RADIAL EXTRACORPOREAL PRESSURE PULSE THERAPY FOR THE PRIMARY LONG BICIPITAL TENOSYNOVITIS A PROSPECTIVE RANDOMIZED CONTROLLED STUDY

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Abstract—Long bicipital tenosynovitis is regarded as one of the common causes of shoulder pain and dysfunction. The traditional therapeutic approach includes a variety of conservative treatments, but these treatments are not substantiated, owing to the lack of proven clinical efficacy. Radial extracorporeal shock wave therapy (rESWT) uses a pneumatically generated and radially propagating low-energy pressure pulse and has been clinically shown to be a new alternative form of treating refractory soft tissue inflammation. While treating patients suffering from long bicipital tenosynovitis, a randomized, controlled trial was conducted to analyze the effects of radial shock wave therapy on pain and function. Seventy-nine adults with long bicipital tenosynovitis were randomized to receive either active (1500 pulses, 8 Hz, 3 bars) or sham treatment through four sessions that were held once a week. All of these adults were assessed before treatment and at time intervals of 1, 3 and 12 months since the completion of the treatment. The outcomes were measured through the visual analogue scale (VAS) and L’Insalata shoulder questionnaire. Mean VAS in the rESWT group showed significant and sustained reduction from 5.67 ± 1.32 at baseline to 2.58 ± 1.49 at one month, 1.83 ± 1.25 at three months and 1.43 ± 0.94 at 12 months from baseline, whereas the sham group’s mean VAS was 6.04 ± 0.97 before treatment and stabilized at 5.57 ± 0.84 at 12 months. Similar trends were found for the function scores. Mean scores were increased after rESWT from 60.57 ± 6.91 at baseline to 79.85 ± 6.59 at 1 month and 83.44 ± 5.21 at 12 months from baseline. Both pain and function scores showed significant differences between the two groups (p < 0.001). Therefore, we recommend rESWT in treating primary long bicipital tenosynovitis. (E-mail: xinggengyan@hotmail.com) Crown Copyright © 2012 Published by Elsevier Inc. on behalf of World Federation for Ultrasound in Medicine & Biology.

Key Words: Radial extracorporeal shock wave therapy, Tenosynovitis, Biceps tendon, Ultrasonic image.

INTRODUCTION

Bicipital tenosynovitis is one of the most common disorders associated with the shoulder joint and is considered a major cause of frozen shoulder. Long bicipital tendon arises from the supraglenoid tubercle and superior glenoid labrum. The tendon slides obliquely through the joint and arches over the humeral head; the proximal portion is intraarticular but extrasynovial (Churgay 2009; Curtis and Snyder 1993; Erickson et al. 1992). Communicating directly with the glenohumeral joint, the synovial sheath ends in a blind pouch located at the distal end of the bicipital groove (Ptasznik and Hennessy 1995). The tendon sliding in the sulcus intertubercularis humeri is passive. In other words, the tendon slides upward during adduction, internal rotation and extension of the shoulder joint. On the other hand, it slides downward during abduction, extorsion and flexion. The tendon and its sheath are adjacent and closely related to each other. When lesions occur, both are often involved simultaneously. The exact cause or result of the lesions remains controversial (Becker and Cofield 1989; Churgay 2009; Claessens and Snoeck 1972; Crenshaw and Kilgore 1966; Guckel and Nidecker 1998; Krupp et al. 2009). Therefore, bicipital tenosynovitis and tendonitis are two closely associated medical conditions.
Injections of nonsteroidal anti-inflammatory drugs (NSAIDs) and glucocorticoids into the sheath have been considered the most common conservative therapies to treat long bicipital tenosynovitis. NSAIDs produce several side effects, especially in the digestive canal. In a series of 18 cases, DePalma and Callery (1954) treated the isolated bicipital tenosynovitis, reporting an immense improvement in 10 cases. This was achieved using a series of hydrocortisone injections administered directly into the tendon under the transverse humeral ligament. Better results have been reported in 74% cases that used a sheath injection (Kennedy and Willis 1976). However, corticosteroid injections have not been recommended at lesion sites because of the possibility of weakening the tendon. The effect of neovascularization has been studied comprehensively for eccentric training, because it illustrates the effective reduction of revascularizations (Ohberg and Alfredson 2004). Surgical treatment is conducted only when conservative treatment fails. The most striking results of tenodesis include rapid relief of moderate or severe pain for patients. Unfortunately, restoration of motion after surgery often yielded poor results (Crenshaw and Kilgore 1966). Only 50% of the cases exhibited satisfactory results, provided the patients continued with follow-up for approximately 13 years (Becker and Cofield 1989). The recovery period for patients with tenotomy or tenodesis of the long head of the biceps who were operated on using the minimally invasive arthroscopy was still more than three months (Kelly et al. 2005; Klepps et al. 2002).

