Extracorporeal Shock Wave Therapy in the Treatment of Chronic Tendinopathies

Abstract
Many clinical trials have evaluated the use of extracorporeal shock wave therapy for treating patients with chronic tendinosis of the supraspinatus, lateral epicondylitis, and plantar fasciitis. Although extracorporeal shock wave therapy has been reported to be effective in some trials, in others it was no more effective than placebo. The multiple variables associated with this therapy, such as the amount of energy delivered, the method of focusing the shock waves, frequency and timing of delivery, and whether or not anesthetics are used, makes comparing clinical trials difficult. Calcific tendinosis of the supraspinatus and plantar fasciitis have been successfully managed with extracorporeal shock wave therapy when nonsurgical management has failed. Results have been mixed in the management of lateral epicondylitis, however, and this therapy has not been effective in managing noncalcific tendinosis of the supraspinatus. Extracorporeal shock wave therapy has consistently been more effective with patient feedback, which enables directing the shock waves to the most painful area (clinical focusing), rather than with anatomic or image-guided focusing, which are used to direct the shock wave to an anatomic landmark or structure.

In the past decade, interest has increased in using extracorporeal shock wave therapy (ESWT) to manage chronic tendinopathies that are refractory to other forms of nonsurgical management. Despite the burden of disease that tendon pathology represents and the amount of work that has been performed in the past two decades, much remains to be learned about the etiology, pathophysiology, and management of these tendinopathies. Current nonsurgical protocols are often more an art than a science.

Numerous studies have evaluated the efficacy of ESWT as a method of managing tendinopathies. Strict comparison of these studies is difficult, however, because of the many variables that define the application parameters of ESWT. These variables include the amount of energy delivered, the method of delivery and focusing, frequency of delivery, and use of anesthesia. In addition, treatment response varies depending on anatomic site, etiology, and severity and chronicity of the condition being treated, as well as in rehabilitation protocols used in conjunction with ESWT. The indica-
tion for the use of ESWT is a chron-
ic tendinopathy, which confuses the
issue further because the definition
of chronic tendinopathy varies;
therefore, patient inclusion criteria
differ between studies. The varia-
tions relate to the nature and dura-
tion of symptoms as well as the as-
sociated physical examination
findings. As a result, at present no
clear consensus exists as to the indi-
cations for the use of ESWT. Addi-
tional clinical data are required to
further establish the ideal treatment
protocol for each musculoskeletal
condition. Despite these deficien-
cies, reported results in the literature
support a therapeutic benefit and
wide safety margin for ESWT for
managing chronic tendinopathies of
the rotator cuff, lateral epicondyle,
and plantar fascia.

Principles of
Extracorporeal Shock
Wave Therapy

The shock wave used in ESWT is an
acoustic pressure disturbance created
by the translation of energy via an
electrohydraulic, electromagnetic, or
piezoelectric device; the wave is
transmitted to the patient through ei-
ther water or a coupling gel. Electro-
hydraulic shock waves are produced
by an electrical discharge across a
spark gap, which causes vaporization
of water and a resultant pulse as
these bubbles cavitate (Figure 1, A).
The pulse is reflected off the ellipti-
cal surface of the treatment head,
causing a shock wave. Electromag-
netically generated shock waves are
created via an electromagnet that
causes rapid motion of an aluminum
foil membrane; that motion com-
presses the nearby fluid, resulting in
the production of a shock wave (Fig-
ure 1, B). Piezoelectrically created
shock waves are produced when an
electrical discharge is applied to sev-
eral piezoelectric crystals mounted
on the inside of the generator (Figure
1, C). The electric discharge causes
rapid contraction and expansion of
the crystals, resulting in a pressure
pulse and subsequent shock wave.

