ESWT for ossøse indikationer

Anders Broegaard

Kiroprarktorerne Valby

Hvad kan behandles med ESWT?

- Non-union/ pseudoartrose
- Stressfraktur
- AVN
- Knogleødem
- Artrose

- Kræver forudgående udredning ved orthopædkirurg samt radiologisk diagnosticering og evaluering!

Søgestreng for non-uninon/pseudoartorsis

Extracorporeal shock wave and bone/nonunion/pseudoartrosis/fracture/stress fracture/avascular necrosis og the femoral head/bone marrow lesion, oedema (RSW/FSW) – 22 studier inkluderet

Udvalgte systematiske reviews og metaanalyser 15 år tilbage – 3 systematiske reviews inkluderet

Basics

- 5-10 % of all fractures show signs of limited bone healing
- Oftest seen in the clavicle, carpals, ribs and long tubular bones.
- (International Journal og Surgery 2015):
- Surgery is still considered as the “golden standard” for the treatment of fracture non-unions. Usually, the previous implant is removed followed by decortication of the fracture site and removal of interposed soft tissue. In long bones the intramedullary space is recanalized and the fracture reduced.
- A very critical point of this surgery, which needs long experience, is to judge the vitality of the bone fragments in the vicinity of the fracture. Stabilization is ensured by appropriate osteosynthetic material (intramedullary nails, plates, screws etc.). The gap is substituted with autologous cancellous bone usually harvested from the iliac crest.

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Extracorporeal shockwave therapy: A systematic review of its use in fracture management

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Affiliations + expand

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Abstract

Extracorporeal shockwave therapy is increasingly used as an adjuvant therapy in the management of nonunions, delayed unions and more recently fresh fractures. This is in an effort to increase union rates or obtain unions when fractures have proven recalcitrant to healing. In this report we have systematically reviewed the English language literature to attempt to determine the potential clinical efficacy of extracorporeal shockwave therapy in fracture management. Of 32 potentially eligible studies identified, 10 were included that assessed the extracorporeal shockwave therapy use for healing nonunions or delayed unions, and one trial was included that assessed its use for acute high-energy fractures. From the included, studies' overall union rates were in favor of extracorporeal shockwave therapy (72% union rate overall for nonunions or delayed unions, and a 46% relative risk reduction in nonunions when it is used for acute high-energy fractures). However, the methodologic quality of included studies was weak and any clinical inferences made from these data should be interpreted with caution. Further research in this area in the form of a large-scale randomized trial is necessary to better answer the question of the effectiveness of extracorporeal shockwave therapy on union rates for both nonunions and acute fractures.

Extracorporeal Shock Wave Treatment for Delayed Union and Nonunion Fractures: A Systematic Review

Annika Willems, MSc, Olav P. van der Jagt, MD, PhD,† and Duncan E. Meuffels, MD, PhD**

Objectives: Nonunions after bone fractures are usually treated surgically with risk of infections and failure of osteosynthesis. A noninvasive alternative is extracorporeal shock wave treatment (ESWT), which potentially stimulates bone regeneration. Therefore this review investigates whether ESWT is an effective and safe treatment for delayed unions and nonunions.

Data Sources: Embase.com, MEDLINE ovid, Cochrane, Web of Science, PubMed publisher, and Google Scholar were systematically searched.

Study Selection: Inclusion criteria included studies with patients with delayed union or nonunion treated with ESWT; inclusion of ≥10 patients; and follow-up period ≥6 weeks.

Data Extraction: Assessment for risk of bias was conducted by 2 authors using the Cochrane tool. Union rates and adverse events were extracted from the studies.

Data Synthesis: Two RCTs and 28 nonrandomized studies were included. One RCT was assessed at medium risk of bias and reported similar union rates between ESWT-treated patients (71%) and surgery-treated patients (74%). The remaining 29 studies were at high risk of bias due to poor description of randomization (n = 1), nonrandomized allocation to control groups (n = 2), or absence of control groups (n = 26). The average union rate after ESWT in delayed unions was 86%, in nonunions 73%, and in nonunions after surgery 81%. Only minor adverse events were reported after ESWT.

Conclusions: ESWT seems to be effective for the treatment of delayed unions and nonunions. However, the quality of most studies is poor. Therefore, we strongly encourage conducting well-designed RCTs to prove the effectiveness of ESWT and potentially improve the treatment of nonunions because ESWT might be as effective as surgery but safer.

Key Words: Extracorporeal shock wave, nonunion, delayed union, bony union, union rates, adverse events

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

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INTRODUCTION

Delayed unions and nonunions are failures of bony healing after fractures, osteotomies, or arthrodesis. In practice, a wide variety exists in the exact definition of delayed unions and nonunions depending on fracture site and criteria used for the assessment of bony union.[1] In this review, we define delayed unions as fractures that do not show radiological union 3 months after a fracture and nonunions as fractures that do not show radiological union 6 months after a fracture.

Literature shows that 3%–5% of all fractures evolve into a nonunion, with highest nonunions rates reported in fractures of the scaphoid (16%), tibia (14%), and femur (14%).[2,3] Patients with nonunions suffer from pain and decreased function, which affects a patient's daily routines and decreases their quality of life.[4,5]

At present, most nonunions are treated with surgery, which is considered to be the "golden standard."[6] Surgical treatment options of nonunions are overall quite successful, with union rates reported between 74% and 95%.[7–10] However, complications can occur such as infection (5%), neurovascular damage (7%), or implant-related problems requiring an additional surgery (5%).[7,11,12] Alternatively to surgery, patients could be treated noninvasively, which could reduce the risk of these complications.

A noninvasive treatment for delayed unions and nonunions is extracorporeal shock wave treatment (ESWT). ESWT is a well-known treatment for fragmentation of kidney

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Article

Extracorporeal Shockwave Therapy in the Treatment of Nonunion in Long Bones: A Systematic Review and Meta-Analysis

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Abstract: Background: Nonunion is one of the most challenging problems in the field of orthopedics. The aim of this study was to perform a systematic review of the literature to evaluate the effectiveness of extracorporeal shockwave therapy (ESWT) in the treatment of nonunion in long bones. Methods: We conducted a search of three databases (PubMed, Scopus, and Web of Science) and found 646 total publications, of which 23 met our inclusion criteria. Results: Out of 1200 total long bone nonunions, 876 (73%) healed after being treated with ESWT. Hypertrophic cases achieved 3-fold higher healing rates when compared to oligotrophic or atrophic cases ($p = 0.003$). Metatarsal bones were the most receptive to ESWT, achieving a healing rate of 90%, followed by tibiae (75.54%), femurs (66.9%) and humeri (63.9%). Short periods between injury and treatment lead to higher healing rates ($p < 0.02$). Conversely, 6 months of follow-up after the treatment appears to be too brief to evaluate the full healing potential of the treatment; several studies showed that healing rates continued to increase at follow-ups beyond 6 months after the last ESWT treatment ($p < 0.01$). Conclusions: ESWT is a promising approach for treating nonunions. At present, a wide range of treatment protocols are used, and more research is needed to determine which protocols are the most effective.

Keywords: pseudoarthrosis; nonunion; extracorporeal shockwave therapy; long bone; systematic review; meta-analysis

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1. Introduction

Pseudoarthrosis, commonly known as nonunion, is among the most challenging pathologies in the orthopedic field. The incidence, which is estimated to be 5–10% [1], but, according to some authors [2], could be as high as 50%, varies greatly depending on the type of fracture, anatomical site, and whether the fracture site is or open or closed. However, because of improved survival rates in patients with polytrauma, the incidence is predicted to increase [3] Nonunions may cause patients long-term physical disability as well as mental health problems, with elevated economic burden [4,5].

A plethora of surgical techniques are used to treat nonunion with a success rate of approximately 80% of patients achieving good to excellent final restoration of mechanical axis alignment and proper length [6]. Nevertheless, these results included all types of nonunions, and in the case of atrophic nonunions, the success rate would be significantly lower. Furthermore, in cases requiring multiple surgeries, the healing rate drops notably. Consequentially, bone regeneration strategies have been implemented for enhancing nonunion healing. Autologous bone grafting is currently the gold standard; however, its supply is limited and its potential for repair is unpredictable [7]. Furthermore, it requires an additional surgical site and is correlated to morbidities linked to the harvesting procedure [8].

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RESEARCH ARTICLE Open Access

Radial extracorporeal shock wave therapy is efficient and safe in the treatment of fracture nonunions of superficial bones: a retrospective case series

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Abstract

Background: A substantial body of evidence supports the use of focused extracorporeal shock wave therapy (fESWT) in the non-invasive treatment of fracture nonunions. On the other hand, virtually no studies exist on the use of radial extracorporeal shock wave therapy (rESWT) for this indication.