Since the late 1980s, extracorporeal shock wave therapy (ESWT) has been used successfully in treating various musculoskeletal disorders, including plantar fasciitis, shoulder calcific tendinitis, lateral epicondylitis, nonunion of fractures of long bone, myositis ossificans and adult femoral head necrosis (Buselli et al. 2010; Furia 2006; Gerdesmeyer et al. 2003; Hausdorf et al. 2010; Hsu et al. 2008; Johnson 2003; Speed et al. 2002; Valchanou and Michailov 1991; Wang CJ et al. 2003b, 2009; Wang L et al. 2008). ESWT has been certified as a noninvasive process causing few complications; it is an effective method in treating refractory musculoskeletal disorders.

There are two types of extracorporeal shock waves (ESWs): focused and radial. The focused shock wave is defined as a sequence of single sonic pulses characterized with high peak pressure (100 MPa), a fast pressure rise (<10 ns) and a short duration (10 μs). The devices used generate energy electromagnetically, electropneumatically or piezoelectrically (Lohrer et al. 2010), which is then transmitted to a small region of interest with the maximum energy level developing subcutaneously at a depth of a few centimeters. This type of ESW, guided by X-ray, is most commonly used in treating urinary lithiasis and bone diseases, including nonunion and avascular necrosis of the femoral head. The radial shock wave (RSW), conversely, is pneumatically generated through the acceleration of a projectile inside the handpiece of the treatment device and is radially transmitted from the tip of the applicator to the target zone. The RSW is a pressure pulse, with its maximum energy at the skin surface that is distributed radially into the tissue. The RSW is characterized by a lower peak pressure and a considerably longer rising time than focused shock waves. The RSW can treat an extended volume of tissue, an advantage that is frequently used in treating soft tissue lesions without anesthesia.

Radial extracorporeal shock wave therapy (rESWT) is developed from the ESWT. Since the late 1990s, rESWT has been used successfully to manage the epicondylitis of the elbow and chronic heel pain (Cacchio et al. 2006; Lohrer et al. 2001). rESWT has also shown promising results in the treatment of tenosynovitis, tendonitis and aseptic synovitis at other sites (Chen et al. 2004; Mariotto et al. 2009; Sems et al. 2006; Storheim et al. 2010). To our knowledge, the efficacy of rESWT has not been reported in the treatment of long bicipital tenosynovitis. In this study, we conducted a prospective, randomized controlled study to address the effects of rESWT on long bicipital tenosynovitis.

**PATIENTS AND METHODS**

The Local Ethics Committee approved this prospective clinical study. All patients provided written, informed consent. Details of the procedure and the associated potential risks were discussed in detail before the study.

Between January 2002 and October 2008, 90 patients diagnosed with bicipital tenosynovitis were recruited for this study. Seventy-nine patients were followed up for at least one year. Patients older than 18 y had anterior shoulder pain for at least 6 months. Most patients were manual workers and sports enthusiasts. A significant number of patients were porters, swimmers and ping-pong players. These were people who frequently used their shoulders. Table 1 describes the details of these 79 patients.