Shock waves have a rapid rise in
pressure to 90% of maximum pres-
sure within 10 nsec. This rapid rise
is followed by periods of pressure
dissipation and of negative pressure
before gradually returning to the am-
bient pressure. The shock wave en-
tering the tissue may be reflected or
dissipated, depending on the prop-
nerties of the tissue. The energy of the
shock wave may act through me-
chanical forces generated directly or
indirectly via cavitation.1

ESWT may be delivered in vari-
ous energy flux densities, measured
in mJ/mm². Lower-energy flux appli-
cation (<0.10 to 0.12 mJ/mm²) is gen-
erally tolerated, with mild to moder-
ate discomfort; high-energy flux
applications (>0.12 mJ/mm²) require
local or regional anesthesia.2 The to-
total amount of energy delivered per
session is determined by multiply-
ing the total flux density by the
number of shock waves delivered.

The frequency of shock wave de-
ivery is another variable in ESWT.
Frequency, which is measured in
hertz, is the number of shock waves
delivered per second. ESWT delivery
devices are capable of delivering a
range of frequencies.

Localizing the delivery of ESWT is
another factor that influences the
outcome of ESWT and makes com-
parison of studies difficult. There are
three commonly used methods of lo-
cализation. The first is anatomic fo-
cusing, in which the wave is directed
at an anatomic location determined
by palpation of the structure, such as
the insertion of the supraspinatus
(supraspinatus tendinosis), the lateral
epicondyle (lateral epicondylitis), or
the medial process of the calcaneal
tuberosity [plantar fasciitis]. The

technician administering this treatment must correctly identify and focus the shock wave. In extremely obese patients or patients with altered anatomy (e.g., a patient who has had surgery in the region), anatomic focusing may be very difficult.

Image-guided focusing, the second method of localization, may be accomplished via guided ultrasound, fluoroscopy, or computed tomography. Fluoroscopic imaging can direct shock waves at specific osseous or calcified structures; ultrasound is also able to direct shock waves at soft-tissue structures, such as an excessively thickened region of the plantar fascia. These methods of focusing allow delivery of shock waves to a very specific area. Unfortunately, the pain-generating area of pathology may not correlate to these anatomic locations. With plantar fasciitis, the pain is often located at the medial calcaneal tuberosity. Using fluoroscopic guidance to focus on that area allows reliable delivery of treatment to the pathologic tissue.

A third method of localization is clinical focusing, in which the shock waves are directed to the most painful area with the aid of patient feedback. This method is the most reliable at directing the shock waves to the painful region. Clinical focusing allows adjustment of the shock wave direction on a patient-by-patient basis. Because of the need for patient input, no anesthetics can be used with this method, a fact that limits the amount of energy that may be delivered through the shock wave. Higher-energy shock waves are poorly tolerated in the absence of anesthesia. Additionally, performing a placebo-controlled, blinded study using clinical focusing is extremely difficult because of the amount of patient feedback required during treatment. To be effective, shock waves must be administered to the correct anatomic location, and sufficient shock wave energy must be delivered to effect the cellular and subcellular histologic, structural, and/or biochemical changes that will improve the patient’s symptoms.

Comparison of studies using different forms of shock wave focusing must be done with the awareness that treatment may have been delivered to different anatomic and pathologic areas. For example, in the case of calcific tendinitis of the supraspinatus, anatomic focusing would direct the shock wave to the insertion of the supraspinatus, image-guided focusing would direct the shock wave to the calcified area, and clinical focusing may focus the energy on yet another area.

Effect on Musculoskeletal Tissue

Application of energy in the form of shock waves affects musculoskeletal tissues in different ways depending on the acoustical impedance of the tissue. The effect of shock waves is most evident at the interface of two materials with different impedance (e.g., bone, tendon). When a shock wave encounters a material with different acoustical impedance, a portion of the energy of the wave is transmitted and a portion is reflected. The ratio of the transmitted energy to reflected energy at the interface varies depending on the properties of the tissues involved. The impulse of the high-pressure shock wave on the material interface may cause tension at this interface. Depending on the physical properties of the material, microstructural changes and cracks may occur.

