exhibit SE051
Talor, Jonathan .....Poster P376
Tamai, Junichi .....Poster P409
Tanaka, Koichi .....Poster P160
Taneichi, Hiroshi .....Poster P408
Tang, Chris .....Paper 189
Tani, Toshikazu .....Paper 184
Tanizawa, Taisuke .....Poster P181
Tanner, Amie M .....Scientific Exhibit SE017, SE018, SE028
Tanner, Michael G .....Scientific Exhibit SE064
Tanzer, Michael .....Poster P082, Scientific Exhibit SE013
Tapankumar, Joshi .....Poster P008
Tashjian, Robert .....Paper 213
Tateiwa, Toshiyuki .....Scientific Exhibit SE007
Tauson, Mary S .....Poster P051
Tavakolian, Jason D .....Poster P255
Tejwani, Nirmal C .....Poster P241
Temple, H Thomas .....Poster P178, P190, P406
Templeman, David C .....Poster P363
Templeton, Jesse Ellis .....Poster P014, P090
Templeton, Kimberly J .....Paper 226
Tennis, Scott .....Poster P148, Scientific Exhibit SE043
Tenuta, Joachim .....Symposia M
Teranishi, Tadashi .....Poster P050, P080
Tetzlaff, John E .....Paper 256
Teuscher, David D .....Symposia V
Thacker, Mihir .....Paper 269
Thacker, Mihir .....Poster P374
Themistocleous, George Sotirios .....Poster P186, P392
Thomas, Andrew Derek .....Paper 044
Thompson, Brian .....Paper 162
Thompson, George H .....Poster P391
Thompson, Matthew .....Paper 209, 286
Thonar, Eugene .....Poster P418
Thordarson, David B .....Paper 116
Thornhill, Thomas S .....Paper 143, 145, Poster P108, Symposia I
Tibone, James E .....Poster P280
Tiedjen, K .....Paper 031
Timon, Stephen J .....Poster P393
Timperley, John .....Paper 204
Tingart, Markus .....Poster P286
Titelman, Robert M .....Poster P274
Title, Craig I .....Poster P435
Tjoumakaris, Fotios P .....Paper 030
Togawa, Daisuke .....Paper 186, Poster P394, P396
Tohyama, Harukazu .....Scientific Exhibit SE035
Tolo, Vernon T .....Symposia J
Toma, Cyril D .....Paper 103
Tomasi, Andrea .....Poster P291
Tomek, Ivan M .....Paper 287
Tomita, Katsuro .....Poster P383
Toni, Aldo .....Scientific Exhibit SE023
Tonino, Pietro M .....Poster P348
Tonnesen, Melissa .....Poster P409
Tontz, William L .....Poster P446
Tontz, William .....Poster P351
Topolski, Mark S .....Paper 146
Torchia, Michael E .....Paper 165
Toritsuka, Yukiyoshi .....Poster P313
Tornetta, Paul .....Paper 064, Poster P204, P235, P329, P362, P363, P447
Torzilli, Peter .....Poster P317
Tosi, Laura Lowe .....Scientific Exhibit SE087
Toussaint, Bruno .....Poster P291
Toyama, Yoshiaki .....Poster P120
Traina, Francesco .....Scientific Exhibit SE023
Trammell, Rita A .....Poster P168
Tran, Franklin .....Poster P323
Tria, Alfred J .....Scientific Exhibit SE079, Symposia C
Tricoire, Jean Louis .....Paper 118
Trieb, Klemens .....Poster P188
Triffon, Mark J .....Scientific Exhibit SE089
Trousdale, Robert T .....Poster P034, Symposia B
Tsai, Stanley .....Scientific Exhibit SE014
Tsai, Wen-chi .....Paper 282
Tsirikos, Athanasios I .....Paper 135, Poster P404, Scientific Exhibit SE066
Tsumura, Nobuhiro .....Poster P160
Tsunekawa, Hiromi .....Poster P400
Tu, Yuan-Kun .....Paper 041
Tucker, Bradford S .....Poster P354
Tucker, Jon B .....Scientific Exhibit SE090
Tucker, Michael .....Paper 169
Tueting, Jonathan L .....Poster P106
Tujimoto, Kazuo .....Poster P160
Turner, Joseph .....Poster P062
Turner, Norman S .....Scientific Exhibit SE049
Tyler, Tim .....Poster P290
Tyler, Wakenda .....Scientific Exhibit SE063
Ueng, Steve Wen-Neng .....Paper 041, Poster P440
Ueno, Masaru .....Scientific Exhibit SE035
Uhl, Timothy L .....Poster P344
Uhland, Zane .....Poster P272
Umer, Massod .....Paper 265
Unger, Anthony S .....Poster P048, Scientific Exhibit SE013
Unni, Krishnan K .....Paper 086, Poster P186
Unwin, Paul .....Poster P191
Urban, Joshua Aaron .....Poster P064
Urban, Robert M .....Paper 093
Vacarro, A R .....Scientific Exhibit SE061
Vaccaro, Alexander .....Poster P385, Symposia S
Vachtsevanos, John G .....Poster P230
Vail, Thomas Parker .....Scientific Exhibit SE080
Vaishnav, Suketu .....Poster P295
Vallier, Heather A .....Poster P236
Van Bosse, Harold J P .....Paper 269
Van Griensven, Martijn .....Paper 104, 193, Poster P249
Van Kleunen, Jonathan P .....Poster P024, P135
Van Rechenberg, Brigitte .....Paper 219
VanderGriend, Robert A .....Poster P245
Vannini, Francesca .....Scientific Exhibit SE024
Vannozzi, Brian .....Poster P175
Varney, Thomas E .....Paper 037
Vasey, Matthew .....Poster P279
Vaughan, Luke Michael .....Symposia W
Verborgt, Olivier .....Paper 211, Poster P157

Verbout, A J ..... Paper 276
Vernon, Cheryl B ..... Scientific Exhibit SE062
Vetrugno, Tommaso ..... Poster P348
Vialle, Emiliano ..... Paper 251
Viceconti, Marco ..... Scientific Exhibit SE023
Vickaryous, Brian ..... Poster P297
Vickaryous, Joseph P ..... Poster P297
Victor, Jan M.K. ..... Poster P157
Vidal, Armando F ..... Paper 109
Vigorita, Vincent J ..... Poster P438
Villanueva, Manuel ..... Poster P150
Villar, Richard N ..... Paper 097, 098
Villarraga, Marta ..... Poster P422
Vinton, Christopher J ..... Paper 037
Viola, Renato ..... Poster P348
Visotsky, Jeffrey L ..... Paper 049, Poster P455, P457, Scientific Exhibit SE054