During physical examination, bicipital groove point tenderness was noted as the most common, isolated finding. The pain was often confirmed through Yergason’s (Yergason 1931) and Speed’s (Nevisaser 1980) tests. Patients usually complained of hypnalgia and restricted movement in the shoulder. Long bicipital tenosynovitis can be diagnosed, subject to the fulfillment of the above conditions. Exclusion criteria included detectable shoulder disorder (dislocation and subluxation of the tendon, tear and calcification of the rotator cuff, subacromial impingement syndrome, former operation of the treated shoulder), local infections and dermatological...
Patients were numbered 1–90 chronologically according to the time they visited the doctor. A computer-generated random-numbers list was paired with the numbered patients. To get a new sequence, the random-numbers list was reset, beginning from small to large numbers. Patients with numbers 60 or below received the RSW treatment, whereas those with numbers above 60 received the sham treatment. The rESWT group was divided into two subgroups: those who had received previous conservative treatments, and those who had not received any previous treatments. Conservative treatments included analgesics, NSAIDs, physiotherapy and administration of corticosteroid injections into the sheaths. We used the ultrasonic equipment to observe the pathologic changes of tendon and tendon sheath in a more visualized and clear manner. Sonograms of the humerus were obtained in the following different positions: in 10–20° of internal rotation (Middleton et al. 1986; Ptasznik and Hennessy 1995), the elbow flexed and the hand resting gently on the patient’s lap. Ultrasonic images were obtained before performing rESWT using Venue 40 (4 MHz, GE Healthcare, Milwaukee, WI, USA) to identify the most seriously affected tendon and sheath areas. These sites were considered for treating with pressure pulses. In some patients (29/79), ultrasound images revealed that the point of maximum tenderness (blue rectangle) is not the most severe edema site (red rectangle) (Fig. 1). The center of the shock wave head was located to contact the skin on the top of the lesion site (red rectangle). Treatment was conducted with an instrument using a pneumatic RSW generator (Dolorclast, EMS, Nyon, Switzerland). Local anesthesia was not used. In each treatment session, 1500 pressure pulses were irradiated at a repetition frequency of 8 Hz to the rESWT group at the nominal peak pressure set on the rESWT device to 3 bar. In the sham group, the treatment head was deflated to avoid forming pressure pulse in the pathological site, and no coupling gel was applied. The machine makes a noise “bang bang” when each pressure pulse is delivered to enhance the sham design. Once per week, rESWT and sham treatments were given to these patients for 4 sessions. During the study, no other therapy was used.

We used a visual analog scale (VAS) for assessing pain (where 0 indicates no pain, and 10 indicates severe pain). The L’Insalata shoulder questionnaire (L’Insalata et al. 1997) was used to assess the symptoms and functions of the shoulder. Patients were evaluated before treatment and followed up after treatment as outpatients. They were followed up through telephone interviews and e-mail at time intervals of one, three and 12 months post-treatment.

Table 1. Details of the 54 subjects who received rESWT and the 25 given sham treatment

<table>
<thead>
<tr>
<th></th>
<th>rESWT group</th>
<th>Sham group</th>
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<tbody>
<tr>
<td>Gender</td>
<td></td>
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</tr>
<tr>
<td>Male</td>
<td>34</td>
<td>18</td>
</tr>
<tr>
<td>Female</td>
<td>20</td>
<td>7</td>
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<tr>
<td>Age (y), mean (range)</td>
<td></td>
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<td></td>
<td>55.80 (27–79)</td>
<td>54.84 (32–77)</td>
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<tr>
<td>Duration of symptoms in months, mean ± SD (range)</td>
<td>22.4 ± 9.7 (6–46)</td>
<td>18.3 ± 8.3 (7–36)</td>
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<tr>
<td>Previous treatments</td>
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<td>9</td>
</tr>
<tr>
<td>No other treatment</td>
<td>31</td>
<td>16</td>
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All data were expressed in terms of mean ± SD. A p value <0.05 was considered significant. Analysis of variance was performed for comparing the scores before and after treatment. Independent Student’s t-test was used to compare the same time points between the groups. SPSS version 13.0 software (SPSS, Inc., Chicago, IL, USA) was used to perform the data analysis.