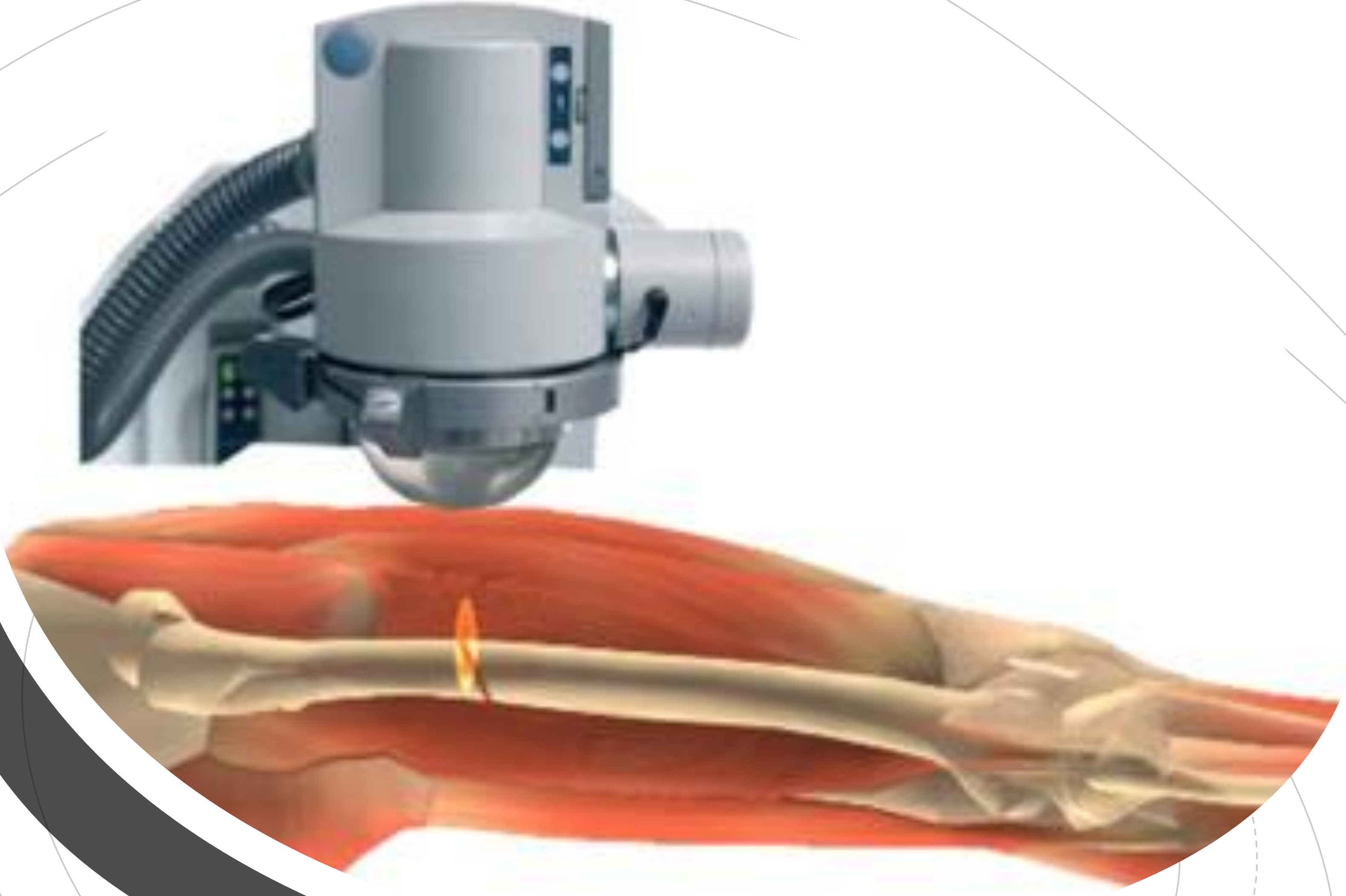
Methods: We retrospectively analyzed 22 patients treated with rESWT for fracture nonunions of superficial bones that failed to heal despite initial surgical fixation in most cases. Radial extracorporeal shock wave therapy was applied without anesthesia in three rESWT sessions on average, with one rESWT session per week and 3000 radial extracorporeal shock waves at an energy flux density of 0.18 mJ/mm^2 per session. Treatment success was monitored with radiographs and clinical examinations.

Results: Six months after rESWT radiographic union was confirmed in 16 out of 22 patients (73%), which is similar to the success rate achieved in comparable studies using fESWT. There were no side effects. The tibia was the most common treatment site (10/22) and 70% of tibia nonunions healed within 6 months after rESWT. Overall, successfully treated patients showed a mean time interval of 8.8 ± 0.8 (mean ± standard error of the mean) months between initial fracture and commencement of rESWT whereas in unsuccessfully treated patients the mean interval was 26.0 ± 10.1 months ($p < 0.05$). In unsuccessful tibia cases, the mean interval was 43.3 ± 13.9 months.

Conclusions: Radial extracorporeal shock wave therapy appears to be an effective and safe alternative in the management of fracture nonunions of superficial bones if diagnosed early and no fESWT device is available. The promising preliminary results of the present case series should encourage the implementation of randomized controlled trials for the early use of rESWT in fracture nonunions.

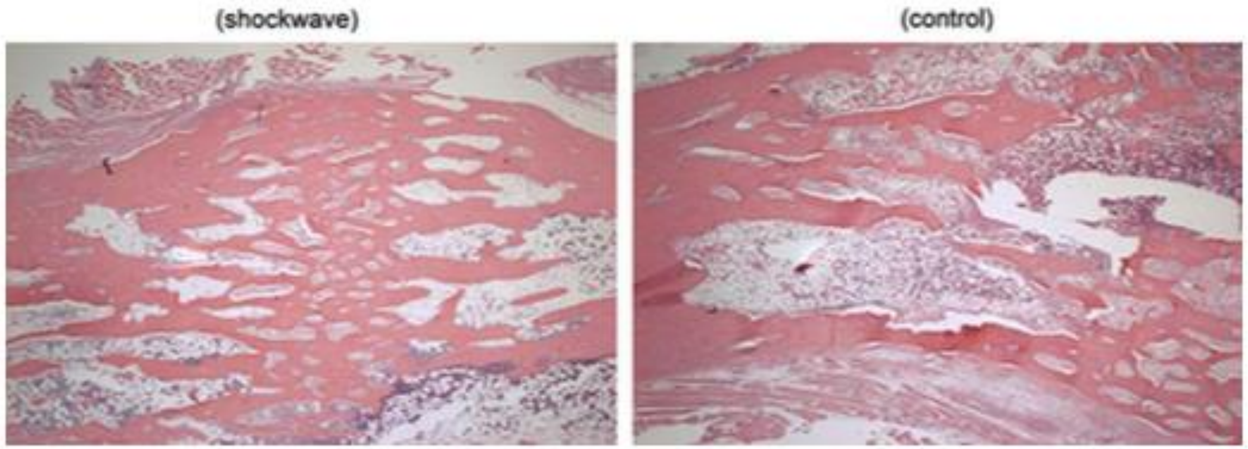
Keywords: Bone, Focused extracorporeal shock wave therapy, Fracture, Nonunion, Radial extracorporeal shock wave therapy

	Furia et al. [21]	**Notarnicola et al. [22]**	**Cacchio et al. [23]**
Indication	5th Metatarsus	Carpal scaphoid	Long bone
Device	Electrohydraulic	Electromagnetic	Electromagnetic
ESWT	2000–4000 impulses 0.35 mJ/mm^2 Single session	4000 impulses 0.09 mJ/mm^2 3 sessions	4000 impulses Group 1: 0.4 mJ/mm^2 Group 2: 0.7 mJ/mm^2 4 sessions
Number of pts (n)	23 vs 20 ESWT vs surgery	58 vs 60 ESWT vs surgery	36 vs 38 vs 37[a] ESWT group 1 vs 2 vs surgery
Union rate	*6 month FU* 91% vs 90% ESWT vs surgery	*12 month FU* 79.3% vs 78.3% ESWT vs surgery	*24 month FU* 94% vs 92% vs 95% ESWT group 1 vs 2 vs surgery
Complications	1 vs 11 ESWT vs surgery	None	23 vs 3 ESWT group1+2 vs surgery
Type of complication	*ESWT*: petechiae *Surgery*: re-fracture, cellulitis, symptomatic hardware		*ESWT*: Petechiae, hematoma *Surgery*: wound infection, temporary paresis



Biologisk effekt af ESWT på knoglevæv

Shockwave-promoted bone healing was associated



↑ Øget eNOS (neovascularisering)

↑ Øget cortical knogle formation.