Vitale, Mark A ..... Paper 021, 024, 133
Vitale, Michael ..... Paper 021, 024, 133, 134
Vohra, Yogesh K ..... Poster P003
Volgas, David A ..... Paper 017, 192, 195, Poster P346
Voor, Michael J ..... Poster P225, P233
Voorhorst, Paul ..... Paper 178
Vrahas, Mark S ..... Paper 064, Poster P108, P221, P222
Vu, Dinh ..... Poster P024, P030, P052
Vural, A Mutlu ..... Poster P109, P143
Wada, Takuro ..... Poster P173
Waddell, David D ..... Paper 051, 158, 159, Poster P359
Waddell, James P ..... Paper 037, Poster P242
Wakabayashi, Ikuko ..... Paper 071
Walch, Gilles ..... Paper 141, 147, Poster P263, Symposia E, N
Walde, Tim ..... Paper 039
Walker, Peter S ..... Scientific Exhibit SE042
Walker, Scott A ..... Paper 289
Wall, Eric ..... Paper 136
Walton, Judie ..... Paper 214
Walz, Brent ..... Poster P025
Wan, Zhinian ..... Poster P016
Wang, Bin ..... Poster P399, P401
Wang, Ching-Jen ..... Poster P136, P153, P433
Wang, Feng-Shen ..... Poster P433
Wang, He ..... Poster P111
Wang, Jeffrey C ..... Poster P395, Symposia K, S
Wang, Joon Ho ..... Poster P309
Wang, Jun-Wen ..... Poster P136
Wang, Ping Hui ..... Paper 136
Wang, Yao ..... Poster P432
Wannomae, Keith K ..... Poster P075
Ward, William G ..... Poster P176
Warner, Jon J P ..... Paper 073, Poster P262, P266, P286, Symposia BB, N
Warnke, Patrick H ..... Poster P365
Warren, Paul D ..... Poster P065
Warren, Russell F ..... Paper 074, 102, Poster P317
Washington, Eleby R ..... Scientific Exhibit SE091
Wasserman, Bruce A ..... Scientific Exhibit SE060
Watanabe, Hitoshi ..... Poster P077
Watson, J Tracy ..... Symposia K, O
Watts, Hugh Godfrey ..... Poster P372
Wayne, Jennifer S ..... Poster P139
Webb, Gavin R ..... Paper 198
Weber, Kristy L ..... Paper 230
Weber, Stephen C ..... Paper 075, Poster P261
Wedemeyer, Michelle A ..... Poster P402
Weeden, Steven H ..... Paper 038
Wei, Steven Yin ..... Paper 233
Weidenhiden, Lars ..... Poster P039
Weiland, Andrew J ..... Symposia Q
Weiler, Andreas ..... Paper 104
Weill, Yoram ..... Poster P208
Weinberg, Jacob ..... Poster P371
Weiner, Scott D ..... Symposia T
Weinstein, David ..... Poster P345
Weinstein, Stuart L ..... Symposia V
Weisman, David S ..... Scientific Exhibit SE071
Weiss, Andrew B ..... Poster P325
Weiss, Charles ..... Scientific Exhibit SE088
Welch, Robert D ..... Paper 260
Wenda, Klaus ..... Paper 181
Weng, Lin-Hsiu ..... Poster P136, P153, P433
Wenger, Doris ..... Paper 086,
Wenz, James F ..... Poster P164, P360
Westerheide, Kenneth ..... Paper 236
Whang, William W ..... Poster P021
White, Kami ..... Paper 037
White, Klane Keele ..... Paper 124, Poster P402
White, Miranda ..... Paper 237
White, Ronald P ..... Paper 249, Scientific Exhibit SE015
Whiteside, Leo A ..... Scientific Exhibit SE030, Symposia W
Whittaker, John-Paul ..... Paper 112
Wiedel, Jerome D ..... Scientific Exhibit SE089
Wild, Lisa ..... Poster P242, P285
Wild, Michael ..... Paper 181
Williams, Andrew ..... Poster P305
Williams, Craig S ..... Paper 049, Poster P455, P457
Williams, Glenn N ..... Poster P353, Symposia CC
Williams, John ..... Poster P030
Williams, Rafael M M ..... Paper 266
Williams, Riley Joseph ..... Paper 074, 109
Williams, Seth ..... Poster P349, P351
Willsey, Daniel S ..... Poster P098
Wilson, Nicole ..... Poster P356
Wilson, Timothy C ..... Poster P344
Wimhurst, James ..... Paper 202
Wimmer, Marcus ..... Poster P134
Wind, William ..... Poster P288
Windsor, Russell E ..... Scientific Exhibit SE079
Wing, David W. ..... Poster P141, P197, P340
Wingrove, Peta ..... Poster P046, Scientific Exhibit SE016
Winkelmann, Winfried WW ..... Scientific Exhibit SE006
Wirt, Michael ..... Poster P224
Wixted, John ..... Paper 037
Wodajo, Felasfa M ..... Paper 083, 228
Wodtke, Joachim Friedrich Karl ..... Paper 277
Wohlrab, David ..... Poster P311
Wojtys, Edward M ..... Symposia P
Wold, David ..... Scientific Exhibit SE065
Wolf, Brian R ..... Paper 074
Wolfe, Michael Wayne ..... Paper 174
Wolfe, Scott W ..... Symposia Q
Wolfinbarger, Lloyd ..... Paper 106
Wong, David Alan ..... Scientific Exhibit SE082
Wong, Karyn ..... Paper 261
Wong, Pamela ..... Poster P407
Wong, Van W ..... Poster P349
Wood, Kirkham B ..... Poster P419, Scientific Exhibit SE061
Wood, Mark L ..... Poster P085
Wood, Peter L R ..... Paper 114
Woods, Kevin R ..... Paper 231, 232
Wright, George E ..... Poster P230
Wright, James G ..... Paper 154, Symposia U, X
Wright, John ..... Paper 001, 004

Wright, Timothy M . . . . . .Paper 091, 287, Poster P038
Wroblewski, Jill . . . . . .Scientific Exhibit SE061
Wu, Dickson . . . . . .Scientific Exhibit SE032
Wu, Hong-Wen . . . . . .Poster P195
Wulke, Andreas Peter . . . . . .Scientific Exhibit SE053
Wunder, Jay . . . . . .Paper 084
Wurtz, L Daniel . . . . . .Poster P020
Wuyts, Floris . . . . . .Paper 211
Xenakis, Theodoros . . . . . .Paper 275
Xia, Wei . . . . . .Poster P432
YaDeau, Jacques . . . . . .Poster P147
Yadao, Melissa A . . . . . .Paper 016
Yagi, Masayoshi . . . . . .Paper 234
Yamamoto, Hiroshi . . . . . .Paper 184