RESULTS

Sonomorphologic findings

Ultrasonic examination conducted before the treatment indicated that the fluid in the sheath of the tendon is an abnormal but nonspecific sonographic finding. Fluid collection within the tendon sheath of the long biceps tendon is considered the most common finding (37/79). In such patients, the long biceps tendon is normal or may have slight abnormalities (Fig. 2a). In 32 patients, a diffusely enlarged tendon and fluid collection within the tendon sheath of the long biceps tendon were detected through ultrasound morphologic changes within the tendon itself. The most notable changes included enlargement, irregularity, poorly-defined margins and separation of fibrils. However, no fluid in the sheath was found in 10 cases.

One month after treatment, among the 32 patients who received ultrasound reexaminations in the rESWT group, the tendon and tendon sheath morphology of 27 patients reverted back to a normal state. This was achieved without tendon sheath effusion or tendon swelling. When transverse scanning at the level of the biceps tendon groove was conducted, the biceps tendon appeared in the form of an echogenic ellipse within the groove. Juxtaposed within the humeral head, the tendon was compressed between it. The supra-spinatus portion of the rotator cuff was located posteriorly and superiorly, and the subscapularis was situated inferiorly and anteriorly. Longitudinal sonogram of the biceps tendon indicated that the tendon was a narrow echogenic band between the surface of the humerus and the deep surface of the deltoid (Fig. 2b). Before and after treatment, five other patients did not report any obvious changes in the ultrasound image. In the sham group, 18 patients received an ultrasound re-check. Fifteen patients of this group did not report any significant changes. The condition of three patients within the sham group improved, with a profound decrease in tendon sheath effusion and the tendon swelling area.

Pain

The mean VAS score of the rESWT group was 5.67 ± 1.32 and 6.04 ± 0.97 in the sham group. Statistical analysis did not show any significant difference between the two groups before treatment intervention (p = 0.213). In the rESWT group, the VAS score decreased to 2.58 ± 1.49, 1.83 ± 1.25 and 1.43 ± 0.94 at one month, three months and 12 months post-treatment, respectively. For the rESWT group, improvement after treatment was statistically significant (F = 125.024, p = 0.000). In the sham group, the VAS score persisted at the same high pre-treatment level, and the VAS score remained relatively stable at 5.93 ± 1.03, 5.95 ± 0.81 and 5.57 ± 0.84 at one month, three months and 12 months post-sham treatment, respectively (F = 1.262, p = 0.292) (Fig. 3). A standard for good clinical results is determined by a VAS score <2 or decreased by 4 when compared with the pretreatment score. One year after treatment, 38 patients and 4 patients of the rESWT group met that standard, respectively. The good ratio was 77.8% (42/54). No patient in the sham group met this standard, with 7 patients having serious pain.

The rESWT group was further divided into two subgroups: one that had received previous conservative treatments and one that had not. The VAS score of the
subgroup that had previous conservative treatments decreased from 5.51 ± 1.25 to 2.70 ± 1.21, 2.03 ± 1.30 and 1.41 ± 0.88 at one month, three months and 12 months post-rESWT treatment, respectively. In the subgroup that received no previous conservative treatment, the mean VAS score also decreased from 5.79 ± 1.38 to 2.48 ± 1.67, 1.68 ± 1.21 and 1.44 ± 0.99 at one month, three months and 12 months post-rEWST treatment, respectively (Fig. 4). Both subgroups showed alleviated pain in patients, with no statistically significant difference in VAS scores between the two subgroups.

