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doi:10.1016/j.ultrasmedbio.2011.06.003

● *Original Contribution*

EFFECTIVENESS OF ESWT IN THE TREATMENT OF KIENBÖCK'S DISEASE

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Abstract—Kienböck's disease is a rare, painful disorder of the wrist that can seriously restrict the quality of life of patients who have the disease. Although a century has passed since the pathology was identified, its etiology is still uncertain, with mechanical, traumatic, vascular, and systemic factors all being advocated. Likewise, there is no consensus regarding treatment, and no approach—either conservative or surgical—has been demonstrated to yield significantly better outcomes. Extracorporeal shock wave treatment (ESWT) has been effective in stimulating fracture healing, and it has been adopted as a therapy to restore vascular supply in those bone conditions characterized by vascular impairment. We report our experience in treating 22 patients with Kienböck's disease at various stages with high-energy shock waves. Our results indicate that ESWT has a positive effect on pain and functional impairment of the wrist, and may delay surgical treatment. Further studies are necessary to understand the full potential of this therapeutic tool. (E-mail: valerio.sansone@unimi.it)   © 2011 World Federation for Ultrasound in Medicine & Biology.

Key Words: Kienböck's disease, Osteonecrosis, Lunate, Extracorporeal shock wave treatment.

INTRODUCTION

The first description of this disease was presented in 1910 by the Austrian radiologist Robert Kienböck. Patients complained of pain, loss of mobility, and prominence in the area of the wrist, and radiographic evaluation showed isolated changes in the proximal aspect of the lunate, with eventual collapse and fragmentation of the bone. Since then, the natural history of this disease has not been clearly defined, although it is most frequently observed among young adult males (aged 20 to 40), and is characterized by a progressive alteration in the bone. In the disease's early stages, there is bone marrow edema and reduced blood supply to the lunate, which leads to lunate collapse and severe arthritic degeneration in the later stages. Although mechanical, anatomic and systemic mechanisms have all been implicated in the development of the disease, no specific etiologic mechanism has been identified. It is most likely that a complex inter-relationship among all of these factors contributes to

the disease process (Beredjiklian 2009). For this reason, a variety of treatments have been proposed, none of which have proved to be curative. The aim of treatment is to alleviate pain, improve function and limit the progression of the disease (Beredjiklian 2009). Treatment is primarily dictated by the patients' symptomatology and functional deficits, and the stage of development of the disease. Regardless of the stage at presentation, a trial of conservative treatment with splinting or casting combined with analgesic or antiinflammatory medication and physiotherapy is typically prescribed. However, none of these conservative treatments aim to address the vascular changes that characterize this condition. Surgical intervention is normally reserved for patients who have failed to find acceptable improvement in symptoms after conservative treatment. Various surgical procedures have been proposed, depending on the stage of pathological development and on anatomic variables such as ulnar variance and radial inclination. Proposed procedures include metaphyseal core decompression (Illarramendi and De Carli 2003), radial shortening (Salomon et al. 2000), ulnar lengthening (Kawoosa et al. 2007), conventional or pedicled vascular bone graft (Shi and Bishop 2002), arthrodesis of the carpal bones (Graner et al. 1966), proximal row carpectomy (Croog

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and Stern 2008) and arthroplasty (Evans et al. 1986). However, as Innes and Strauch (2010) demonstrate in their systematic review of retrospective data from uncontrolled studies, no single treatment methodology described gives a statistically significantly better outcome. They also concluded that there are insufficient data to determine whether the outcomes of any intervention are superior to placebo or to the natural history of the disease. For this reason, research of alternative treatments such as ESWT is valuable. ESWT has been successfully used in the treatment of conditions that, in certain aspects, resemble Keinböck's disease, such as femoral head osteonecrosis (Wang et al. 2005). In this study, Wang et al. reported a significant reduction in subjective pain and extension of bone lesions of the femoral head. On the basis of these favorable clinical results, we performed a preliminary study that aimed to evaluate the effect of shock waves in the management of Kienböck's disease.

MATERIALS AND METHODS

From 2005–2009, 22 patients (16 male, 6 female) symptomatic for Kienböck's disease were treated with high-energy ESWT. The mean age of patients was 37.4 y (range, 23 to 55). All patients were clinically evaluated by a single examiner for pain according to a visual analog scale (VAS) with a score range of 0 = no pain to 10 = very severe pain; and also for range of motion (ROM) on four planes: dorsal flexion (DF), palmar flexion (PF), radial displacement (RD) and ulnar displacement (UD). The values were compared pre- and post treatment at follow-up. The follow-up program consisted of a clinical evaluation at 60 d, 180 d and one year post treatment, and then every six months for a maximum of four years. Patients also underwent magnetic resonance (MR) imaging pretreatment, and at 60 and 180 d.