Yamamoto, Takuaki . . . . . .Paper 271, Poster P069, P218
Yamane, Shigeru . . . . . .Poster P396
Yamashita, Keishi . . . . . .Poster P077
Yamashita, Toshihiko . . . . . .Poster P173
Yang, K. Y. . . . . .Poster P087, P433
Yang, Kuang-Ying . . . . . .Paper 241, Poster P006, P093
Yang, Kuender D . . . . . .Poster P433
Yang, Lang . . . . . .Poster P215
Yang, Rong-Sen . . . . . .Poster P357
Yao, Jian . . . . . .Poster P134
Yasko, Alan W . . . . . .Paper 230
Yasuda, Kazunori . . . . . .Poster P332, Scientific Exhibit SE035
Yasumura, Kenske . . . . . .Poster P332
Yaszemski, Michael J . . . . . .Paper 224
Yatabe, Taku . . . . . .Poster P120
Yates, Piers . . . . . .Poster P368
Yen, Yi-Meng . . . . . .Poster P373
Yeo, Seng-Jin . . . . . .Poster P093
Yeom, Jin-Sup . . . . . .Poster P413
Yian, Edward . . . . . .Poster P262, P265
Ying, Lilly . . . . . .Poster P315
Yonekura, Akihiko . . . . . .Paper 179
Yoo, Jae-Chul . . . . . .Poster P309
Yoo, Jung U . . . . . .Poster P388
Yoo, Jung-Han . . . . . .Paper 047, Poster P294
Yoon, Helen . . . . . .Paper 256
Yoon, Kyoung Ho . . . . . .Paper 283
Yoon, Pil Whan . . . . . .Poster P183
Yoshida, Akira . . . . . .Poster P383
Yoshikawa, Hideki . . . . . .Poster P001, P060, P076, P084
Yoshimine, Fumihiro . . . . . .Poster P120
Yoshimura, Ichiro . . . . . .Poster P326
Yoshiya, S . . . . . .Scientific Exhibit SE039
Yoshiya, Shinichi . . . . . .Paper 234, Poster P160, P319, P417
You, Jae Won . . . . . .Poster P458
Young, Anthony M . . . . . .Paper 032, 094, Poster P002
Young, Sean . . . . . .Paper 235
Yu, Bing . . . . . .Paper 013
Yuan, Xunhua . . . . . .Paper 241, Poster P087
Yun, Andrew . . . . . .Poster P016, P043
Zackai, Elaine H . . . . . .Poster P409
Zakerski, Debbie . . . . . .Poster P198
Zalavras, Charalampos . . . . . .Poster P180
Zatorski, Laurine . . . . . .Scientific Exhibit SE012
Zawadsky, Mark W . . . . . .Poster P031, P147
Zeichen, Johannes . . . . . .Paper 104
Zeifang, Bjoern . . . . . .Paper 181
Zeleznik, Michael . . . . . .Poster P039
Zhang, Hong . . . . . .Paper 260
Zhang, Jing Fan . . . . . .Poster P326
Zhao, Li . . . . . .Poster P407
Zhu, Lihua . . . . . .Poster P398
Zhu, Min . . . . . .Poster P320
Zhu, Zezhang . . . . . .Poster P401
Ziegler, Oliver . . . . . .Scientific Exhibit SE037
Zigler, Jack E . . . . . .Paper 251
Zizic, Thomas M. . . . . .Poster P170
Zizzo, Maureen . . . . . .Scientific Exhibit SE065
Zlowodzki, Michael . . . . . .Paper 162
Zobitz, Mark E . . . . . .Scientific Exhibit SE051
Zoppi, Adriana . . . . . .Paper 091
Zuckerman, Joseph D . . . . . .Poster P361, Scientific Exhibit SE055
Zurakowski, David . . . . . .Poster P282, P286
de Beer, Justin . . . . . .Poster P121
de Pablos F, Julio . . . . . .Symposia F
van Glabbeek, Francis . . . . . .Paper 211
van Riet, Roger P . . . . . .Paper 078, 211

3D . . . . . SCIENTIFIC EXHIBIT SE074
AC Joint / Bankart Repair / Slap . . . . . PAPER 071,073,074
. . . . . POSTER P262,P269,P280,P290,P295,P297
Access to Care . . . . . SCIENTIFIC EXHIBIT SE080
Accuracy . . . . . SCIENTIFIC EXHIBIT SE084
Acetabular . . . . . SCIENTIFIC EXHIBIT SE008,SE009
Acetabulum . . . . . SCIENTIFIC EXHIBIT SE071
ACL Deficient . . . . . PAPER 015,016,106,231,232,233,234,235,238
. . . . . POSTER P306,P308,P321,P323,P326,P328,P330,
. . . . . P336,P342,P353
ACL Graft Selection / Placement Fixation . . . . . PAPER 234,235,236
. . . . . POSTER P304,P308,P315,P316,P317,
. . . . . P318,P323,P328,P342,P345,P353
ACL Outcomes . . . . . PAPER 014,015,016,234,235,236,237,238,240
. . . . . POSTER P304,P305,P306,P316,P318,
. . . . . P323,P326,P328,P330,P342,P343,P353
Acupuncture . . . . . SCIENTIFIC EXHIBIT SE081
Adult . . . . . SCIENTIFIC EXHIBIT SE055
Aging . . . . . SCIENTIFIC EXHIBIT SE088
Alignment . . . . . SCIENTIFIC EXHIBIT SE030,SE034,SE038
Allograft Ligament Transplantation . . . . . SCIENTIFIC EXHIBIT SE082
Allograft Disease Transmission . . . . . SCIENTIFIC EXHIBIT SE082
Allograft/Vascular Fibular Grafts . . . . . PAPER 087,088,223,226
. . . . . POSTER P190,
Alternative Medicine . . . . . SCIENTIFIC EXHIBIT SE081
Anatomy / Biomechanics . . . . . PAPER 286,288,290
. . . . . POSTER P093,P095,P097,P103,P110,P111,P113,
. . . . . P116,P121,P137,P138,P144,P146,P148,P149,P152,
. . . . . P159,P160,P163,P166,P171
Anatomy and Basic Science . . . . . POSTER P003,P046,P053,P086
Ankle Instability . . . . . POSTER
. . . . . P431,P434,P437,P442,P444,P445,P447
Antibiotics . . . . . SCIENTIFIC EXHIBIT SE089
Antibiotic Bone Cement . . . . . SCIENTIFIC EXHIBIT SE086
Arthritis . . . . . SCIENTIFIC EXHIBIT SE025,SE047,SE054
Arthrofibrosis . . . . . SCIENTIFIC EXHIBIT SE043
Arthroplasty . . . . . SCIENTIFIC EXHIBIT SE003,SE004,SE006,
. . . . . SE008,SE012,SE013,SE014,SE017,SE018,SE019,SE021,
. . . . . SE023,SE025SE028,SE029,SE030,SE036,SE039,SE040,,
. . . . . SE041,SE042,SE043,SE044,SE048,SE051,SE079,SE080
Arthroplasty / Primary / . . . . . PAPER 077,080,143,144,145,146,
Revision and Arthrodesis 147,148,149,150,212
. . . . . POSTER P258,P271,P273,P283,P293,P297,P301