**Symptoms and functions of the shoulder**

In the rESWT group, the mean score of the L’Insalata shoulder questionnaire was 60.57 ± 6.91 and 58.60 ± 7.04 for the sham group. Statistical analysis did not show any difference between the two groups before the treatment ($p = 0.244$). In the rESWT group, the L’Insalata score increased to 79.85 ± 6.59, 82.50 ± 5.48 and 83.44 ± 5.21 at one month, three months and 12 months post-treatment, respectively ($F = 169.622$, $p = 0.000$). In the sham group, the L’Insalata score was 60.24 ± 5.49, 59.96 ± 5.22 and 64.92 ± 5.00 at one month, three months and 12 months post-treatment, respectively (Fig. 5). Improvement of the symptoms and shoulder functions after treatment was statistically significant in the rESWT group but not in the sham group. The standard for good symptom and function recovery is achieving L’Insalata scores >85 or increased by >20 units when compared with scores before the treatment. After a period of one year, 23 and 19 patients met that standard in the rESWT group, respectively, with their recovery rate being 77.8% (42/54). On the other hand, the sham group had only 3 patients with a function recovery score that exceeded 20. Eight other patients’ L’Insalata scores were worse when compared with their scores before treatment.

The L’Insalata score of patients in the rESWT subgroup who had received previous conservative treatments increased from 58.52 ± 7.12 to 76.87 ± 5.56, 81.22 ± 5.39 and 82.04 ± 5.60 at one month, three months and 12 months post-rEWST treatment, respectively. In the subgroup that received no previous conservative treatment, the L’Insalata score also increased from 62.10 ± 6.44 to 82.06 ± 6.48, 83.45 ± 5.43 and
84.48 ± 4.74 at one month, three months and 12 months post-rESWT treatment, respectively (Fig. 6). Both subgroups showed increased symptoms and functions. After one month, the no-conservative-treatment subgroup did better than the conservative-treatment group \( (p = 0.003) \), with patients showing signs of faster recovery.

**Complications**

The risk of complications associated with rESWT was low. Subdermal hematoma was minor but was an early complication in a number of cases (Loew et al. 1999). We used 3 bars’ pressure in the shoulder, but no hematoma was detected in our patients. Only four patients complained of pain during the treatment. The pain dissipated after the procedure. Two patients developed transitory numbness, and two other patients developed reddening of the skin. This was resolved within 24 h without further intervention. During the 12-month follow-up period, no evidence of necrosis was detected in the humeral head (Liu et al. 2006), and no rotator cuff–related disease was induced by rESWT.

**DISCUSSION**

Tenosynovitis of the long head of the biceps tendon is common, but it rarely occurs in the form of an isolated disease. The bicipital tendon sheath communicates with the shoulder joint cavity and both parts of the long biceps tendon. The horizontal and intertubercular parts may be involved in inflammatory synovial diseases, such as rheumatoid arthritis or adhesive capsulitis. In the most common cases, bicipital tenosynovitis is an associated lesion of the impingement syndrome. Defects or degeneration of the rotator cuff are commonly found at clinical and imaging examinations (Crenshaw and Kilgore 1966; Guckel and Nidecker 1998; Post and Benca 1989). The impingement syndrome is a common cause for soft tissue inflammation of the shoulder, including the tendinitis of the rotator cuff, subacromial bursitis and bicipital tendinitis. If the intrinsic reason of the disease is attributed to sustained impingement, completely curing the disease would be extremely difficult. Most of the patients in this study used their shoulders excessively, with their shoulders undergoing degenerative changes in the tendon. Patients with tearing of the rotator cuff and impingement have been excluded in our study. We therefore recruited only patients who used their shoulders excessively or exhibited tendon degeneration. This is one of the factors we attribute to gaining satisfactory results in this study.

Radial pressure pulse is a pneumatically generated, low-to-medium-energy type of shock wave therapy. In a radial pressure pulse therapy, the focal point is not centered on the target zone, as it would be in the ESWT. Rather, the focal point is on the tip of the applicator. The pressure and the energy density are decreased by the third power of the penetration depth in the tissue. The radial pressure pulse has higher energies concentrated in the superficial tissue, and with the sheath and tendon of biceps just subcutaneous to the force, they are able to receive a stronger energy.