↑ Øget VEGF (Vascular Endothelial Growth Factor)

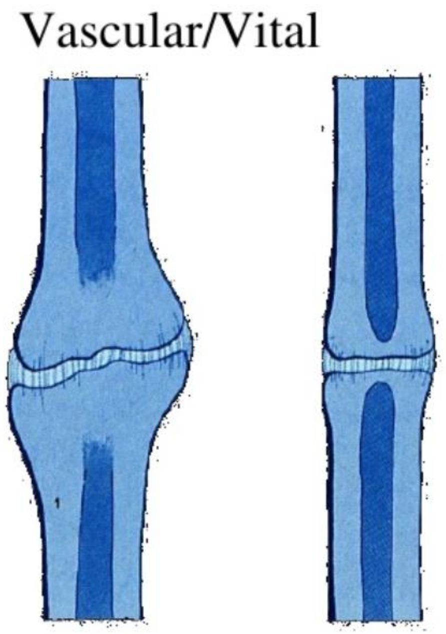
↑ Øget BMP-2 (bone morphogenetic protein – øget kngoledannelse)

↑ Øget PCNA (**Proliferating cell nuclear antigen**) DNA syntese

Non Union Frakturer

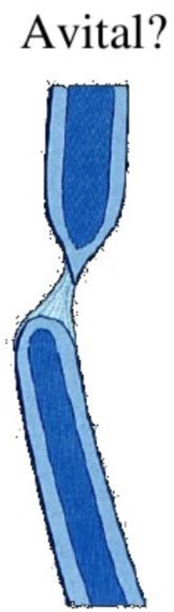
Hypertrofisk

Formation af callus men ingen kontakt imellem brudlinjer

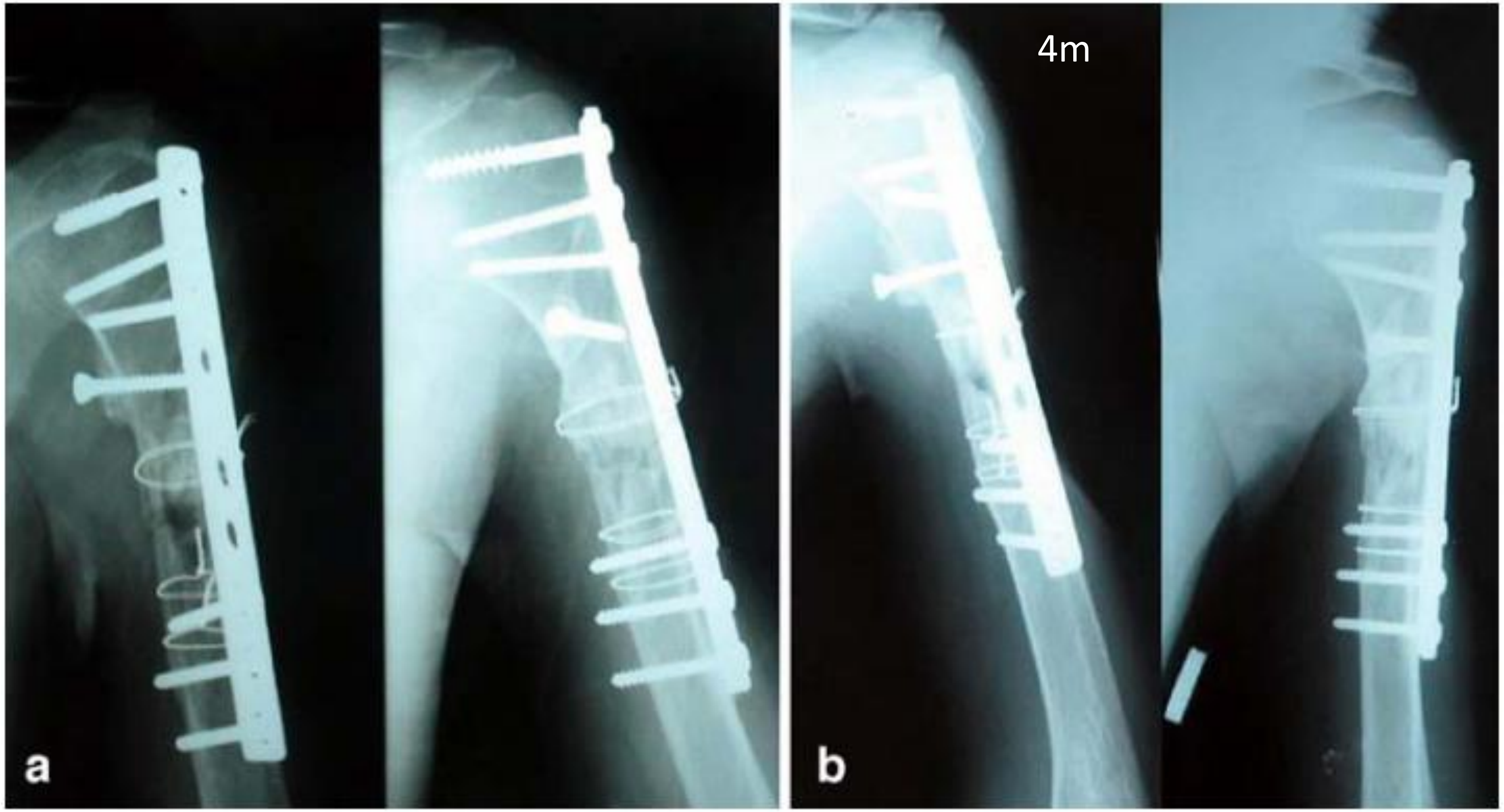


Atrofisk

Ingen callus formation og ingen kontakt mellem brudlinjer



Cases



Cases

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Review

Extracorporeal shockwave therapy (ESWT) – First choice treatment of fracture non-unions?

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HIGHLIGHTS

- Non-healing fractures (pseudarthroses, non-unions) still are a challenging problem in orthopedics.
- ESWT is a non-invasive procedure that achieves comparable results to surgical approaches.
- Complications associated with ESWT are on rare occasions and minimal if present.
- Peer-reviewed literature shows excellent results with medium/high energy focused ESWT, with faster return to competition and athletic activity.

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ABSTRACT

Fracture non-unions are still a challenging problem in orthopedics. The treatment of non-unions remains highly individualized, complex, and demanding. In most countries the surgical approach with debridement of the non-union gap, anatomical reduction and appropriate osteosynthesis along with autologous bone grafting is considered as the standard of care. One of the very first non-urologic applications of extracorporeal shockwave treatment (ESWT) concerned non-healing fractures. Since the early 1990ties the knowledge of the working mechanism has increased enormously. The purpose of this review article is to demonstrate by peer-reviewed literature in conjunction with our own experiences that ESWT can be an efficient, non-invasive, almost complication-free and cost effective alternative to surgical treatment of non-healing fractures.

1. Introduction

In the last 40 years extracorporeal shockwave therapy (ESWT) has evolved as the standard therapy for concrement disintegration in urology. Convincing clinical aspects lead to a rapid ubiquitous dissemination of this treatment modality and include excellent efficacy, non-invasiveness and the lack of significant complications. Observing osseous thickening of the iliac bone in 1 year follow-up X-rays after employment of shockwaves in ureter or bladder stones, Gerald Haupt [1] recognized already in 1990 for the first time the dynamic interaction of ESWT with a biological tissue. During stone treatment shockwaves propagated through the bone and provoked hypertrophy whereupon the mechanism was unclear. Since the first report of Valchanov [2] in 1991 applying shockwaves for non-healing fractures the perception and understanding of this technology has grown enormously. In the beginning the hypothesis of the working mechanism was that shockwaves create micro-lesions in the treated bone (focus) without damaging the adjacent soft tissue. It was assumed that these treatment triggered micro-lesions gaining the capability to stimulate and reactivate bone healing in non-healing fractures. Tischer [3] expressed first doubts of this theory demonstrating new bone formation after shockwave application in healthy femura of rabbits without creating micro-lesions.