High-energy ESWT has been used in the field of urology for many years to manage nephrolithiasis. The delivery of shock wave energy to the calculus results in its fragmentation and subsequent dissolution. Application of this modality to musculoskeletal conditions was proposed based on a similar theory that the shock wave energy could cause fragmentation of calcific lesions seen in calcific tendinitis. Most published studies of ESWT report using a low-energy source for managing tendinosis of the supraspinatus, lateral epicondylitis, and plantar fasciitis. Additionally, low-energy ESWT has been used to manage patellar tendinosis, Achilles tendinosis, bone nonunion, medial shin syndrome, and osteonecrosis of the hip.

The exact mechanism of action in the treatment of chronic tendinopathies is unknown. It has been hypothesized that the energy delivered via ESWT could result in increased diffusion of cytokines across vessel walls into the pain-generating region, resulting in resolution of the tendinopathy via the stimulation of angiogenesis and the healing response. In a recent preclinical study in a rat model, shock waves induced neovascularization at the tendon-bone junction, this was confirmed by posttreatment histologic examination and angiogenesis-related markers. This effect appeared to increase through 8 weeks and persist through 12 weeks after shock wave administration.

Other studies have proposed that pain relief obtained from ESWT may be a result of ESWT-induced nerve fiber degeneration, or possibly of hyperstimulation analgesia. The theory of hyperstimulation analgesia involves stimulation of a brain stem feedback loop involving serotonergic activation via the dorsal horn, which exerts a descending inhibitory control of pain signal transmission. Clinical pain relief after shock wave application may be caused by reduced calcitonin gene–related protein expression in the dorsal root ganglion neurons. The exact mechanism of action of shock waves in the management of musculoskeletal conditions is unknown.

In a rabbit model, high-energy shock wave application (0.6 mJ/mm²) caused damage to the tendon and paratenon, including an increase in diameter and fibrinoid necrosis, as well as an inflammatory reaction in the peritendinous area. These changes remained 4 weeks after shock wave application.
wave application. The lower-energy shock waves did not cause tendon damage.\textsuperscript{6,7} Application of higher-energy shock waves (1.2 mJ/mm\textsuperscript{2}) to a calcified turkey gastrocnemius tendon resulted in significant ($P < 0.05$) impairment of tensile strength, while shock waves of 0.6 mJ/mm\textsuperscript{2} had no effect on tensile strength.\textsuperscript{8} These studies demonstrate that high-energy ESWT has the potential to cause injury to tendon, whereas low-energy applications fail to produce the same injury.

ESWT is often used near articular cartilage. In their study of the effect of shock waves on normal rabbit articular cartilage, Vaterlein et al\textsuperscript{9} reported no changes in the cartilage on macroscopic, radiologic, or histologic examination at 0, 3, 12, and 24 weeks after administration of 2,000 pulses of shock waves at 1.2 mJ/mm\textsuperscript{2}. That amount of energy is much higher than is used clinically in any human study. No reports of articular cartilage injury have been reported after ESWT in humans.

### Tendinopathies

Tendinopathies can be painful overuse conditions with the potential for causing chronic limitations of activity. Tendinosis is the noninflammatory intratendinous degeneration that causes a decrease in the mechanical properties of the tendon. Tendon tears may occur in the later stages of the disease. These degenerative processes are associated with collagen fiber disorientation, increased cellularity, and angiofibroblastic degeneration. Many of the current treatment regimens are aimed at reducing an inflammatory response through the use of nonsteroidal anti-inflammatory drugs (NSAIDs) and corticosteroid injections. Recent evaluation of the pathophysiology and histology of tendinosis demonstrates that these disorders are degenerative, not inflammatory. There is a conspicuous absence of inflammatory cells and vascular changes in the areas of maximum involvement, which suggests ineffective vascular supply to the affected region.\textsuperscript{10} These findings indicate that alternative treatments may be more effective. In humans, tendinopathies frequently occur in the common extensors of the elbow (eg, lateral epicondylitis) and at the insertion of the supraspinatus (eg, rotator cuff tendinitis).