Articular Cartilage . . . . . PAPER 018,103,105,107,108,
. 109,110,231,233,238,240
. . . . . POSTER P311,P320,P325,P331,P334,
. . . . . P337,P341,P349,P350,P351,P354
Athletic Injury . . . . . SCIENTIFIC EXHIBIT SE068
Avascular Necrosis . . . . . PAPER 271,273
. . . . . POSTER P001,P063,P077,P085
Back Pain / Other . . . . . PAPER 183,184,187,188,189,
. 251,252,256,257,259
. . . . . POSTER P389,P390,P393,P397,
. . . . . P400,P403,P405,P413,P418
Basic Science . . . . . PAPER 058,062,063,125,186,193,194,199,260
. . . . . POSTER P095,P096,P097,P101,P104,P116,P117,
. . . . . P140,P146,P149,P157,P161,P170,P171,P200,P203,
. . . . . P205,P206,P209,P211,P215,P216,P217,P218,P219,
. . . . . P224,P227,P229,P231,P238,P241,P244,P249,P394,
. . . . . P407,P416,P418,P422,P426,P452,P453,P459,P462
Basic Science / Tumor / Infection . . . . . PAPER 265,267
. . . . . POSTER P373,P376
Bearing Surfaces . . . . . PAPER 032,094,095,096,098,099,100,278
. . . . . POSTER P002,P003,P009,P013,P033,P042,P045,
. . . . . P052,P054,P057,P059,P070,P071,P075,P081
Benign . . . . . PAPER 088,090,224
. . . . . POSTER P175,P178,P180,P181,P182,P186,P188,P189
. . . . . SCIENTIFIC EXHIBIT SE063
Biceps . . . . . PAPER 141
. . . . . POSTER P252,P260,P261,P268
Bilateral Procedures . . . . . PAPER 003
. . . . . POSTER P111,P125,P143
Biological . . . . . SCIENTIFIC EXHIBIT SE083
Biomaterials . . . . . SCIENTIFIC EXHIBIT SE048,SE051,SE076
Biomechanics . . . . . POSTER P429
. . . . . SCIENTIFIC EXHIBIT SE050,SE051
Biomechanics / Anatomy . . . . . PAPER 125,257
. . . . . POSTER P383,P384,P388,P400,P402,P417,P422,P427
Biopsy . . . . . SCIENTIFIC EXHIBIT SE070
Blood Loss . . . . . PAPER 208
. . . . . POSTER P056
Bone . . . . . SCIENTIFIC EXHIBIT SE048,SE052,SE075
Bone Grafts . . . . . SCIENTIFIC EXHIBIT SE008,SE019
Bone Graft / Fusion . . . . . PAPER 122,129,185,253,260
. . . . . POSTER P380,P384,P385,P388,P392,P396,
. . . . . P402,P407,P416,P419,P426
Bone Loss . . . . . POSTER P251
. . . . . SCIENTIFIC EXHIBIT SE010,SE019
Bone Transplantation . . . . . SCIENTIFIC EXHIBIT SE082
Bone Tumors . . . . . SCIENTIFIC EXHIBIT SE063,SE070
Calcaneus Fractures . . . . . PAPER 117,118,119,120
Carpal . . . . . PAPER 042,043
. . . . . POSTER P458
. . . . . SCIENTIFIC EXHIBIT SE074
Carpus / Metacarpal / Phalanges . . . . . PAPER 041,044,045
. . . . . POSTER P451,P452,P453,P455,P456,
. . . . . P457,P463,P464
Cartilage Transplantation . . . . . PAPER 103,108,109,110
. . . . . POSTER P320,P349,P350,P351
Cemented . . . . . PAPER 203
. . . . . POSTER P011,P014,P057,P080,P085
. . . . . SCIENTIFIC EXHIBIT SE003,SE015,SE035
Cemented Total Hip Arthroplasty . . . PAPER 202,203,249,250,277,280
. . . . . POSTER P010,P014,P023,P024,P028,P039,P083
Cementless . . . . . SCIENTIFIC EXHIBIT SE013,SE016,
. . . . . SE017,SE019,SE023,SE045
Ceramic . . . . . SCIENTIFIC EXHIBIT SE007
Cerebral Palsy . . . . . SCIENTIFIC EXHIBIT SE066
Cervical . . . . . PAPER 121,130,182
. . . . . POSTER P379,P384,P392,P405,P409,P410,
. . . . . P411,P412,P417,P420,P428,P429
. . . . . SCIENTIFIC EXHIBIT SE060
Cheilectomy . . . . . SCIENTIFIC EXHIBIT SE024
Chemotherapy . . . . . SCIENTIFIC EXHIBIT SE062
Chi Qi . . . . . SCIENTIFIC EXHIBIT SE081
Clavicle Fractures . . . . . POSTER P284,P285,P299
Collagen Synthesis . . . . . SCIENTIFIC EXHIBIT SE077
Compartment Syndrome/Limb Salvage . . . . . PAPER 070
. . . . . POSTER P201,P221,P222
Complementary Medicine . . . . . SCIENTIFIC EXHIBIT SE081
Complications . . . . . PAPER 033,034,035,036,126,127,189,207,210,
. 247,248,253,275,276,277
. . . . . POSTER P006,P007,P010,P017,P018,P021,P022,
. . . . . P032,P040,P043,P061,P064,P065,P068,P069,
. . . . . P070,P074,P088,P382,P394,P395,P404,P406,P411,
. . . . . P412,P421,P423
. . . . . SCIENTIFIC EXHIBIT SE031,SE032,SE043
Computer . . . . . PAPER 151
. . . . . POSTER P368
. . . . . SCIENTIFIC EXHIBIT SE084
Cost Analysis . . . . . SCIENTIFIC EXHIBIT SE065
Culturally Competent . . . . . SCIENTIFIC EXHIBIT SE091
Deformity . . . . . PAPER 030,134,140,261,262,264,268,270
. . . . . POSTER P251,P369,P371
. . . . . SCIENTIFIC EXHIBIT SE060,SE063
Degenerative Disc Pain / Disease . . PAPER 129,130,188,251,252,256,259
. . . . . POSTER P389,P400,P418,P420
Diagnostic Imaging . . . . . PAPER 142,216,217,220
. . . . . POSTER P295,P298
Disc Herniation . . . . . PAPER 183,188,256
. . . . . POSTER P397,P418
Dislocations . . . . . PAPER 031,038,242,248,275
. . . . . POSTER P010,P017,P018,P032,P039,P041,P043,
. . . . . P051, P068,P069,P070,P087,P088
Distal Radius . . . . . PAPER 048,049,050
. . . . . POSTER P449,P450,P454,P460,P465
Distal Radius/Forearm/Elbow . . . . . PAPER 196,197,198
. . . . . POSTER P229,P232,P245

Distraction . . . . . POSTER P251
DRUJ / TFCC. . . . . PAPER 048
. . . . . POSTER P462,P465
Economic / Cost Analysis . . . . . PAPER 151,155
. . . . . POSTER P359,P360,P361,P365,P366
. . . . . SCIENTIFIC EXHIBIT SE065
Education . . . . . POSTER P356,P358,P361,P362,P363,P365,P366,P367
Elbow . . . . . POSTER P355