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Treatment recommedations

- The current peer-reviewed literature clearly shows that treatment of fracture non-unions with electrohydraulic and electromagnetic shockwave sources possessing wide focusses (big devices) delivering high energy flux densities is effective.
- As these devices are used at high energy levels for non-union treatments usually sedation or general- or regional anesthesia is required.
- Electrohydraulic systems are used in a single session whereas electromagnetic devices are recommended to be applied from two to four sessions.
- To be suitable for ESWT the non-union should be in correct anatomical position.
- According to the literature atrophic and oligotrophic non-unions have an inferior probability of bony healing after ESWT than hypertrophic non-unions. However, according to our experience we could not see a significant difference in the outcome between these non-union types.
- Nevertheless, we could determine a non-union gap of being larger than 5 mm in long bones as a negative predictor for outcome, thus surgical options should be considered in these cases.

Treatment recommendations

As ESWT is initiating healing inter alia by anginogenesis where capillaries are crossing the non-union gap it increases success when avoiding micro movements for four to six weeks after the treatment.

If necessary this can be achieved by orthosis, plaster cast and/or no weight bearing for this period of time. In very instable non-unions especially in the lower limb it might be necessary to apply an external fixator in the same session to ensure sufficient stability.

ESWT vs surgery

Contrary, ESWT can be performed as an outpatient procedure or alternatively admission overnight in the hospital. The procedure itself only takes between 25 and 45 min, is easy to be performed and has a short learning curve.

Minor side effects include reddening and swelling and occasionally petechial bleedings and hematomas without clinical impact. However, no major side effects are reported

Along, the patients' age, comorbidities such as diabetes or osteoporosis, use of corticosteroids, metabolic disorders, smoking or alcohol have a strong influence on bone healing.

ESWT vs surgery

Due to our experience around 75% of referred patients suffering from a non-union fracture are suitable for ESWT.

Besides the clear advantages for the patient not undergoing major surgery with the associated risks and complications, also the financial effort of different treatment options is increasingly recognized by the health care systems worldwide. Savings of around 65%–85% (depending on different assurance modalities) are achieved in Austria treating non-union fractures with ESWT in place of surgery.

Protocol

fESWT; 2000-8000 impulses, 2-6 Hz, 0,15-0,8 mJ/mm2, 2-5 treatments at weekly intervals.

rESWT; 2000-3000 impulses, 3-8 Hz, 0,2-0,3 mJ/mm2, 3-4 treatments at weekly intervals..

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Søgestreng for stress fraktur

Extracorporeal shock wave and stress fracture (RSW/FSW) – 11 studier inkluderet

Udvalgte systematiske reviews og metaanalyser 15 år tilbage – 0 systematiske reviews inkluderet

Stressfracture

Stressfractures are common painful conditions in athletes, usually associated to biomechanical overloads.

Low risk stress fractures usually respond well to conservative treatments, but up to one third of the athletes may not respond, and evolve into high-risk stress fractures.

Surgical stabilization may be the final treatment, but it is a highly invasive procedure with known complications.

ESWT, based upon the stimulation of bone turnover, osteoblast stimulation and neovascularization by mechanotransduction, have been successfully used to treat delayed unions and avascular necrosis.

Repetitive cyclic loading of bones is the most relevant etiologic factor in the genesis of stress fractures.

The fine balance between Bone Microdamage & Remodeling marks the outcome of bone failure under repetitive loading conditions (7).

The three possible scenarios for bone failure under fatigue loading are: normal bone & abnormal loading – normal loading & abnormal bone and abnormal loading on abnormal bone.

The most common bones affected are tibia, metatarsals, fibula, navicular, pelvis and femur (4), (23).

The global incidence ranges from 1% to 20% depending on the physical activities of the patients (11).

They usually appear as a progressive localized bone pain after physical activity or sports (18). Symptoms usually disappear with rest and have short recovery periods.

The ethiology of stress fractures is a biomechanical misbalance of loads that result in a progressive breakage of the gait kinetic chain(29). This is very relevant in athletes and military personnel that repetitively overload under-trained skeletons and cause unbalanced bone remodeling resulting in bone failure (18).

Diagnosticering

Clinical diagnosis is relatively easy with physical examination that shows pain at a pin pressure point that may or not be associated to swelling.

There is pain when eccentric loads are applied to the muscles inserted on the affected bone, and specific tests have been described for stress fractures such as the hyperextension, the fulcrum or the hop tests (38).

There is a higher risk in Caucasians, as well as in women with nutritionals menstrual disorders. (Stress fracture risks are more related to inadequate training and exercise programs (13), (19), (24).

Stress fractures are classified upon the risk of a complete bone failure, as low, medium or high risk (5), (6), (30).

Frederickson (12), (14) described an image-based classification using both X rays and MRI, associating recovery time with four stages of bone damage.

It is especially valuable to determine prognosis. Low risk stress fractures usually respond to conservative treatments, while high risk fractures usually require surgical procedures in order to prevent a complete fracture.

Up to one third of low risk stress fractures may not respond to conventional treatments and continue with pain during exercise (14), (25), (33). They may evolve into high-risk stress fractures if load conditions and bone turnover is not balanced.

It is a primary goal of the sports medicine and orthopedic specialists to prevent the progression of a low risk stress fracture.

Radiological evaluation

Diagnostic images are mandatory in order to determine staging (30). The first reports of a radiological classification of stress fractures was done by Savoca (34) in 1971, and he correlated clinical symptoms with early metaphyseal sclerosis, periosteal reaction or partial fractures.

Magnetic resonance images are the best tool to determine bone marrow edema, periosteal reaction and soft tissue damages in all stages of stress fractures (8). Bone scans are very sensitive to determine increased bone turnover areas in early stages, but it is not very specific as many other situations may mark as false positive, and is an invasive procedure with potential risks (26), (35). However, in early stages it is the most specific and sensitive test available, as radiographic findings only appear after three weeks of the initial microfracture (9), (36).

Treatment

Treatment of stress fractures is based on a mechanical and a biological approach (37).

Load control on the mechanical side is the basic treatment, in order to allow the biological bone turnover to recover the stressed area.

In patients with localized bone pain and a history of mechanical stress, a diagnosis with x rays, bone scans and MRI will confirm the diagnosis.

All accepted treatment protocols include as a gold standard a progressive retraining and physical therapy that goes from total rest to sprint running and specific agility drills.

Conservative treatment is a long process that may take as much as 3–6 months.

This is usually too long for a professional athlete, so most of non-surgical treatments are focused on reducing the recovery time. The most common form of treatment with physical therapy is a two-stage protocol (15), (27).

The first stage is based on rest and pain control, while the second is focused on muscle balance and strength, balance, proprioception, flexibility and progressive sports specific re-training (20), (21), (27).

Surgery

Surgery is not a simple procedure, and usually requires an invasive protocol with internal fixation, grafting and a long recovery time, with known and well reported complications (10), (39), (40), (41).

There are more reports on surgery and their complications than studies that support improving the healing process and the bone turnover on stress fractures.

Scientific evidence

Hotzinger (81) reported the first case of stress fractures treated with ESWT at the ISMST meeting in London in 1999. He studied the role of MRI in the diagnosis of multiple stress fractures of the tibia, and treated a case with high-energy shockwaves with good results.

After this first case report, several clinical studies on ESWT and stress fractures have been conducted with good results, (1), (2), (3), (16), (17), (22), (25), (28), (31), (32), (42).

Fig. 2. The treatment is done placing the ESWT unit over the stress fracture area. The use of membrane applicators with focused energy has the better results. The treatment area is marked previously under X-rays.

Protocol

fESWT, 2000-3000 impulses, 2-6 Hz, 0,08-0,7 mJ/mm2, 1-3 treatments at weekly intervals.

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Søgestreng for AVN/ONFH

Extracorporeal shock wave avascular necrosis/osteo necrosis of the femoral head og the femoral head (RSW/FSW) – 9 studier inkluderet

Udvalgte systematiske reviews og metaanalyser 15 år tilbage – 0 systematiske reviews inkluderet

AVN/ONFH

The etiology of osteonecrosis of the femoral is multifactorial.

Osteonecrosis also named avascular necrosis (AVN), bone infarction, aseptic necrosis, and ischemic bone necrosis is a disease where there is cellular death (necrosis) of bone components due to interruption of the blood supply.

Avascular necrosis of the femoral head (ONFH) is more common in the hip joint than in other locations (knee, talus etc.).

Treatment of ONFH is disease stage dependent.

For early stages, femoral head preservation procedures are preferred including core decompression, muscle pedicle grafting and de-rotational osteotomy. Core decompression with bone grafting is considered the gold standard.

However, the results are inconsistence and unpredictable. An effective non-invasive method of treatment is imperative.