Although there lacks a precise formula to convert between the pressure and the energy flux density (EFD), which are commonly used in generating a focused extracorporeal shock wave, the maximal 4 bars’ pressure of our machine (Swiss Dolor Clast) is about 0.16 mJ/mm² according to the specification and other references. The pressure 3 bars we used is about 0.12 mJ/mm², which is similar to the pressure used in treating other soft tissue disorders such as subacromial shoulder pain (Engebretsen et al. 2011), lateral epicondylitis (Spacc et al. 2005) and plantar fasciitis (Lohrer et al. 2010). Because of its low energy, radial waves have another advantage over focused shockwave, because they cause less pain in the patient and thus can be administered without anesthesia, thereby side effects of the treatment.

Bad symptoms and functions before the treatment intervention may be caused by two main factors. First, serious pain prevents patients from moving their shoulders. Second, patients in this study had anterior shoulder pain for at least 6 months, and some of them also had adhesions around the shoulder joint, which may limit their range of motion. Pain was reduced significantly by about 60%, while improvements in symptoms and functions were relatively small at one month after the pressure
pulse treatment. Pain relief expanded the patients’ range of motion, with improvement in symptom and function. However, the pressure pulse could not release the adhesive joint in some of the patients, which led to lower L’Insalata scores.

In the rESWT group, 12 patients (22.2%) did not show any improvement in pain and function scores, even after being treated for a period extending from one month to one year. This suggests that surgery is unavoidable when the rESWT is not effective.

Changes in clinical assessments in the rESWT group were noticeable the first month after treatment, with changes more difficult to detect in subsequent follow-ups. In the sham group, clinical assessments did not show any significant change in the period extending from one month to one year post-treatment, indicating that long bicipital tenosynovitis did not have any self-healing tendency. Alternatively, the repair effect induced by the pressure pulse may not be permanent.

Whether tendinitis or tenosynovitis of the biceps exists as a separate entity, the course of their natural progression remains a controversial subject. Many studies have focused on biceps tendonitis (Churgay 2009; Neviaser 1980; Post and Benca 1989). Singaraju et al. (2008) also speculate that pain may result from the interaction of the tendon with the surrounding soft tissue, including the tendon sheath, rather than a single entity. We support Crenshaw and Kilgore’s (1966) theory that the sheath is more vulnerable than the tendon. Tenosynovitis is the chief cause of pain in the anterior part of the shoulder during the early stages of disease development. In the acute stage, pathologic changes consist of capillary dilation and cellular infiltration of the sheath and synovium. Pain persists with the progression of the disease, along with the presence of tendon edema and filmy adhesions to its sheath. In the chronic stage, changes consist of fraying and narrowing of the biceps tendon, cystic inclusions, minimum to moderate synovial proliferation and fibrosis, replacement of the tendon fiber with the fibrous tissue and organized dense fibrous adhesions between the tendon and its sheath. During surgery, an examination of the biceps tendon in the groove would confirm these characteristics of tenosynovitis (Neviaser 1980). In our sonographic findings, abnormal sheaths were detected in most cases. Swollen tendon was also common in patients with chronic tenosynovitis.

With the availability of various imaging modalities to examine the shoulder, ultrasound is the most effective because it is fast, safe, inexpensive, widely available, well-tolerated and noninvasive, which would permit more dynamic investigations. Read and Perko (1998) compared 42 consecutive surgical cases with preoperative sonographic readings. They reported 0.95 accuracy, 0.8 sensitivity and 1.0 specificity through ultrasound imaging of longhead biceps tendinitis. Thus, the authors concluded that ultrasound is a sensitive and accurate method to identify patients with biceps tendon pathology. In our study, when comparing “ultrasound image manifestation location” with “maximum tenderness location,” we found that the most painful area was not the most serious site as determined by the ultrasound. We thus believe that the ultrasound image–guided location method is more accurate when compared with the trigger point method. This would ensure that the shock waves concentrate directly on the most seriously affected area.