### Tendinosis of the Supraspinatus Tendon

The use of ESWT for managing tendinosis of the shoulder has focused on calcific tendinitis of the supraspinatus. Nonsurgical approaches include activity modification, physical therapy, NSAIDs, corticosteroid injections, and ultrasound. Surgery is done when these modalities fail. Numerous case series, nonrandomized controlled trials, and nonplacebo-controlled trials demonstrate clinical improvement with use of both high- and low-energy ESWT in patients with calcific tendinitis of the supraspinatus with dissolution of the calcifications.\textsuperscript{2,11,12} Although limited by their study design, these studies support the use of ESWT in chronic calcific tendinitis of the supraspinatus (Table 1).

ESWT has been compared with other common treatment methods (Table 2). Haake et al\textsuperscript{18} studied the method of delivery of ESWT in a controlled, prospective, randomized trial. Fifty patients were randomized to receive two sessions of 4,000 pulses of ESWT at 0.78 mJ/mm\textsuperscript{2} after receiving local anesthesia. The authors used fluoroscopic guidance to focus the shock waves on either the insertion of the supraspinatus or the calcified area of the rotator cuff. The group whose treatment was directed at the calcified area showed statistically significant ($P < 0.05$) improvement in Constant and Murley scores compared with the group whose treatment was focused on the supraspinatus insertion. Charrin and Noel\textsuperscript{19} evaluated ultrasonic guidance to directly deliver low-energy ESWT impulses to manage calcific tendinitis of the rotator cuff in 32 patients. Fifty-five percent of patients improved at 6 months, but results were less favorable than with computed tomography guidance.

Resorption of calcification after ESWT has been found to correlate with improved outcomes. Patients with complete resorption of calcification after ESWT at 0.60 mJ/mm\textsuperscript{2} had significantly better scores than those with either partial resorption ($P = 0.02$) or with no radiomorphologic changes ($P = 0.0003$).\textsuperscript{20} In their study evaluating radiographic predictors of favorable response to ESWT using magnetic resonance imaging, Maier et al\textsuperscript{12} suggested that the absence of contrast enhancement around the deposit is a strong predictive parameter of a positive response to ESWT. The presence and type of calcification seems to be important in determining whether ESWT will be effective. Noncalcific tendinitis of the supraspinatus has not been successfully managed with ESWT (Table 3).

### Lateral Epicondylitis

Lateral epicondylitis is a painful condition originating from the common extensor origin at the elbow. The pathogenesis generally consists of abnormalities of the extensor origin, most commonly involving the extensor carpi radialis brevis muscle, with resultant microtears and histologic changes of angiofibroblastic hyperplasia. Treatment strategies have been directed at relieving inflammation through rest, activity modification, NSAIDs, splints, or injections. Corticosteroid injection has been proved to have therapeutic value in the short term, with 1-year results equivalent between injection and placebo. Surgery is considered when these nonsurgical measures fail to provide pain relief.

ESWT has been studied as an alternative to surgery for managing lateral epicondylitis, with favorable
results. Several nonrandomized studies and case series have been published, generally with improved symptoms and grip strength as a result of ESWT (Table 4).

Perlick et al\textsuperscript{26} compared ESWT (two sessions of 1,000 impulses of 0.23 mJ/mm\textsuperscript{2}) with surgical treatment consisting of partial resection of the lateral epicondyle and extensor origin in the affected area. Using the Roles and Maudsley pain score, 73\% of patients in the surgical group had good or excellent results, compared with 43\% in the ESWT group. Crowther et al\textsuperscript{27} published a prospective randomized controlled study involving 73 patients who received either corticosteroid injection or ESWT. Patients in the injection group received 20 mg of triamcinolone with 1.5 mL of 1\% lidocaine. Those in the ESWT group received three sessions of 2,000 low-energy shock waves (<0.10 mJ/mm\textsuperscript{2}) per session under ultrasound guidance with no anesthesia. In the ESWT group, 48 of 51 patients completed the protocol, compared with 25 of 42 in the injection group. At 3 months, pain relief as measured on a visual analog scale (VAS\textsubscript{r} range, 1-100) decreased from 67 to 12 in the injection group, and from 61 to 31 in the ESWT group. However, the high rate of refusal in the injection group introduced a notable selection bias.