. . . . . SCIENTIFIC EXHIBIT SE053,SE071
Elbow Basic Science / Biomechanics . . . . . POSTER P255,P259,P260,P281,P287
Elbow Dislocation . . . . . SCIENTIFIC EXHIBIT SE053
Elbow / Hand . . . . . POSTER P310,P339
Elbow / Tendon Injuries / Contracture / Radial Tunnel Syndrome . . . . . PAPER 077
. . . . . POSTER P252,P254,P260,
. . . . . P272,P275,P276,P277,P294
Endoscopic Spinal Surgery . . . . . PAPER 124,260
. . . . . POSTER P397,P405
Epidemiology/Procedural/ Outcomes . . . . . PAPER 061,064,068,069,161,
. 163,164,165,191,192,195,196,197,200
. . . . . POSTER P203,P210,P220,P234,P237,P239,P240,P247
Ergonomics . . . . . SCIENTIFIC EXHIBIT SE090
Extensor Mechanism. . . . . PAPER 180
. . . . . POSTER P111,P112,P119,P124,P138,P139,P151,
. . . . . P160,P161,P165
External Fixation . . . . . SCIENTIFIC EXHIBIT SE056
Failure. . . . . SCIENTIFIC EXHIBIT SE031
Femoral. . . . . PAPER 039,201,202,203,278
. . . . . POSTER P010,P022,P024,P028,P046,P057,
. . . . . P060,P079,P080,P084,P085
. . . . . SCIENTIFIC EXHIBIT SE003,SE010,SE015,SE016,SE023
Femur . . . . . SCIENTIFIC EXHIBIT SE071
Femur/Patella . . . . . PAPER 061,062,169,170,194
. . . . . POSTER P202,P206,P230,P231
Foot / Ankle . . . . . PAPER 012,021,065,066,268,269,270
. . . . . POSTER P216,P223,P234,P236,P332,P245,
. . . . . P369,P373
Forearm. . . . . SCIENTIFIC EXHIBIT SE071
Forefoot . . . . . POSTER P435,P436,P443
Fracture. . . . . PAPER 113,117,119
. . . . . POSTER P434,P442,P443,P447
. . . . . SCIENTIFIC EXHIBIT SE026,SE055,SE056,SE057,
. . . . . SE058,SE061
Fracture Healing . . . . . PAPER 064,067,162,167,195,197,198,199
. . . . . POSTER P203,P204,P209,P215,P217,P221,P222,
. . . . . P225,P227,P236,P237,P239,P240,P241
Frozen Shoulder / Shoulder Contractures . . . . . PAPER 076
. . . . . POSTER P273
Fusion. . . . . POSTER P429
. . . . . SCIENTIFIC EXHIBIT SE024
Gait. . . . . SCIENTIFIC EXHIBIT SE066
Gender . . . . . SCIENTIFIC EXHIBIT SE075,SE087
Gene Therapy . . . . . SCIENTIFIC EXHIBIT SE076,SE077
Geriatrics . . . . . SCIENTIFIC EXHIBIT SE088
Giant Cell. . . . . PAPER 088,226
. . . . . POSTER P183
Growth Factors. . . . . SCIENTIFIC EXHIBIT SE077
Hallux Valgus. . . . . PAPER 116
. . . . . POSTER P435,P443
Health. . . . . SCIENTIFIC EXHIBIT SE087
Hemiarthroplasty . . . . . PAPER 146
. . . . . POSTER P266,P271,P279,P297
Hindfoot / Ankle . . . . . PAPER 112,113,114,115,117,119,120
. . . . . POSTER P433,P437,P439,P440,P441,P442,P444,
. . . . . P445,P446
Hip. . . . . SCIENTIFIC EXHIBIT SE005,SE006,SE012,
. . . . . SE017,SE018,SE021
Hip / DDH Rehab . . . . . PAPER 030,136,137,138,139,140
. . . . . POSTER P370,P374,P378
Hip Dysplasia. . . . . PAPER 272,275
. . . . . POSTER P050,P060,P076
Hip Fracture . . . . . PAPER 165,166,167,200
. . . . . POSTER P201,P205,P207,P218,P219,P226,P230,P244
Hip Scores . . . . . SCIENTIFIC EXHIBIT SE005
Humerus . . . . . POSTER P199,P241
Iliac Crest Bone Graft . . . . . POSTER P385,P388,P404
Ilizarov . . . . . POSTER P251
. . . . . SCIENTIFIC EXHIBIT SE049
Imaging. . . . . PAPER 081,224
. . . . . POSTER P175,P178,P181,P188,P189,P190,P192
Impingement . . . . . PAPER 211
. . . . . POSTER P293,P295
Implant . . . . . SCIENTIFIC EXHIBIT SE031,SE038,SE040,SE044,SE083
Infected Total Hip Arthroplasty . . . . . PAPER 276,277
. . . . . POSTER P012,P017,P037,P040
Infection . . . . . SCIENTIFIC EXHIBIT SE086,SE089
Infection / Metabolic Disease / Tumor . . . . . PAPER 185,186,190
. . . . . POSTER P383,P391,P402,P406,P413
Infectious. . . . . PAPER 082
Injuries . . . . . PAPER 012,013,014,018,102,105,238,239
. . . . . POSTER P309,P319,P321,P323,P327,P332,P333,
. . . . . P334,P339,P346,P352,P354
Instrument / Pedicle Screw . . . . . PAPER 121,257
. . . . . POSTER P383,P389,P410,P426,P427
Instability . . . . . SCIENTIFIC EXHIBIT SE026,SE053
Instrumentation . . . . . PAPER 121,128,129,181,185,255
. . . . . POSTER P380,P381,P383,P384,P392,P396,P408,
. . . . . P415,P422,P424,P427,P428
. . . . . SCIENTIFIC EXHIBIT SE038,SE042
Interactive. . . . . SCIENTIFIC EXHIBIT SE074
Internal/External Fixation . . . . . PAPER 063,066,161,162,165,167,170
. . . . . POSTER P199,P200,P201,P205,P206,P213,P214,
. . . . . P215,P216,P219,P221,P222,P227,P229,P230,P231,
. . . . . P233,P237,P240,P244,P248
Internal Fixation . . . . . SCIENTIFIC EXHIBIT SE055,SE056,SE057
Internet. . . . . SCIENTIFIC EXHIBIT SE091
Intramedullary Fixation . . . . SCIENTIFIC EXHIBIT SE055,SE057,SE058
Kinematics. . . . . SCIENTIFIC EXHIBIT SE030,SE039,SE044
Knee . . . . . PAPER 022,025,026
. . . . . POSTER P371
. . . . . SCIENTIFIC EXHIBIT SE068,SE079
Knee/Hip/Osteoarthritis/ Total Hip Arthroplasty . . . . . PAPER 156,157,158,159,160
. . . . . POSTER P194,P196,P197,P198
Knee Arthroscopy. . . . . PAPER 011,016,017,018,019,104,235,237
. . . . . POSTER P307,P316,P323,P325,P327,P329,P331,
. . . . . P340,P343,P347,P348,P352
Ligament . . . . . SCIENTIFIC EXHIBIT SE050,SE051,SE068
Long Bone . . . . . SCIENTIFIC EXHIBIT SE058
Lumbar . . . . . PAPER 122,125,129,251
. . . . . POSTER P380,P382,P385,P386,P389,P395,P396,