Cacchio et al. (2006) suggested the use of rESWT in the management of calcific tendinitis of the shoulder as a safe and effective treatment that led to a significant reduction in pain and improvement of shoulder function after four weeks of treatment, without causing any adverse effects. Radial extracorporeal pressure pulse therapy also significantly decreases pain, improves function and increases the quality of life when compared with patients treated with a placebo for recalcitrant plantar fasciitis (Gerdesmeyer et al. 2008). Although another study (Lohrer et al. 2010) compared focused wave with radial pressure pulse using functional measures, focused therapy may be superior to rESWT in plantar fasciitis using the same low-intensity energy flux densities. However, focused shock wave, which is superior to radial wave in the treatment of other diseases, has not yet been shown to be effective in the clinic.

Home-training and local corticosteroid injection is the common modality in treating aseptic inflammation of the soft tissue. In the treatment of the greater trochanter pain syndrome (Rompe et al. 2009), both corticosteroid injection and home training were significantly less successful than RSW therapy during a four-month follow-up period. Corticosteroid injection was significantly less successful when compared with home training or shock wave therapy at the 15-month follow-up. However, another single-blinded, randomized, controlled trial revealed that no significant difference was found between the supervised exercises and rESWT groups treated for subacromial shoulder pain throughout a one-year follow-up (Engebretsen et al. 2011).

Despite its successful clinical application in treating soft tissues pathologies, the exact mechanism of how shock wave induces healing is not completely understood. Several authors propose that its effect can be attributed to the transduction of the acoustic shock wave signal containing a biological signal. Cavitation is associated with mechanical and chemical effects and is believed to be therapeutic. Mechanical alterations are principally caused by shearing effects, whereas the chemical phenomena have been mainly attributed to the development of free radicals (Speed 2004). Many authors have
attributed the stimulation effects from shock wave at the tissue level to the development of mending phenomena, in association with neovascular angiogenesis. This is associated with an increase of RNA-synthetase and a re-balancing of intracellular homeostasis coupled with an increase in nitric oxide (Thiel 2001; Wang et al. 2003a). Rats with collagenase-induced Achilles tendinitis treated with a single shock wave showed that the shock wave treatment resolved edema, swelling and inflammatory cell infiltration into the injured tendons. Tenocytes at the hypertrophied cellular tissue and newly developed tendon tissue express strong proliferating cell nuclear antigen (PCNA) after being subjected to shock wave treatment. This suggests that physical shock waves can increase the mitogenic responses of tendons. Moreover, proliferation of tenocytes adjunct to hypertrophied cell aggregate and newly formed tendon tissue coincided with the intensive transforming growth factor–β1 and insulin-like growth factor–1 expression (Chen et al. 2004). In this study, these physiologic effects may have contributed to the repair of biceps tendon and sheath. Sugiooka et al. (2010) demonstrated the effectiveness of RSWs by introducing NF-kB decoy into tendon cells. RSW treatment combined with local NF-kB decoy administration could be a novel therapeutic strategy for chronic tendinopathy. However, the underlying mechanisms of shock wave therapy has not been explored and requires further investigation.

Wess (2008) suggested that shock wave treatment may reorganize pathologic memory traces, thus providing real and permanent pain relief. Haist and von Keitz-Steeger (1995) postulated three hypotheses about the mechanisms: (i) Shock waves damage cell membranes and nociceptors cannot build up a potential to transmit pain signals; (ii) stimulated by shock waves, nociceptors send a high frequency of impulses, which are suppressed because of gate-controlled mechanism; and (iii) shock wave induced pericellular free radicals to change the chemical milieu such that pain-suppressing substances are released. The above hypotheses explain how shock wave treatment alleviates pain in the shoulder.

**CONCLUSIONS**

When primary pathogenesis like impingement syndrome is excluded, radial shock wave therapy for the primary long bicipital tenosynovitis of the shoulder produces a high rate of success in achieving pain relief and functional restoration. Negligible complications were induced, regardless of whether patients had received previous conservative treatment. Radial pressure pulse could be the preferred method for treating long bicipital tenosynovitis.

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