The amount of pain relief among the patients who received ESWT after failure of corticosteroid injection was consistently higher than the pain relief in patients who had ESWT without prior injections. In trials by Rompe et al\textsuperscript{23} and Decker et al,\textsuperscript{28} 92\% and 100\% of patients, respectively, had been previously injected with corticosteroids for lateral epicondylitis. These studies had long-term failure rates of 10\% and 15\%, respectively. In a study with no prior attempts at corticosteroid in-

Table 1
Extracorporeal Shock Wave Therapy for Calcific Tendinosis of the Supraspinatus

<table>
<thead>
<tr>
<th>Author</th>
<th>Study Design and Focusing</th>
<th>ESWT Protocol</th>
<th>Pretreatment Constant Score</th>
<th>Posttreatment Constant Score (6 mos)</th>
<th>Pain Relief (%)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loew et al\textsuperscript{13}</td>
<td>Randomized parallel case series Fluoroscopic guidance with local anesthetic</td>
<td>Group 1: No treatment Group 2: 2,000 pulses at 0.1 mJ/mm\textsuperscript{2} Group 3: 2,000 pulses at 0.3 mJ/mm\textsuperscript{2} Group 4: Two sessions of 2,000 pulses at 0.3 mJ/mm\textsuperscript{2}</td>
<td>44.5 ± 8.3 39.4 ± 11.2 39.0 ± 11.8 43.5 ± 13.1</td>
<td>47.8 ± 11.4 51.6 ± 20.1 63.7 ± 14.6 68.5 ± 13.1</td>
<td>5 30 60 70</td>
<td>Energy-dependent success, with improved scores and increasing resorption of calcific lesions with more energy</td>
</tr>
<tr>
<td>Cosentino et al\textsuperscript{14}</td>
<td>Single-blind, randomized, placebo-controlled trial Sonographic focusing at calcified lesion</td>
<td>Group 1: Four sessions of 1,200 pulses at 0.00 mJ/mm\textsuperscript{2} Group 2: Four sessions of 1,200 pulses at 0.28 mJ/mm\textsuperscript{2}</td>
<td>48 45</td>
<td>50 71</td>
<td>76 (6 mos) 44 (6 mos)</td>
<td>Significant ((P &lt; 0.001)) improvement in ESWT group Significantly ((P &lt; 0.001)) more calcific resorption in ESWT group than in control group (71% complete or partial versus 0%)</td>
</tr>
<tr>
<td>Gerdesmeyer et al\textsuperscript{15}</td>
<td>Double-blind, randomized, placebo-controlled trial Fluoroscopic focusing on calcific lesions</td>
<td>Group 1: Sham treatment Group 2: 1,500 pulses at 0.32 mJ/mm\textsuperscript{2} Group 3: 6,000 pulses at 0.08 mJ/mm\textsuperscript{2}</td>
<td>64.2 60 62.7</td>
<td>77.9 (12 mos) 91.6 (12 mos) 80.4 (12 mos)</td>
<td></td>
<td>High-energy ESWT had improved results compared with low-energy ESWT. Both were better than placebo</td>
</tr>
</tbody>
</table>

ESWT = extracorporeal shock wave therapy
jection, however, the failure rate was 40% at 3 months.27 The higher rate of failure in patients who have not previously received injection indicates that failure of corticosteroid injection may be a useful factor in selecting patients for ESWT.

There is insufficient evidence in the literature to make a final determination on the role of ESWT in the management of lateral epicondylitis. Although Rompe et al23 reported that three treatments of 1,000 impulses at 0.08 mJ/mm² without anesthesia using anatomic localization is effective in providing notable pain relief, two other studies24,25 indicated that similar treatment protocols of 1,500 to 2,000 low-energy impulses with or without local anesthesia are no more effective than placebo. This suggests that anatomic localization may not be an adequate method for determining the optimal site of application. Failure of corticosteroid injection may be an important and positive predic-