ESWT has shown beneficial effects in ONFH. ESWT improves pain and function of the hip and regression of the ONFH lesion. ESWT is more effective than core decompression with or without bone grafting,

Cocktail therapy that combined HBO, ESWT and oral alendronate is shown effective for patients with early osteonecrosis.

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Research Article

Quantitative Magnetic Resonance Imaging of Femoral Head Articular Cartilage Change in Patients with Hip Osteonecrosis Treated with Extracorporeal Shock Wave Therapy

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Background. Multiple reports have demonstrated the therapeutic potential of extracorporeal shock wave (ESWT) in osteonecrosis of the femoral head (ONFH). However, few studies reported the changes in hip articular cartilage after the intervention. This study aimed to investigate the effect of ESWT on femoral head cartilage using a novel technique, quantitative T2-mapping magnetic resonance imaging. *Methods.* A total of 143 eligible patients with unilateral early-stage ONFH were randomized into the ESWT group and control group. Seventy-three patients in the ESWT group received two sessions of ESWT with oral drug treatment, while seventy patients in the control group received oral drug treatment only. The visual analog pain scale (VAS) and Harris hip score (HHS) at 3-month, 6-month, and 12-month follow-up were used as the clinical evaluation index. The radiological evaluation index used the T2 mapping values, necrotic size, and China-Japan Friendship Hospital (CJFH) classification. *Results.* A total of 143 patients (62 females and 81 males) were finally included, and the characteristics before treatment were comparable between the two groups. At the last follow-up (12 months), the T2 values and ΔT2 changes in the ESWT group were all smaller than those in the control group ($p = 0.042$; $p = 0.039$), while the CJFH classification of ONFH and necrotic lesion size were not statistically significant. At 3 months and 6 months, the VAS in the ESWT group was lower than that in the control group ($p = 0.021$; $p = 0.046$) and the HHS in the ESWT group was higher ($p = 0.028$; $p = 0.039$). However, there were no significant differences in the VAS and HHS at 12 months between the ESWT and control groups. *Conclusions.* The results of the current study indicated that, based on drug treatment, ESWT is an effective treatment method for nontraumatic ONFH, which could result in significant pain relief and function restoration. Furthermore, it could delay the injury of femoral head cartilage during the progression of ONFH.

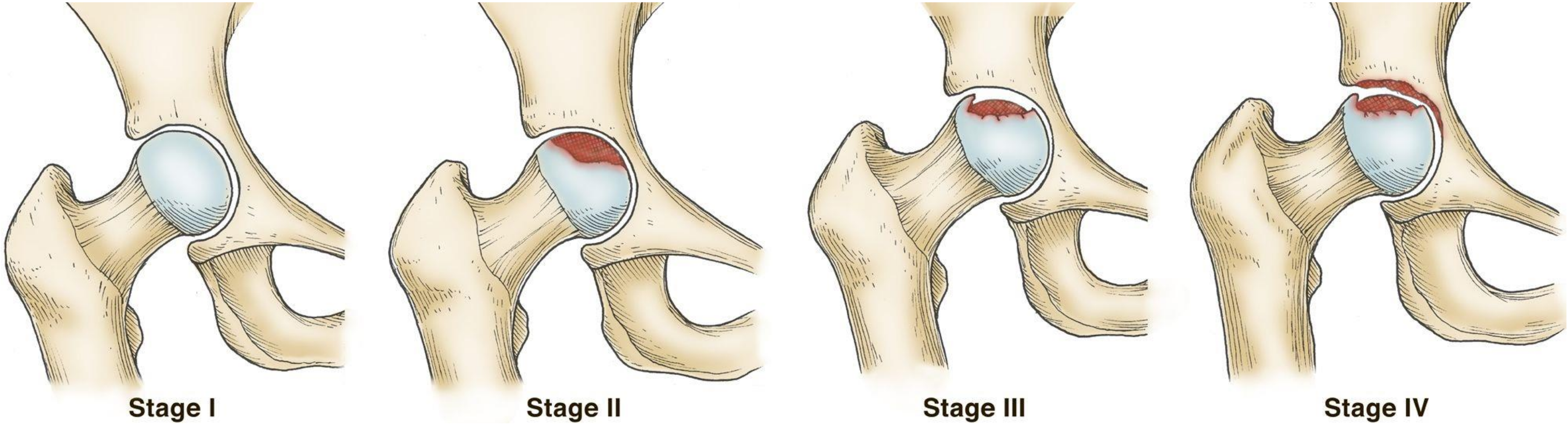
1. Introduction

Osteonecrosis of the femoral head (ONFH) is a major side effect related to high-dose corticosteroid administration, which occurs frequently in relatively young adults (age, 30–50 years) [1, 2]. It is a progressive pathological condition characterized by large amounts of death of bone cells and tissue necrosis due to insufficient circulation, leading to femoral head collapse and secondary hip osteoarthritis. Most patients, if left not treated, may require total hip arthroplasty (THA) in the early stage. Postcollapse ONFH has been one of the most common reasons for primary THA in many

Stage	Findings	Location description	Quantification
0	Normal	None	None
1	Radiography and computed tomography are normal. Magnetic resonance imaging (MRI) and biopsy are positive.	Medial Central Lateral	Areas of involvement: A, B, or C (<15%, 15–30%, and >30%, respectively)
2	Radiography is positive. Sclerosis, osteolysis and focal osteoporosis are found	Medial Central Lateral	Areas of involvement: A, B or C (<15%, 15–30% and >30%, respectively)
3	Crescent sign and early flattening of articular surface	Medial Central Lateral	Areas of involvement: A, B or C (<15%, 15–30% and >30%, respectively) Amount of surface depression and collapse: A, B or C (<2 mm, 2–4 mm and >4 mm, respectively)
4	Femoral head with joint space is narrowing. Osteoarthritis with acetabular changes	None	None

Osteonecrose af caput femoris (ONFH)

AKA Avaskulær nekrose



Resultater

Overall clinical outcomes showed good or excellent in 76% (22 of 29) fair and poor in 24% (7 of 29) for ESWT group, and 21% (6/28) good or excellent and 79% fair or poor in the surgical group respectively.

These results demonstrated that ESWT is more effective than core decompression and bone grafting for early ONFH in long-term follow-up.