Patients were graded according to the imaging classification of Lichtman (Allan et al. 2001). Twelve patients were classified at Stage I—normal bone architecture, normal morphologic patterns with a transversal zone of bone thickness. Four patients were classified at Stage II—increased bone density with normal dimensions, shape and position of the lunate. Three patients were classified at Stage IIIa—fragmentation and or collapse of lunate structure with proximal migration of capitate bone, and three patients at Stage IIIb—same alterations but with disruption of carpal architecture, eventually associated with scapho-lunate dissociation and scaphoid rotation. We had no Stage IV patients (the pathological changes of Stage IIIb with extensive carpal arthritis). Patients who were pregnant or undergoing treatment with oral anticoagulant drugs were excluded from the study. The Research Board of the Istituto Ortopedico Galeazzi IRCCS approved the research protocol, and all

patients participating in the study gave their informed consent.

The treatment program consisted of three individual sessions of shock wave therapy performed every 30 days, using an electromagnetic shock wave system with double ecografic and radiographic targeting (MODULITH® SLK Electromagnetic shock wave lithotripter, Storz Medical, Tägerwilen, Switzerland). At each treatment session, 4000 shocks were applied under local anaesthesia (Lidocaine 2% to 5 mL), at energy flux density of 0.35–0.40 mJ/mm^2 and at frequency 4 Hz/s. The affected wrist was dressed in a splint during treatment and for the following 15 d.

RESULTS

The mean VAS scores of the study population showed a marked improvement after treatment at 60 d, with a decrease of 4.52 points (8.25 pretreatment to 3.73 at 60 d; $p < 0.001$) in subjective pain (Fig. 1). At the one-year follow-up, VAS scores were still significantly improved when compared with the pretreatment scores (8.25 pretreatment, 5.07 at 1 year $p < 0.001$). Although the number of cases in the later stages (Stage II, IIIa and IIIb) was too small to be able to make statistically valid comparisons regarding the effect of the treatment at each individual stage of the disease, some general trends could be observed. The improvement was seen at all stages of the disease, although it was greatest among the Stage 1 cases (mean 8.5 pretreatment to 2.01 at 60 d), and the patients were able to resume most of their daily or working activities without needing a splint. The scores then remained constant or gradually worsened over time, although the deterioration was only statistically significant for the Stage 1 cases ($p < 0.05$).

The ROM measurements showed a similar trend, with a marked—if less dramatic—improvement between pretreatment and 60-d follow-up, and then a leveling off
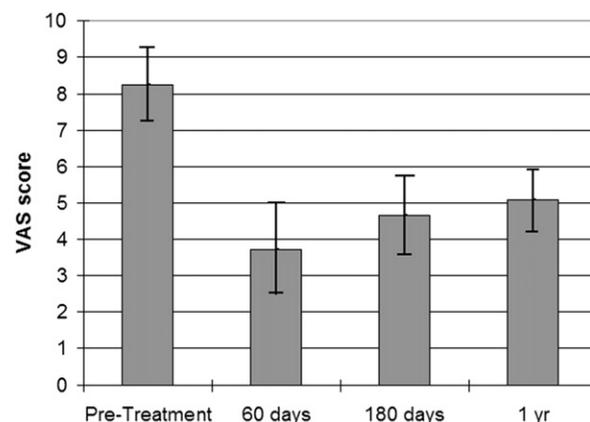

Fig. 1. Mean VAS scores for the total study population, with standard deviations, over the follow-up period.

or deterioration in values (Table 1). There was a statistically significant increase in ROM ($p < 0.05$) on all planes except UD before and after treatment at 60 d. The most significant improvement was in RD, which showed a statistically significant improvement ($p < 0.05$) between the mean values pretreatment and at one-year follow-up, although ROM in all planes improved over the course of follow-up (DF = $+7.3°$, PF = $+7.8°$, RD = $+5.5°$, UD = $+0.7°$).

The bone edema was observed as an area of low signal intensity on T2-weighted MR scans (Fig. 2). It was usually diffuse and involved the entirety of the lunate. MR imaging showed a noticeable reduction of the bone edema in all patients (Fig. 3), which corresponded to an improvement in pain and articular motion scores. When a well-defined necrotic area was present, a significant or complete reduction of peri-lesion edema was always observed, although no substantial change was seen in the necrotic area.