### Table 2

**Extracorporeal Shock Wave Therapy Compared With Other Treatments**

<table>
<thead>
<tr>
<th>Study</th>
<th>Study Design and Focusing</th>
<th>ESWT Protocol</th>
<th>Pretreatment Constant Score</th>
<th>Posttreatment Constant Score (12 mos)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haake et al16</td>
<td>Prospective, randomized, single-blind comparison with 6 × 0.5 Gy x-ray</td>
<td>ESWT group: 2,000 pulses at 0.33 mJ/mm² x-ray group: 6 × 0.5 Gy with cobalt 60 gamma rays (30 pts randomized to either group)</td>
<td>50.1</td>
<td>97.8</td>
<td>No statistically significant differences between the groups</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>47.6</td>
<td>87.4</td>
<td></td>
</tr>
<tr>
<td>Rompe et al2</td>
<td>Prospective quasirandomized comparison with surgical extirpation Fluoroscopic guidance focused on calcification</td>
<td>Surgery group (29 pts): Surgical excision and curettage of calcific lesion ESWT group (50 pts): 3,000 pulses at 0.6 mJ/mm²</td>
<td>18.0 ± 3.4 Homogenous calcifications Inhomogenous calcifications</td>
<td>32 ± 4.1</td>
<td>No significant difference at 1 year, but ESWT had improvement at 2 years Surgery was better with homogenous calcifications, and both groups with inhomogenous calcifications were equal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>17.4 ± 4.7 Homogenous calcifications Inhomogenous calcifications</td>
<td>33.1 ± 3.9</td>
<td></td>
</tr>
<tr>
<td>Pan et al17</td>
<td>Randomized controlled trial Clinical focusing with ultrasonic guidance to most painful area</td>
<td>ESWT group (33 shoulders): Two sessions of 2,000 pulses at 0.26-0.32 mJ/mm² TENS group (30 shoulders): Three sessions weekly for 4 weeks</td>
<td>63.8 ± 14.2</td>
<td>92.1</td>
<td>ESWT is more effective than TENS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>65.7 ± 15.8</td>
<td>77.5</td>
<td></td>
</tr>
</tbody>
</table>

ESWT = extracorporeal shock wave therapy, TENS = transcutaneous electric nerve stimulation

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tive factor in determining a favorable response to ESWT. Further studies are required to answer these questions.

Plantar Fasciitis

Plantar fasciitis, which affects approximately 10% of the US population over the duration of a lifetime, is characterized by pain localized at the origin of the plantar fascia on the calcaneus. This pain is worse in the morning and after prolonged periods of non-use, and it is exacerbated by stretching of the plantar fascia. The pathogenesis is unclear, but the condition may be a result of repetitive overloading causing microtears and degeneration. Treatment protocols for plantar fasciitis include combinations of rest, stretching, NSAIDs, corticosteroid injections, and orthotics or casting. Patients refractory to nonsurgical management are occasionally offered surgical intervention consisting of varying degrees of plantar fascial release.

Several authors have suggested using ESWT to manage plantar fasciitis. Prospective, randomized, placebo-controlled trials of ESWT for treating plantar fasciitis have shown both improvement and no change compared with the placebo group. Rompe et al conducted a prospective, randomized, placebo-controlled trial of patients with chronic plantar fasciitis who had failed nonsurgical therapy for at least 6 months. The authors compared three sessions of 2,000 pulses of ESWT at 0.11 mJ/mm² with sham treatment. The treatment group showed statistically significant improvement at 6 months as measured by the Roles and Maudsley pain score. Similar results were reported in one other prospective trial using ESWT for managing plantar fasciitis. One prospective, randomized, placebo-controlled trial of the running athlete with chronic plantar fasciitis demonstrates benefit with clinically focused ESWT application without anesthesia. All of these studies used image guidance (fluoroscopic or ultrasonic), and none used any form of anesthesia. Image guidance was used to direct the shock wave to the tip of the calcaneal spur, followed by clinical focusing of the shock wave to the area of maximal pain.

Ogden et al published the largest prospective, randomized, placebo-controlled series to date of ESWT in the treatment of plantar fasciitis (302 patients). This study is unique in that it used high-energy shock waves, necessitating regional ankle block anesthesia on all patients, allowing theoretically superior blinding of the patients to the treatment. To be considered successful.