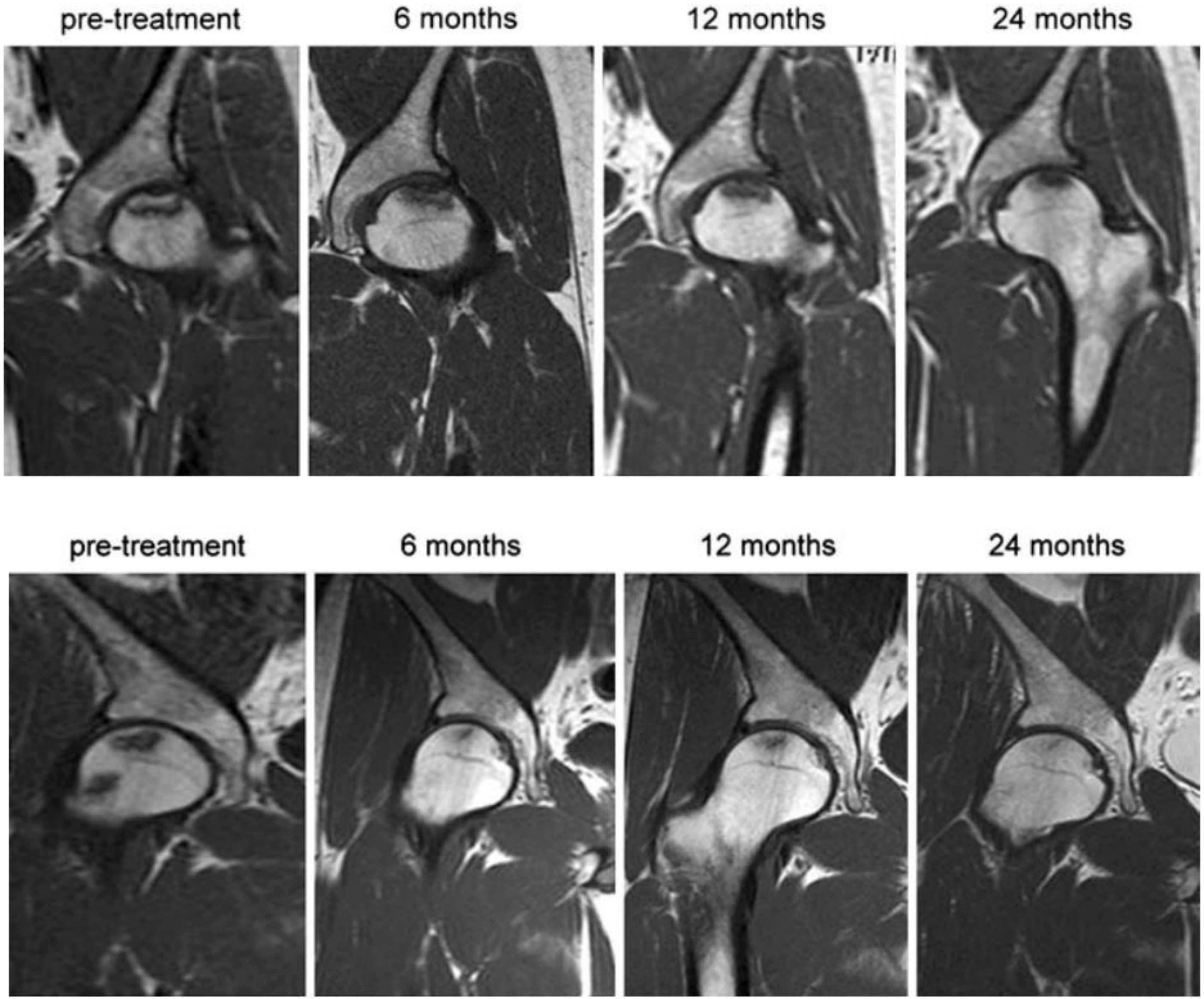
fESWT effects on ONFH

It appears that application of shockwave results in regeneration effects in hips with ONFH.

In animal experiment, ESWT was shown to increase mRNA and protein of BMP-2 as well as up-regulation of VEGF expression in perinecrotic subchondral bone of the femoral head. VEGF expression suggests the ingrowth of neovascularization and improvement of blood supply to the femoral head.

The findings are in concert with the results of histopathological observation and immunohistochemical analysis, ESWT was suggested to promote angiogenesis and bone remodeling and regenerative effect through the induction of the NO pathway in ONFH.

It also showed that ESWT may be effective in the prevention of collapse of the femoral head with early ONFH.


pre-treatment
6 months
12 months
24 months
pre-treatment
6 months
12 months
24 months

Protocol for ONFH

Focused ESWT

2400-6000 impulses, 2-6 Hz, 4-6 treatments at weekly interval, 0,4-0,6 mJ/mm2

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Søgestreng for bone Marrow Lesion/Oedema

Extracorporeal shock wave and bone marrow lesion, oedema (RSW/FSW) – 4 studier inkluderet

Udvalgte systematiske reviews og metaanalyser 15 år tilbage – 0 systematiske reviews inkluderet

Bone Marrow Lesion/Oedema (BMO)

BMO is typified by an “inflammatory pattern”in MRI (low signal intensity int1-W and high signal intensity int2-W sequences).

Typical BMO histological features are marked by fibrosis and inflammatory infiltrate which often reflects the occurrence of pain in the affected bone segment (1,2).

BMO usually affects the epiphyses of weight-bearing joints—hip,knee, foot and ankle

The hip is the most common site of BMO.

BMO is normally spontaneously self-limiting within 4–24months (3); however, there is a risk of fracture due to the weakened bonearchitecture [8].

Progression to avascular osteonecrosis is a rare occurrence, although it has been described in the literature (3,4-8).

There is no gold standard for the treatment of BMO; treatment is traditionally conservative and includes reduced weight-bearing, physical therapy, analgesics and vasoactive prostacyclin analog drugs like iloprost, although some authors have even resorted to treating the condition surgically, performing a bone core decompression (3,7,8).

However, there is consensus regarding the importance of an early treatment to relieve pain and to avoid weakening the bone trabeculae which could potentially lead to a collapse of the subchondral bone.

Rheumatol Int
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ORIGINAL ARTICLE

Effectiveness of extracorporeal shock wave therapy in bone marrow edema syndrome of the hip

Cristina d'Agostino · Pietro Romeo · Vito Lavanga · Salvatore Pisani · Valerio Sansone

Received: 17 January 2014 / Accepted: 12 March 2014

Abstract There is no gold standard for treatment of bone marrow edema syndrome of the hip (BMESH). Usually, treatment is conservative, owing to the favorable and self-limiting prognosis. In musculoskeletal disorders, the effectiveness of extracorporeal shock wave therapy (ESWT) has been widely recognized and recent research supports its use in the treatment of the first stages of avascular osteonecrosis of the proximal femur and in other conditions where bone marrow edema is present. On this basis, we performed a prospective study to evaluate the effectiveness of ESWT in normalizing the symptoms and imaging features of BMESH. Twenty consecutive symptomatic patients underwent two treatments of high-energy ESWT and were followed-up at 2, 3 and 6 months, with a final clinical follow-up at mean 15.52 ± 1.91 months. Patients underwent magnetic resonance imaging of the hip and were evaluated according to the Harris hip score. The mean improvement in HHS over the course of the study was of 58.5 ± 14.9 points ($p < 0.0001$), and the mean edema area reduced from 981.9 ± 453.2 mm^2 pre-treatment to 107.8 ± 248.1 mm^2 at 6 months. ESWT seems to be a powerful, non-pharmacological tool that produces rapid pain relief and functional improvement and aids the normalization of the vascular and metabolic impairments which characterize BMESH.

Keywords Bone marrow edema syndrome · Extracorporeal shock wave therapy · Hip · Femoral head · Conservative treatment · Magnetic resonance imaging

Introduction

The term bone marrow edema (BME) describes a wide range of focal bone lesions of different origin and is most likely a vascular reaction to external or internal disorders [1]. Although the correlations with other diseases such as aseptic osteonecrosis, algodistrophy, trabecular microfractures and osteoporosis of pregnancy are still debated, bone marrow edema syndrome (BMES) is now an accepted clinical entity. It is typified by an "inflammatory pattern"

The therapeutic protocol consisted of two sessions of shock wave therapy, 48h apart, using a shockwave electromagnetic source [Modulith SlK StorzMedical,Switzerland] fitted with a double ecographic and radiographic pointing device. Each treatment consisted of 4,000 shots at high-energy level, with mean energy fluxdensity value of 0.5mJ/mm2(range 0.4–0.6mJ/mm2). Partial weight-bearing (two crutches) was prescribed for 30 days after treatment.

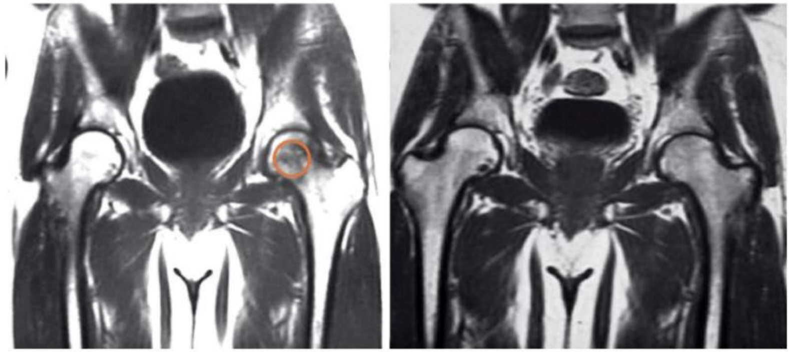

Fig. 1 Pre- and 6 months post-treatment T1-weighted images showing the normalization of a large bone marrow edema of the left femoral head, in a 47-year-old male patient. The *circle* marks the edema

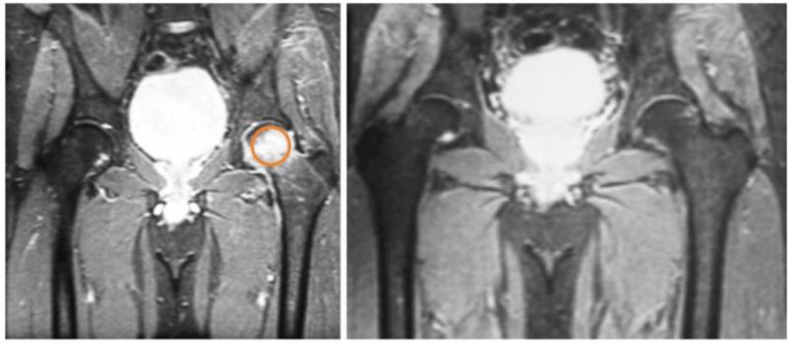

Fig. 2 Pre- and 6 months post-treatment T2-weighted images of the same patient

Therapeutic protocol: 3 sessions, 3 days apart, 0,5 mJ/mm2, 2500-4000 shocks at 4-5 treatment points at 500 shocks.