. . . . . P402,P407,P415,P419
. . . . . SCIENTIFIC EXHIBIT SE060
Malignant. . . . . SCIENTIFIC EXHIBIT SE063
Malunion . . . . . SCIENTIFIC EXHIBIT SE026
Management . . . . . SCIENTIFIC EXHIBIT SE065
Mechanics . . . . . SCIENTIFIC EXHIBIT SE030,SE037
Medical Liability. . . . . SCIENTIFIC EXHIBIT SE091
Medicare. . . . . SCIENTIFIC EXHIBIT SE080
Meniscal. . . . . SCIENTIFIC EXHIBIT SE045
Meniscal Repair / Transplants . . . . . PAPER 107
. . . . . POSTER P322
Meniscus. . . . . PAPER 233,238,240
. . . . . POSTER P322,P340,P348
Metastatic. . . . . PAPER 225,227,228,229,230
. . . . . POSTER P173,P177
Metal on Metal . . . . . SCIENTIFIC EXHIBIT SE005,SE021
Metatarsal Phalangeal Joint. . . . . SCIENTIFIC EXHIBIT SE024
Minimal Invasive Surgery . . . . . SCIENTIFIC EXHIBIT SE057,SE079,SE084
Miscellaneous . . . . . PAPER 031,042,043,046,047,052,060,070,081,
. 082,085,097,116,156,157,172,191,223,250,275
. . . . . POSTER P016,P017,P053,P058,P067,P071,P072,
. . . . . P075,P077,P089,P104,P148,P153,P161,P162,P170,
. . . . . P175,P180,P183,P185,P189,P192,P195,P196,P180,
. . . . . P201,P210,P211,P212,P214,P220,P431,P433,P435,
. . . . . P436,P443,P446,P449,P450,P455,P456,P459,P461
Motion . . . . . SCIENTIFIC EXHIBIT SE074
MRI / Imaging . . . . . PAPER 011,018,101,107,231,232,235
. . . . . POSTER P313,P314,P316,P317,P325,P331

Musculoskeletal . . . . . SCIENTIFIC EXHIBIT SE087
Navigation . . . . . SCIENTIFIC EXHIBIT SE084
Neuromuscular . . . . . PAPER 135,261,263
. . . . . POSTER P369,P370,P373,P375,P377
. . . . . SCIENTIFIC EXHIBIT SE066
New Technique/Device . . . . . PAPER 121,122,130,181,
. 184,187,189,190,251,252
. . . . . POSTER P383,P384,P393,P396,P398,P399,P415,
. . . . . P418,P419,P422,P426,P428
Nonunion/Malunion . . . . . POSTER P199,P203,P204,
. . . . . P221,P222,P237,P241,P242
Novel Techniques/Imaging . . . . . PAPER 061,062,166,192
. . . . . POSTER P203,P211,P212,P214,P223,P229,P230,
. . . . . P235,P240,P241,P242,P244,P245,P246
Oncology . . . . . SCIENTIFIC EXHIBIT SE070
Open Surgical Treatment. . . . . SCIENTIFIC EXHIBIT SE054
Orthosis/Prosthesis . . . . . SCIENTIFIC EXHIBIT SE067
Osteochondral Transplantation. . . . . PAPER 105,107,108,109,110
. . . . . POSTER P320,P331,P349,P350,P351,P354
Osteolysis. . . . . PAPER 092,093,099,242
. . . . . POSTER P005,P009,P029,P075,P083
. . . . . SCIENTIFIC EXHIBIT SE019,SE048
Osteolysis Acetabular . . . . . PAPER 091,241
. . . . . POSTER P007,P087
Osteoporosis. . . . . PAPER 081,089,184,185,186,187,189,221
. . . . . POSTER P393,P394,P400,P422
Osteosarcoma. . . . . PAPER 086,087,221,225,229
. . . . . POSTER P173,P185,P186
Osteotomy . . . . . PAPER 059,271,272,274
. . . . . POSTER P050,P118,P128,P132,P139,P141,P163
Outcome . . . . . PAPER 031,033,034,036,037,040,091,096,099,
. 123,124,126,128,129,151,152,154,182,184,
. 185,188,190,201,202,203,204,205,207,208,
. 210,243,248,251,252,256,257,259,271,278
. . . . . POSTER P006,P007,P009,P010,P012,P017,P018,
. . . . . P020,P021,P023,P024,P026,P027,P028,P033,P034,
. . . . . P044,P045,P048,P049,P050,P051,P056,P057,PO58,
. . . . . P065,P066,P068,P072,P073,P078,P080,P086,PO87,
. . . . . P357,P359,P360,P362,P363,P365,P366, P368,P386,
. . . . . P389,P390,P391,P404,P406,P408,P411,P414,P420
. . . . . SCIENTIFIC EXHIBIT SE005,SE012,SE018,SE021,
. . . . . SE023,SE027,SE028, SE031,SE032,SE034,SE043,SE066
PMMA . . . . . SCIENTIFIC EXHIBIT SE086
Pain. . . . . SCIENTIFIC EXHIBIT SE081
Patellar . . . . . SCIENTIFIC EXHIBIT SE027
Patella-Femoral . . . . . PAPER 020
. . . . . POSTER P313,P331,P347
Pathologic . . . . . SCIENTIFIC EXHIBIT SE063
Patient Education . . . . . SCIENTIFIC EXHIBIT SE091
PCL Reconstruction . . . . . PAPER 017,239
. . . . . POSTER P307,P327,P344
Pediatric . . . . . PAPER 170,198
. . . . . POSTER P202
Pediatric Spine . . . . . PAPER 124,253,255
. . . . . POSTER P387,P391,P403,P405,P409,P421,P424
Pelvis and Acetabulum . . . . . PAPER 161,162,163,164,192
. . . . . POSTER P208,P228,P235,P243,P244,P246,P247,P248
Perioperative Complications PAPER 069,163,164,191,192,193,194,199
. . . . . POSTER P221,P222,P227,P232,P238,P248
Periprosthetic Fractures. . . . . PAPER 168
Polyethylene. . . . . PAPER 032,091,092,094,095,242,279
. . . . . POSTER P002,P013,P019,P029,P038,P042,P045,
. . . . . P054,P059,P075,P081
. . . . . SCIENTIFIC EXHIBIT SE040,SE045
Posterolateral . . . . . SCIENTIFIC EXHIBIT SE068
Practice . . . . . SCIENTIFIC EXHIBIT SE065
Prevention . . . . . SCIENTIFIC EXHIBIT SE089
Primary Total Hip. . PAPER 032,038,039,091,093,094,207,208,241,280
Arthroplasty Cementless . . . . . POSTER P002,P009,
. . . . . P011,P013,P015,P022,P028,P031,P032,P044,P047,
. . . . . P048,P054,P059,P060,P078,P083,P086
Prophylaxis . . . . . SCIENTIFIC EXHIBIT SE089
Prosthesis . . . . . SCIENTIFIC EXHIBITSE003,SE004,SE005,SE007
. . . . . ,SE010,SE013,SE027,SE035,SE040
Prosthetic/Allograft . . . . . PAPER 084,223,224,230
Combo/Reconstructions . . . . . POSTER P179,P180
Quality Control . . . . . PAPER 151,152,153,154
. . . . . POSTER P357,P358,P361,P363,P365,P367