<table>
<thead>
<tr>
<th>Study</th>
<th>Study Design and Focusing</th>
<th>ESWT Protocol</th>
<th>Results</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schmitt et al</td>
<td>Prospective, randomized, placebo-controlled Ultrasound to supraspinatus insertion with local anesthetic</td>
<td>Three sessions of 2,000 pulses at 0.11 mJ/mm²</td>
<td>Pretreatment</td>
<td>Posttreatment (12 wks)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sham treatment ESWT</td>
<td>42.2 ± 13</td>
<td>64.2 ± 25.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>40.7 ± 13.3</td>
<td>60.9 ± 29.6</td>
</tr>
<tr>
<td>Speed et al</td>
<td>Prospective, randomized, double-blind, placebo-controlled Localization followed by clinical focusing to maximal tenderness</td>
<td>Three sessions of 1,500 pulses at 0.12 mJ/mm²</td>
<td>Sham treatment ESWT</td>
<td>Pretreatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>59.5 ± 16.1</td>
<td>58.5 ± 19.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>53.6 ± 20.2</td>
<td>48.7 ± 21.0</td>
</tr>
</tbody>
</table>

ESWT = extracorporeal shock wave therapy
fully treated, the patient was required to meet four criteria: [1] 50% improvement in pain testing with a dolorimeter, [2] 50% improvement over pretreatment VAS pain score, [3] improvement in distance and time walked without pain, and [4] no use of pain medication. Using these criteria, the authors reported that 56% more patients who received treatment had successful results, compared with those in the placebo group. Because of the large difference in the amount of energy delivered through this treatment compared with low-energy shock wave therapy, however, it is not possible to compare this trial with the remainder of the literature.

In a large trial by Buchbinder et al., in which 160 patients completed the treatment protocol, there was no statistically significant difference in any outcome measured between the ESWT and placebo groups. This study was very similar to that of Rompe et al. in regard to the amount and energy of shock waves delivered and the time between treatments. The patients in the two trials also had similar mean duration of symptoms, although the study by Buchbinder included patients experiencing symptoms for as little as 8 weeks, whereas Rompe’s minimum was 6 months. The trial of Buchbinder et al. included patients with plantar heel pain and ultrasonic evidence of plantar fascial thickening. Rompe et al. required pain at the insertion of the plantar fascia on the medial calcaneal tuberosity. These patient populations were not necessarily the same. Although both studies used image guidance for the localization technique, the shock waves were focused on different areas. Rompe et al. focused their shock waves on the tip of the calcaneal spur followed by clinical focusing, while Buchbinder used ultrasound to focus

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### Table 4

#### Extracorporeal Shock Wave Therapy for Lateral Epicondylitis

<table>
<thead>
<tr>
<th>Study</th>
<th>Study Design and Focusing</th>
<th>ESWT protocol</th>
<th>Results</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rompe et al²³</td>
<td>Prospective, randomized, placebo-controlled, Anatomic guidance at lateral epicondyle</td>
<td>Group 1: 3,000 pulses at 0.08 mJ/mm² Group 2: 30 pulses at 0.08 mJ/mm²</td>
<td>Excellent or Good Roles and Maudsley Outcome (24 wks)</td>
<td>Treatment group had decrease in pain on VAS and increase in grip strength compared with sham group</td>
</tr>
<tr>
<td>Haake et al²⁴</td>
<td>Prospective, randomized, placebo-controlled, double-blind, Ultrasonic guidance at muscle insertion at lateral epicondyle with local anesthetic</td>
<td>Group 1: Shielded shock wave treatment (sham) Group 2: Three sessions of 2,000 pulses at 0.07-0.09 mJ/mm²</td>
<td>66/101 69/105</td>
<td>No difference in outcome between groups. Side effects in treatment group included three syncopal episodes and four migraine headaches. None in control group</td>
</tr>
<tr>
<td>Speed et al²⁵</td>
<td>Prospective, randomized, placebo-controlled, double-blind, Ultrasonic guidance to region of interest followed by clinical focusing to most painful area (no anesthetic)</td>
<td>Group 1: Sham treatment Group 2: 1,500 pulses at 0.12/0.18 mJ/mm²</td>
<td>VAS Pain Score (3 mos) 67.2 73.4 51.5 47.9</td>
<td>No added effect of ESWT over placebo. Short follow-up. Higher-energy shock waves used without anesthetic brings into question accuracy of delivery of therapy</td>
</tr>
</tbody>
</table>