Observational Study

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High-energy focused extracorporeal shock wave therapy for bone marrow edema syndrome of the hip

A retrospective study

Leilei Zhang, MD, Yuzhi Cui, MD, Dawei Liang, MD, Jie Guan, MD, Youwen Liu, MD*, Xiantao Chen, PhD*

Abstract

The objective of this retrospective study was to evaluate the efficacy of high-energy focused extracorporeal shock wave therapy (HF-ESWT) on painful bone marrow edema syndrome (BMES) of the hip and shorten the natural course of disease.

Thirty-four consecutive patients with BMES of the hip were treated with HF-ESWT in our department between August 2017and July 2018. The progression and treatment results of BMES were evaluated by imaging examination and clinical outcomes. The clinical outcomes include hip pain and function which were measured using the visual analog scale (VAS) and Harris hip score (HHS), respectively, and the VAS and HHS of all patients were calculated and evaluated before treatment (s0), at 1 month (s1), 3 months (s2), 6 months (s3)post-treatment. Imaging examination including Pelvic radiographs and frog views and double hip magnetic resonance imaging (MRI) were also obtained and scheduled before treatment, at 1, 3, 6, and the final follow-up post-treatment to exclude avascular necrosis and other pathology.

All patients successfully completed the treatment and follow-up. Compared with pretherapy, the pain was alleviated to varying degrees and the HHS was significantly improved, and the VAS was significantly reduced at S1–2 (1- and 3-months post-treatment) after therapeutic intervention ($P < .05$). The mean improvements were strongly statistically significant between S0 and S1 and between S1 andS2 ($P < .0001$) and less significant between S2 and S3 ($P < .01$). The mean improvement between 6 months (S3) and final follow-up (more than 12 months) was not statistically significant. The MRI findings demonstrated that the diffuse BMES in the femoral head and neck disappeared completely.

HF-ESWT is a safe, effective, reliable, and noninvasive treatment in patients with painful BMES of the hip, and it can accelerate the recovery of BMES of the hip, shorten the treatment time and course of disease, improve hip joint function and the quality of life of patients.

Abbreviations: BMES = bone marrow edema syndrome, ESWT = extracorporeal shock wave therapy, HF-ESWT = high-energy focused extracorporeal shock wave therapy, HHS = Harris hip score, MRI = magnetic resonance imaging, ONFH = osteonecrosis of the femoral head, SD = standard deviations, VAS = visual analog scale.

Keywords: bone marrow edema syndrome, extracorporeal shock wave therapy, hip

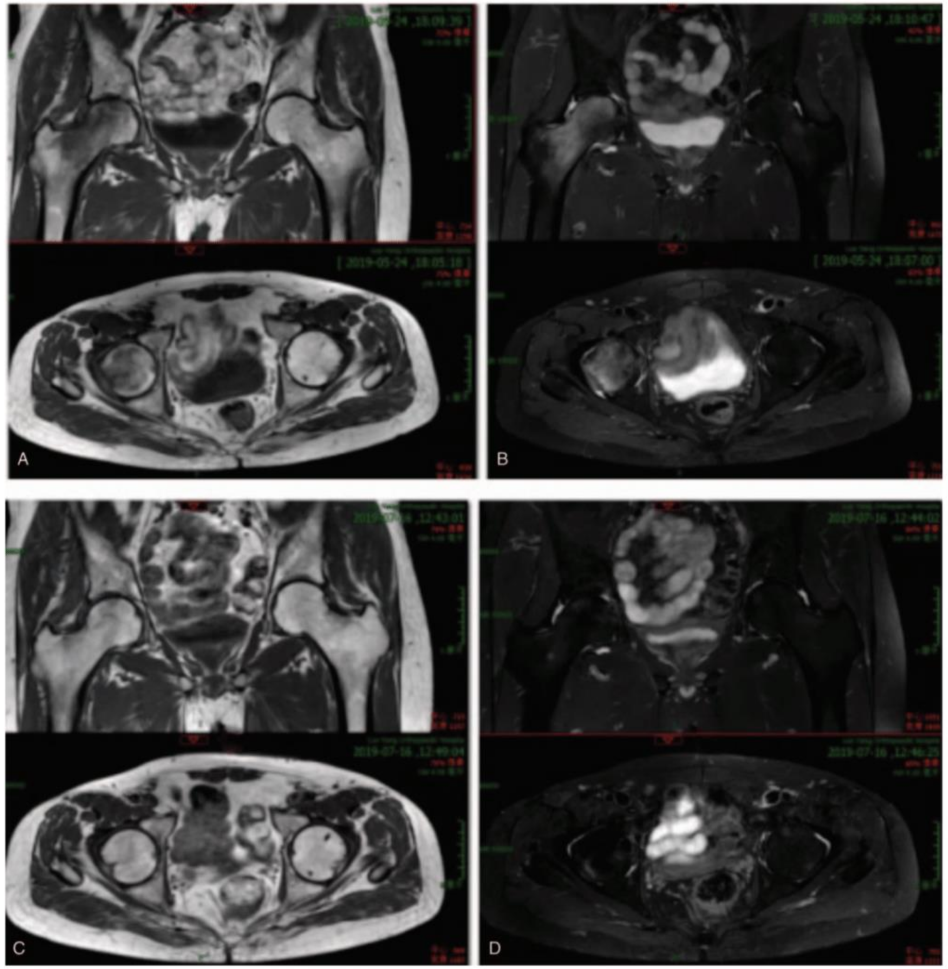

Figure 4. The pretherapy MRI (A,B) showing a large BME within the right hip. The MRI of 1.5 months posttreatment (C,D) showing reduction in the diffuse hyperintense signal of the femoral head and neck disappeared basically, and only a small amount of fluid remained in the hip joint cavity.

and Practice

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Extracorporeal Shock Wave Therapy Is Effective in the Treatment of Bone Marrow Edema of the Medial Compartment of the Knee: A Comparative Study

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Keywords

Bone marrow edema syndrome · Knee · Medial compartment · Conservative treatment · Extracorporeal shock waves · Magnetic resonance imaging