RBRVS . . . . . SCIENTIFIC EXHIBIT SE080
Radiographic . . . . . PAPER 031,032,091,094,095,201,202,205,206,
. 208,241,243,249,271,278,279
. . . . . POSTER P001,P002,P007,P015,P019,P029,P031,P039,P041,
. . . . . P045,P047,P048,P049,P050,P053,P057,P064,P066,P070
. . . . . SCIENTIFIC EXHIBIT SE015,SE021,SE022,SE028,SE035
Reconstruction/Limb Salvage Techniques. . . . PAPER 082,083,084,086,
. 087,088,224,225,229
. . . . . POSTER P176,P177,P183,P184,P190,P191,P192
Reconstructive . . . . . PAPER 041,042,044,045,047
. . . . . POSTER P092,P115,P118,P125,P135,P139,P147,
. . . . . P156,P456,P459,P461,P463,P465
Reduction . . . . . SCIENTIFIC EXHIBIT SE058
Regenerate . . . . . POSTER P251
Reimbursement . . . . . SCIENTIFIC EXHIBIT SE080
Repair . . . . . SCIENTIFIC EXHIBIT SE068
Replacement. . . . . SCIENTIFIC EXHIBIT SE079
Research. . . . . SCIENTIFIC EXHIBIT SE076,SE091
Research/Basic . . . . . POSTER P361,P364,P365
Research/Clinical . . . . . PAPER 151,153,154
. . . . . POSTER P357,P358,P362
Resistance . . . . . SCIENTIFIC EXHIBIT SE089
Restrictions of Motion . . . . . SCIENTIFIC EXHIBIT SE053
Retrospective . . . . . SCIENTIFIC EXHIBIT SE062
Revision SE008,SE012,SE014,SE016,SE018,SE028,SE029
Revision Total Knee Arthroplasty . . . . . PAPER 002,006,009,171,172,
. 175,176,177,178,179,180,287
. . . . . POSTER P099,P100,P102,P103,P105,P112,P122,
. . . . . P126,P139,P165
Revision: Acetabular . . . . . PAPER 243,244,245,246,247,248,280
Component. . . . . POSTER P005,P007,P018,P029,P033,P051,P062,P087
Revision: Femoral Component . . PAPER 093,201,202,203,204,205,206
. . . . . POSTER P003,P004,P011,P024,P035,P046,P049,
. . . . . P053,P056,P070,P079,P084
Revision: Periprosthetic Fractures . . . . POSTER P008,P056,P066,P079
Risk Factors. . . . . SCIENTIFIC EXHIBIT SE075
Rotator Cuff . . . . . PAPER 101
. . . . . POSTER P309,P324,P335
. . . . . SCIENTIFIC EXHIBIT SE054
Rotator Cuff/Basic Science . . . . . PAPER 142,217,218,219,220
. . . . . POSTER P256,P257,P264,P270,P278,P286,P289
Rotator Cuff/Clinical . . . PAPER 075,141,142,149,150,211,213,214,215,
. 216,217,219
. . . . . POSTER P263,P264,P265,P273,P274,P278,P279,
. . . . . P291,P293,P295,P296
Safety. . . . . SCIENTIFIC EXHIBIT SE082,SE083
Sarcoma . . . . . SCIENTIFIC EXHIBIT SE062
Scoliosis . . . . . PAPER 027,028,123,124,126,127,128,131,
. . . . . 132,133,134,135, 253,254,255,258,260
. . . . . POSTER P372, P381,P387,P398,P399,P400,
. . . . . P401,P403, P413,P421
. . . . . SCIENTIFIC EXHIBIT SE066,SE067
Screws . . . . . POSTER P429
Senior . . . . . SCIENTIFIC EXHIBIT SE088
Shoulder . . . . . PAPER 101,102
. . . . . POSTER P309,P312,P314,P335,P338
. . . . . SCIENTIFIC EXHIBIT SE054
Shoulder Basic Science . . . . . PAPER 217,219,220
. . . . . POSTER P257,P264,P266,P270,P278,P280,P283,
. . . . . P288,P289,P290,P300,P301
Shoulder Instability . . . . . PAPER 071,072,073,074
. . . . . POSTER P262,P265,P269,P273,P282
Soft Tissue Tumors. . . . . SCIENTIFIC EXHIBIT SE070
Soft Tissue Sarcoma. . . . . PAPER 221,222,227,228
. . . . . POSTER P182,P187
. . . . . SCIENTIFIC EXHIBIT SE062
Spinal Cord Trauma. . . . . POSTER P379
Spine. . . . . POSTER P224
Spondylolisthesis / Spondylolysis. . . . . POSTER P396
Sports . . . . . POSTER P355

Stability . . . . . SCIENTIFIC EXHIBIT
. . . . . SE003,SE014,SE023,SE056,SE058
Stability / Minimally Invasive Surgery . . . . . PAPER 207,209,272,278
. . . . . POSTER P032,P063
Stem Cells. . . . . SCIENTIFIC EXHIBIT SE076
Stress Injury . . . . . SCIENTIFIC EXHIBIT SE075
Surgical . . . . . SCIENTIFIC EXHIBIT SE032,SE038
TKA . . . . . SCIENTIFIC EXHIBIT
. . . . . SE027,SE028,SE030,SE031,SE032,SE034,SE035,
. . . . . SE036,SE038,SE039,SE041,SE043,SE044
TKR . . . . . SCIENTIFIC EXHIBIT SE032,SE044,SE045
Techniques . . . . . SCIENTIFIC EXHIBIT SE079
Tendon . . . . . PAPER 047,111
. . . . . POSTER P355,P431,P432,P433,P438,P445,P459,P463
. . . . . SCIENTIFIC EXHIBIT SE051
Tendon Repair . . . . . SCIENTIFIC EXHIBIT SE077
Tennis . . . . . POSTER P355
Thoracic . . . . . SCIENTIFIC EXHIBIT SE060
Thromboembolic . . . . . PAPER 040
. . . . . POSTER P006
Tibial Plateau . . . . . PAPER 061,063,064
. . . . . POSTER P215
Tibial Shaft And Plafond . . . . . PAPER 067,068,070
. . . . . POSTER P204,P213,P234,P239
Tissue Engineering . . . . . SCIENTIFIC EXHIBIT SE076,SE077
Total Elbow Arthroplasty and . . . . . PAPER 078,079,080
Elbow Reconstruction . . . . . POSTER P253,P255
Total Joint Replacement . . . . . SCIENTIFIC EXHIBIT SE086
Total Hip . . . . . SCIENTIFIC EXHIBIT SE004,SE007,SE010,
. . . . . SE012,SE013,SE018
Total Hip Arthroplasty. . . . . PAPER 031,033,034,035,037,092,093,095,
. . . 096,098,099,100,201,207,208,209,210,244,248,275,276,279,280
. . POSTER P003,P005,P006,P009,P012,P015,P018,P019,P020,P021,
. . . . . P024,P025,P026,P027,P028,P029,P030,P032,P033,P036,
. . . . . P037,P038,P039,P042,P043,P045,P047,P048,P052,P055,
. . . . . P056,P058,P062,P064,P065,P068,P069,P071,P072,P073,
. . . . . P075,P078,P079,P080,P081,P082,P083,P086,P088,P089,P090