ESWT = extracorporeal shock wave therapy, VAS = visual analog scale
the shock waves on the thickest part of the plantar fascia. This difference may be several millimeters, resulting in delivery of shock waves to two very different areas. Maier et al36 reported that a pretherapeutic finding of calcaneal bone marrow edema on magnetic resonance imaging was a good predictor of successful outcomes with ESWT. There was no correlation, however, of thickness of the plantar aponeurosis, soft-tissue signal changes, or soft-tissue contrast uptake to clinical outcomes. This may explain the differences in outcomes in the Rompe and Buchbinder trials. Therefore, because the Buchbinder trial focused on the thickest part of the plantar fascia, it is understandable that the ESWT treatments were not as effective as the treatment aimed at the calcaneal spur.

Although the study of Buchbinder et al37 contradicts the remainder of the literature regarding ESWT in the management of chronic plantar fasciitis, concerns regarding the focusing of shock waves in that trial are difficult to overlook. Based on the preponderance of well-designed studies showing favorable results, it seems that ESWT is an effective modality for managing chronic plantar fasciitis in patients who have failed nonsurgical treatment. Treatment should be directed at the tip of the calcaneal spur or by clinical focusing on the most painful area.

Other Tendinoses

Patellar and Achilles tendinopathies have been less well studied than the three tendinopathies already discussed. Peers et al39 conducted the only study to date that retrospectively compares ESWT with patellar tenotomy and resection of degenerative tissue in patients with patellar tendinosis. The patients presented with symptoms that persisted for at least 6 months despite nonsurgical treatment. Both groups showed improvement after treatment, and no significant differences were noted in the Victorian Institute of Sport Assessment or VAS at 6- and 24-month follow-ups.

Achilles tendinosis was evaluated in a study comparing 2,000 pulses of ESWT at 0.23 ml/mm² with surgical treatment.40 Good and excellent results were seen in 69% and satisfactory results in 15% of the surgical group at 1-year follow-up, compared with good and excellent results in 29% and satisfactory results in 43% of the ESWT group. Because of the paucity of information, no definitive conclusions regarding the indications or expected outcomes of ESWT for either patellar or Achilles tendinosis can be made at this time.

ESWT is a promising method of managing chronic tendinopathies. Alone or in conjunction with other treatment modalities, ESWT may provide pain relief and improved function in many patients who have failed other treatment. Calcific tendinosis of the supraspinatus has been managed effectively with ESWT with minimal side effects. Treatment of noncalcific tendinosis of the supraspinatus by ESWT is no more effective than placebo, however, as shown in two well-designed prospective, randomized, controlled studies, and it cannot be recommended at this time.21,22 The evidence is inconclusive as to the effectiveness of ESWT for managing lateral epicondylitis, but it seems to be effective with clinical focusing in patients with chronic disease who are treated with appropriate energy levels. Several studies have indicated that plantar fasciitis responds to ESWT.

Shock wave therapy is noninvasive, well-tolerated, and relatively inexpensive compared with surgical treatment.27 Because of the multiple variables inherent in ESWT treatment protocols, strict comparisons of published results are problematic. However, there is sufficient information to conclude that ESWT is an appropriate treatment in the right circumstances, such as for calcific tendinosis and plantar fasciitis that have failed nonsurgical management. Further investigation of ESWT in the treatment of chronic tendinopathies is warranted and recommended.

References

Evidence-based Medicine: Evidence-based studies are not in the following references: 15, 16, 21, 22, 24, 25, 27, 32, 34, 35, and 37.

Citation numbers printed in bold type indicate references published within the past 5 years.