DISCUSSION

ESWT is successfully used in the treatment of various musculoskeletal conditions, including lateral epicondylitis, plantar fasciitis, calcified tendonitis of the shoulder and delayed union and nonunion of bone fractures (Speed 2004; Valchanou and Michailov 1991). The biochemical and metabolic effects of SW on living tissues have still not been fully clarified, even though both *in vitro* and *in vivo* studies have demonstrated that they can stimulate angiogenic activity (Wang et al. 2003; Nurzynska et al. 2008; Zimpfer et al. 2009). Further data suggest that the positive biological effects would be mediated mainly by the production of nitric oxide (Mariotto et al. 2009), proliferating cell nuclear antigen (PCNA) and vascular endothelial growth factor (VEGF) (Stojadinovic et al. 2008; Wang et al. 2004) or by improving the recruitment of circulating endothelial progenitor cells because of enhanced expression of chemo-attractant factors (Aicher et al. 2006). This pro-angiogenic effect of SW was also demonstrated in myocardial ischemic lesions (Fukumoto et al. 2006) and in cutaneous "complicated" wounds (Schaden et al. 2007).

Shock waves have also been used successfully in other bone vascular disorders (Wang et al. 2005). These authors report how a single high-energy treatment was more effective than core decompression and nonvascular fibular grafting in patients at early stages of osteonecrosis of the femoral head (ARCO stage I-II and III). The same authors (Wang et al. 2004) earlier reported that shock waves activate a local increase of transforming growth factor–β1, VEGF-A and bone morphogenetic protein in osteoblasts, as well as being able to induce the growth and differentiation of mesenchymal stem cells toward

Table 1. ROM scores over time for total population

Plane of movement	Pretreatment	60 d (post treatment)	180 d (post treatment)	1 y (post treatment)
DF (0–60°)	$35.7° \pm 9.8°$ (min 20°–max 55°)	$46.1° \pm 10.5°$ (min 25°–max 60°)	$43.4° \pm 9.4°$ (min 20°–max 55°)	$43° \pm 10°$ (min 20°–max 55°)
PF (0–60°)	$32° \pm 9.8°$ (min 15°–max 45°)	$42° \pm 9.6°$ (min 25°–max 60°)	$40° \pm 10.9°$ (min 20°–max 60°)	$39.8° \pm 8.4°$ (min 25°–max 55°)
RD (0–20°)	$9.3° \pm 4.4°$ (min 5°–max 20°)	$15.2° \pm 3.6°$ (min 10°–max 20°)	$15.2° \pm 3.9°$ (min 10°–max 20°)	$14.8° \pm 3.3°$ (min 10°–max 20°)
UD (0–30°)	$22.5° \pm 5.9°$ (min 10°–max 30°)	$25.7° \pm 5.2°$ (min 15°–max 30°)	$25.9° \pm 5.2°$ (min 15°–max 30°)	$23.2° \pm 5.7°$ (min 10°–max 30°)

The values are given as the mean and standard deviation with the range in parentheses.
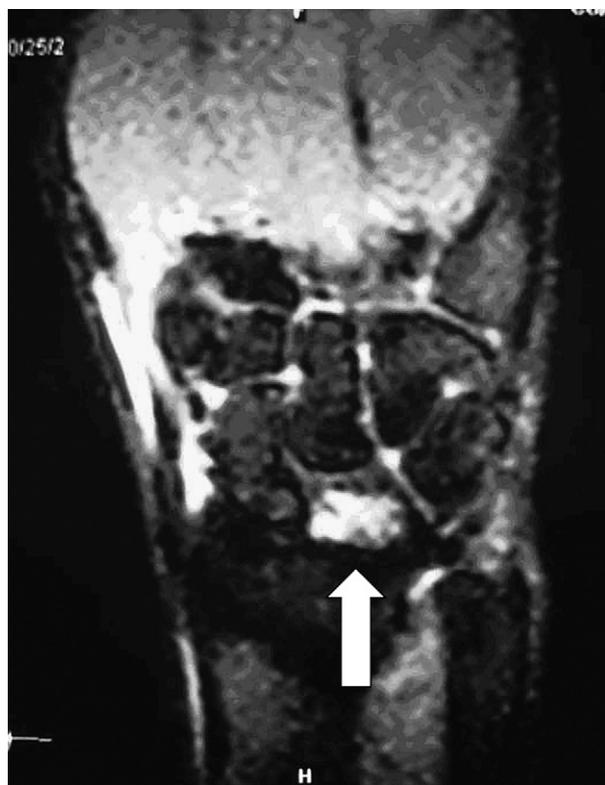
Fig. 2. Coronal NMR T2-weighted images for Kienböck's disease Stage I patient. Note the normal shape of the lunate before ESWT treatment. The arrow marks the increased bone marrow density (bone marrow edema).
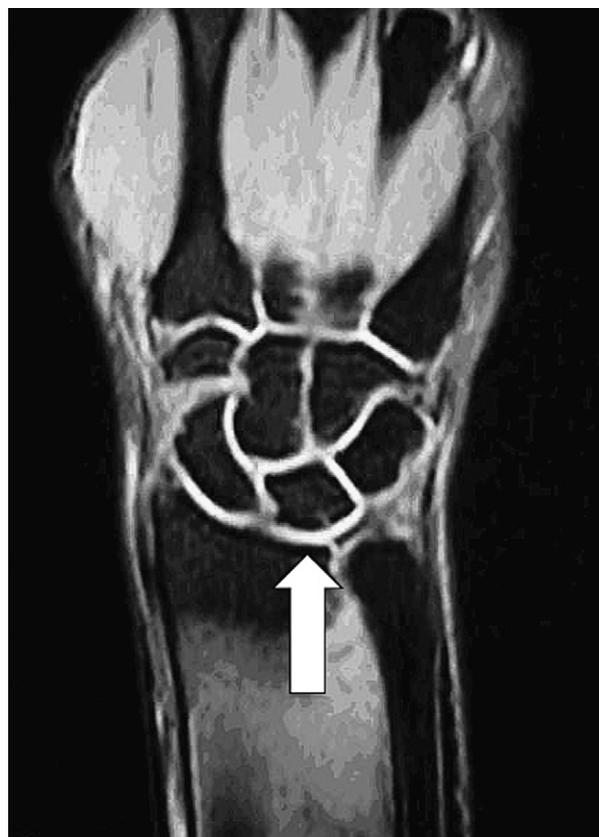
Fig. 3. Coronal NMR T2-weighted images for Kienböck's disease Stage I patient. Sixty days after treatment, the bone marrow edema is absent.