Total Knee . . . . . SCIENTIFIC EXHIBIT SE010,SE013
Total Knee Arthroplasty. . . . . PAPER 281
Blood Transfusions . . . . . POSTER P092,P125
Total Knee Arthroplasty . . . . PAPER 001,003,004,060,171,172,174,175
Complications . . . . POSTER P094,P097,P100,P102,P105,P107,P108,
. . . . . P115,P116,P117,P120,P124,P125,P126,P136,P161,P162
Total Knee Arthroplasty . . . . . PAPER 173,174,287
Components . . . . . POSTER P096,P097,P099,P100,P102,P104,P106,
. . . . . P107,P111,P113,P116,P121,P122,P124,P126,P131,
. . . . . P133,P134,P138,P146,P154,P155,P157,P167,P169,P171
Total Knee Arthroplasty. . . . . PAPER 001,002,003,004,005,006,
General Outcome. 007,008,009,010,174,290
. . . . . POSTER P099,P100,P104,P106,P107,P108,P109,
. . . . . P116,P125,P126,P135,P136,P147,P151,P153,
. . . . . P155,P158,P161,P162,P165,P167,P168
Total Knee Arthroplasty Infection . . . . . PAPER 004
. . . . . POSTER P094,P162
Total Knee Arthroplasty Kinematics. . . . . PAPER 282,286,289,290
. . . . . POSTER P096,P101,P105,P110,P111,P113,P121,
. . . . . P131, P138,P144,P157,P159,P160
Total Knee Arthroplasty. . . . . PAPER 052,281,285,290
Novel Techniques . . . . . POSTER P092,P098,P102,P106,P108,P112,
. . . . . P127,P147,P160,P164,P166
Total Knee Arthroplasty . . . . . PAPER 005,052,060,173,175,283
Other Clinical Conditions. . . . POSTER P094,P108,P135,P153,P162
Total Knee Arthroplasty Patella . . . . . PAPER 010,176,177
. . . . . POSTER P096,P099,P102,P119,P150,P157,P165
Total Knee Arthroplasty . . . . . PAPER 008
Posterior Cruciate Ligament . . . . . POSTER P096,P099,P131
Total Knee Arthroplasty Results. . . . . PAPER 001,002,004,005,006,008,
. 010,171,175,176,282,285,287
. . . . . POSTER P094,P098,P100,P103,P104,P105,P106,
. . . . . P108,P109,P113,P114,P117,P123,P126,P129,P130,
. . . . . P135,P142,P143,P155,P156,P158,P165,P167
Total Knee Arthroplasty Technique. . . . . PAPER 003,055,284,285,290
. . . . . POSTER P098,P105,P109,P112,P124,P138,P139,
. . . . . P143,P145,P149,P150,P154,P156,P158,P164
Track . . . . . SCIENTIFIC EXHIBIT SE075
Trauma. . . . . PAPER 071,148,219
. . . . . POSTER P253,P254,P255,P266,P267,P276,P277,
. . . . . P285,P290,P292,P294,P299
. . . . . SCIENTIFIC EXHIBIT SE053,SE056,SE057,SE071
Trauma/Fractures . . . . . PAPER 021,023,024,027,028,029
. . . . . POSTER P378
Trochanteric . . . . . SCIENTIFIC EXHIBIT SE014
Tumor/Metabolic Disease . . . . . POSTER P298
Tumors . . . . . SCIENTIFIC EXHIBIT SE062
Unicompartment Arthroplasty . . . . . PAPER 002,006,053,
. 054,055,056,057,058
. . . . . POSTER P093,P095,P113,P127,P129,P152
Unicompartmental . . . . . SCIENTIFIC EXHIBIT SE040
Upper Extremity. . . . . PAPER 261,266
Valgus deformity . . . . . SCIENTIFIC EXHIBIT SE034
Validation. . . . . SCIENTIFIC EXHIBIT SE084
Visco supplement . . . . . PAPER 051, 158,159,160
Wear . . . . . SCIENTIFIC EXHIBIT SE045
Women. . . . . SCIENTIFIC EXHIBIT SE087
Work-Related Musculoskeletal Disorders . . . SCIENTIFIC EXHIBIT SE090
Workers' Compensation . . . . . SCIENTIFIC EXHIBIT SE090
Wrist . . . . . SCIENTIFIC EXHIBIT SE074
Xenotransplantation . . . . . SCIENTIFIC EXHIBIT SE083

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- ☐ 102 Periprosthetic Hip and Knee Replacement Fractures
- ☐ 122 Managing Bone Loss in Revision THR
- ☐ 164 Complications in Primary THA: Avoidance and Management
- ☐ 202 Hip Arthroscopy
- ☐ 221 Technology 2004: Alternatives Bearing Surfaces: The Good, the Bad and the Indifferent
- ☐ 262 How to Perform Difficult Primary THR
- ☐ 302 Revision in Total Hip Arthroplasty: Understanding and Management of Osteolysis
- ☐ 322 Achieving Stability and Leg Length Equality in Total Hip Arthroplasty
- ☐ 362 Osteonecrosis of the Hip: Management in the 21st Century
- ☐ 402 Surgical Strategies to Improve Total Hip Arthroplasty for the New Millennium I: Primary Total Hip Arthroplasty
- ☐ 422 Surgical Strategies to Improve Total Hip Arthroplasty for the New Millennium II: Revision Total Hip Arthroplasty

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- ☐ 4 Optimizing Outcomes Following Complications of Primary Total Knee Arthroplasty
- ☐ 15 Controversial Issues and Hot Topics in Primary Total Knee Replacement
- ☐ 20 Future Directions in Total Hip Replacement and Total Knee Replacement -- Lessons Learned from Joint Replacement Registries
- ☐ 103 Prevention and Management of Instability with Primary and Revision Hip and Knee Arthroplasty
- ☐ 185 Revision Total Knee Arthroplasty: Planning, Management and Controversies
- ☐ 203 Complications After Total Knee Arthroplasty: Prevention and Management
- ☐ 223 The Surgical Treatment of Articular Cartilage Defects of the Knee
- ☐ 263 Total Knee Replacement in the Young Patient
- ☐ 284 Primary Total Knee Arthroplasty: Surgical Technique and Principles
- ☐ 403 Surgical Options in the Middle Aged Arthritic Knee

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Basic Research

- ☐ 325 Gene Therapy and Tissue Engineering in Orthopaedic Surgery

Foot and Ankle

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