Abstract

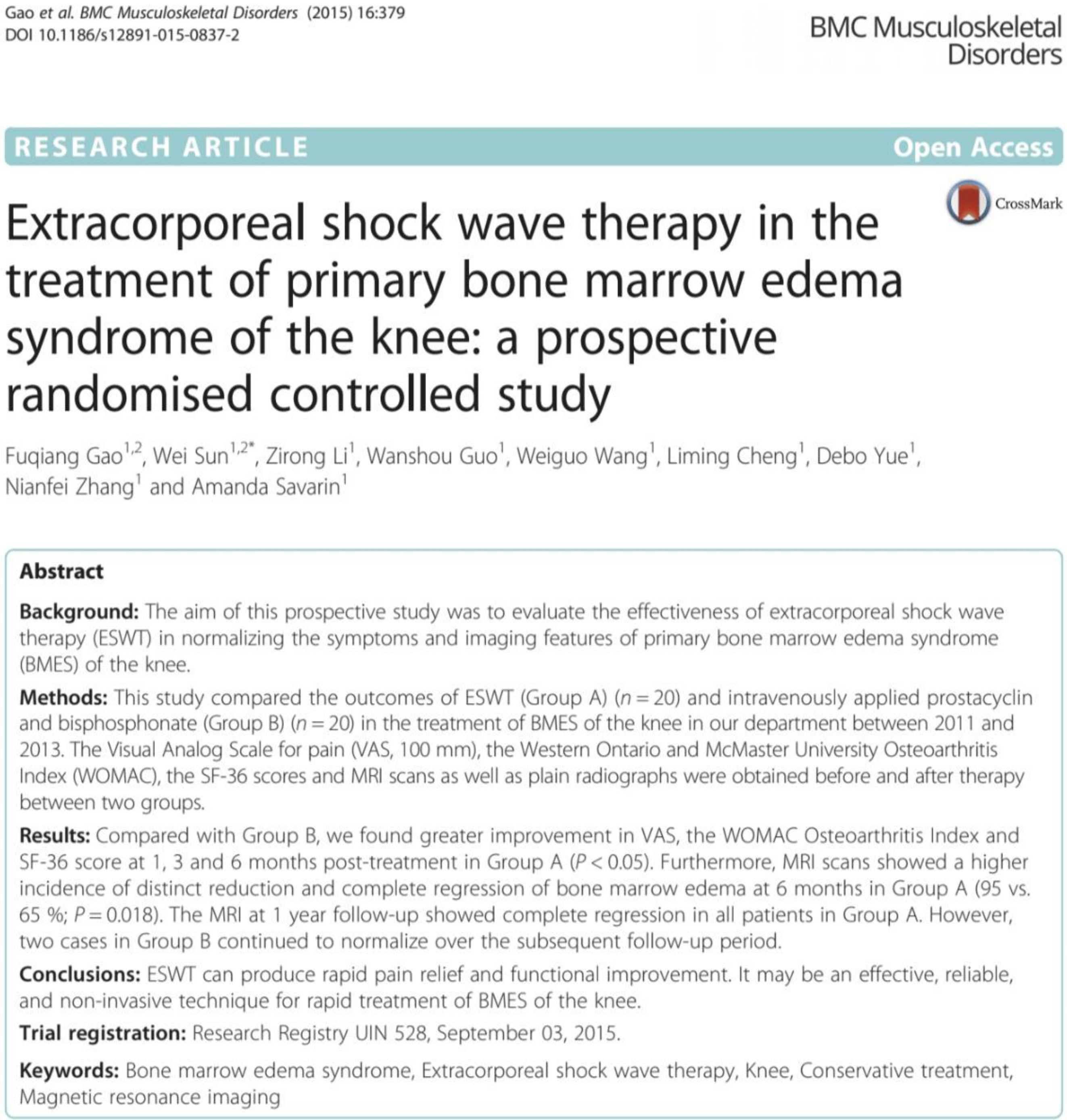
Objective: To test the hypothesis that shock wave therapy can produce a statistically significant improvement in symptoms and imaging features of the knee bone marrow edema syndrome (BMES) within 6 months of treatment. ***Subjects and Methods:*** Eighty-six consecutive patients suffering from BMES of the medial compartment of the knee were prescribed a course of high-energy extracorporeal shock wave therapy (ESWT) and clinically followed up at 3 and 6 months and finally from 14 to approximately 18 months after treatment. Thirty-one patients were unable to undergo ESWT but returned for the 6-month and final follow-up; these were referred to as the conservative (control) group, while the other 55 patients constituted the ESWT group. The Western Ontario and McMaster Universities Arthritis Index (WOMAC) and Visual Analog Scale (VAS) score of each patient were calculated at every follow-up. The BME area was assessed using magnetic resonance imaging before treatment and at the 6-month follow-up. ***Results:*** Statistically significant improvements were observed in clinical scores and in the BME area for both the ESWT and the control group ($p < 0.05$). The improvements in the ESWT group were statistically better in all parameters compared with the control group: the ESWT group had a reduction in the BME area of 86% versus 41% in the control group, the VAS pain score improved by 88% in the ESWT group versus 42% in the control group, and the WOMAC score improved by 65% in the ESWT group versus 22% in the control group. Clinical scores were significantly better for patients with medial tibial lesions in the ESWT group. ***Conclusion:*** In this study, ESWT reduced pain and the BME area in the knee, with significant clinical improvement noticed 3 months after treatment.

Introduction

Bone marrow edema (BME) is an accumulation of fluid in extracellular marrow spaces, and it is a feature of numerous physiological and pathological states. This reversible, nonspecific condition, which usually spreads from the medullar space into the subchondral region of the joint, appears as an area of ill-defined, homogeneous, intermediate signal intensity on T1-weighted (T1W) images

Treatment consisted of 1session of shock wave therapy every3 weeks for 9 weeks (3 times in total) using a shock wave electro-magnetic source (Epos Ultra Lithotripter; Dornier MedTechGmbH, Wessling, Germany) fitted with an echographic outlinepointing device. At each treatment session, 2,000 shots were applied at high energy, with energy flux density ranging from 0.22 to0.43 mJ/mm2and a frequency of 4 Hz. Protected weight bearing (2 crutches) was prescribed as long as pain was present, and analgesics were given on demand. Restriction of physical activity was also recommended, whereas cycling and swimming were encouraged, if tolerated.

Fig. 1. MR images of a patient treated with shock wave therapy. The fat-suppressed fast spin echo T2W MR images show the reduction in the hyperintense signal of the subchondral tibial plateau bone (arrows) from before treatment to the 6-month follow-up in the coronal plane (**a**, **b**) and the sagittal plane (**c**, **d**).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DOI 10.1186/s12891-015-0837-2

BMC Musculoskeletal Disorders

RESEARCH ARTICLE Open Access

Extracorporeal shock wave therapy in the treatment of primary bone marrow edema syndrome of the knee: a prospective randomised controlled study

Fuqiang Gao[1,2], Wei Sun[1,2*], Zirong Li[1], Wanshou Guo[1], Weiguo Wang[1], Liming Cheng[1], Debo Yue[1], Nianfei Zhang[1] and Amanda Savarin[1]

Abstract

Background: The aim of this prospective study was to evaluate the effectiveness of extracorporeal shock wave therapy (ESWT) in normalizing the symptoms and imaging features of primary bone marrow edema syndrome (BMES) of the knee.

Methods: This study compared the outcomes of ESWT (Group A) ($n = 20$) and intravenously applied prostacyclin and bisphosphonate (Group B) ($n = 20$) in the treatment of BMES of the knee in our department between 2011 and 2013. The Visual Analog Scale for pain (VAS, 100 mm), the Western Ontario and McMaster University Osteoarthritis Index (WOMAC), the SF-36 scores and MRI scans as well as plain radiographs were obtained before and after therapy between two groups.

Results: Compared with Group B, we found greater improvement in VAS, the WOMAC Osteoarthritis Index and SF-36 score at 1, 3 and 6 months post-treatment in Group A ($P < 0.05$). Furthermore, MRI scans showed a higher incidence of distinct reduction and complete regression of bone marrow edema at 6 months in Group A (95 vs. 65 %; $P = 0.018$). The MRI at 1 year follow-up showed complete regression in all patients in Group A. However, two cases in Group B continued to normalize over the subsequent follow-up period.

Conclusions: ESWT can produce rapid pain relief and functional improvement. It may be an effective, reliable, and non-invasive technique for rapid treatment of BMES of the knee.

Trial registration: Research Registry UIN 528, September 03, 2015.

Keywords: Bone marrow edema syndrome, Extracorporeal shock wave therapy, Knee, Conservative treatment, Magnetic resonance imaging

Shock wave treatment: The shock wave treatment was applied using an Electromagnetic Shock Wave Emitter (Dornier CompactDELTA II; Germany), with a penetration depth of between 0 and 150 mm and a focus diameter of 4 mm.

Shock waves were focused around (on the margins of) the femoral head under radiographic guidance. The treatment area was prepared with a coupling gel to minimize the loss of shock wave energy at the interface between the head of the device and the skin. In Group A, patients were subjected to high-energy ESWT,and the parameters are prepared and used as follows: number of levels, 3–4; at a high energy flux density (EFD) of > 0.44 mJ/mm2 (level 3); 3000–4000 impulses at a frequency of 2–3 Hz. Each patient underwent two therapy sessions (the time interval between successive procedures was 1 week). The number of the frequency selected depends on the patient’s condition.

Conclusions: In summary, ESWT is an effective, reliable, and non-invasive technique for rapid treatment of BMESK, followed by a progressive normalization of the MRI appearance. ESWT represents an innovative technology applicable to orthopedics, although further development is required. Further exploration of its mechanisms and prospects would be worthwhile, as it has the potential to resolve the suffering of BMESK patients rapidly and effectively.

Fig. 5 Pre- (**a**) and 6 months posttreatment (**b**) T2-weighted images showing the normalization of a large bone marrow edema within the medial femoral condyle of the left knee, in a 62-year old male patient. (Note: The patient consented to publish the specific information.)

Protocol

fESWT, 2-4 Hz, 0,22-0,6 mJ/mm2 x 2000-4000 impulses, 2-3 treatments, 48 Hours to 1 week apart

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SciMedCentral Journal of Fractures and Sprains

Case Series

Extracorporeal Shockwave Therapy in the Treatment of Bone Disorders: Fracture Nonunions, Delayed Unions, Chronic Stress Fractures and Bone Marrow Edema: A Case Report Series in a Private Practice Setting

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Abstract

Extracorporeal shockwave therapy (ESWT) is increasingly used as an adjuvant therapy in the management of nonunions, delayed unions, chronic stress fractures, bone marrow edema and more recently fresh fractures. This is in an effort to increase union rates and bone healing or obtain unions when fractures have proven recalcitrant to healing.

We describe 6 cases of fractures, bone marrow edema and stress fractures which were unable to be corrected by conventional conservative care but which we were finally able to heal using extracorporeal shockwave therapy.

Des questions

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Questions

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Antworten

Responder

Answer