osteoprogenitor cells. More recently, Tamma et al. (2009) reported that shock wave stimulation induces bone repair through the proliferation and differentiation of osteoblasts.

Furthermore, shock waves can have an immediate analgesic effect. This is thought to be a result of the desensitization of nociceptive fibers (Alves et al. 2009), although we should also consider the reduction in intraosseous pressure as a contributory factor in pain reduction. It has been shown that in hip osteonecrosis (Hoi Koo et al. 1999) and in various vascular pathologies of the wrist (including Kienböck's disease; Alam et al. 1999) the severity of pain is often strongly related to the degree of bone marrow edema (BME), which is caused by an impairment of the microvascular circulation. Often the reduction—or disappearance—of BME after shock wave treatment corresponds to a decrease in pain. This could imply a close relationship between the metabolic effects of SWs and their capability to induce the restoration of normal microvascular circulation.

The most satisfactory results in our study were in the VAS pain scores, and these were particularly pleasing when compared with those found in the literature. In all the studies analyzed by Innes and Strauch (2010) (which

concerned patient cohorts of a similar size), a proportion of patients did not see any improvement in pain post-treatment, whereas all of our patients, regardless of stage, showed a marked, statistically significant and persistent decrease in pain. On the other hand, no patient in our study declared themselves completely pain free (VAS = 0), whereas a proportion of patients in all of the other studies analyzed did score an absence of pain. Unsurprisingly, the most significant improvement was seen in the Stage I patients, although these were the only cases that showed a statistically significant deterioration after 60-d follow-up. Our results for ROM were rather more erratic for all stages of the disease, with a wide range of values reported for patients at each stage of the disease and follow-up point. However, ROM did not decrease in any patient over the length of the study, and some patients saw a major improvement in functionality after treatment. When comparing with Innes and Strauch (2010), we analyzed ROM in four planes rather than a single aggregate value, but if our results are aggregated, then a statistically significant ($p < 0.05$) improvement was seen at all stages.

Because there is still debate on the optimal treatment for Kienböck's disease, the results of our study seem to

demonstrate that ESWT should be considered a valid treatment option, particularly because of its noninvasive nature, the absence of side effects and its relatively low cost. There is agreement that an early diagnosis is fundamental, because the purpose of treatment is to arrest, or recover when possible, the progression of the pathology toward carpal collapse. The results we observed encourage us to increase the use of ESWT in the treatment of Kienböck's disease in its early stages. Moreover, SW may be a valid palliative therapy for treating the symptoms of patients in the advanced stages of the disease.

CONCLUSIONS

In our study, we observed a long-lasting pain reduction and a less significant recovery of the ability to articulate. However, what seems most interesting was the association between pain reduction and the resolution of the BME. Shock wave treatment is a new frontier in modern medicine, and more research is needed to investigate the full potential of this therapy. With regard to its application in the treatment of Kienböck's disease, further studies will be required to optimize the treatment protocols, and to understand fully the positive effects of SW.

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