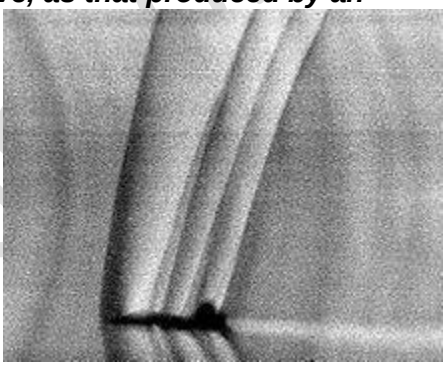
Shock Wave Therapy

Professor Tim Watson
School of Health & Social Work
University of Hertfordshire
E Mail : t.watson@herts.ac.uk
Web Pages : www.electrotherapy.org

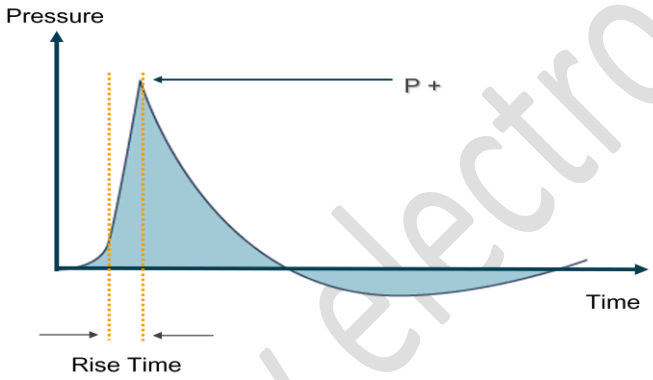
Shockwave - The Essentials

A SHOCKWAVE is essentially a PRESSURE DISTURBANCE that propagates rapidly through a MEDIUM. It can be defined thus : ***A large-amplitude compression wave, as that produced by an explosion or by supersonic motion of a body in a medium*** which just a formal version of the first sentence.



Although the adjacent image is from a plane flying at supersonic speed, it clearly illustrates the principle.

Obvious examples of shock waves are the sonic boom from an aircraft, thunder or the sound following an explosion. A shockwave is, put simply, an acoustic wave, as is a means of transmitting energy.



A clinically useful shockwave is effectively a controlled explosion (Ogden et al 2001), and when it enters the tissues, it will be reflected, refracted, transmitted and dissipated like any other energy form. The energy content of the wave will vary and the propagation of the wave will vary with tissue type. Just like an ultrasound wave, the shock wave consists of a high pressure phase followed by a low pressure (or relaxation) phase. When a shock wave reaches a 'boundary', some of the energy will be reflected and some transmitted.

GENERAL PROFILE OF A SHOCKWAVE (GYMNA UNIPHY)

Shockwave - A Brief History

Shock waves were initially employed as a non invasive treatment for kidney stones (from the early 1970's, with treatment proper starting in the 1980's), and it has become a first line intervention for such conditions. In the process of the animal model experimentation associated with this work, it was identified that shockwaves could have an effect (an adverse one initially) on bone.

This led to a series of experimental investigations looking at the effect of shockwaves on bone, cartilage and associated soft tissues (tendon, ligament, fascia) resulting in what is now becoming an intervention of increasing popularity, most especially for the recalcitrant lesions of these tissues, though the clinical uses are expanding and now include wound management, treatment of fractures and numerous additional applications. The use of shock waves to treat bone problems was researched through the early 1980's. with the earliest clinical work (that I can easily identify) being

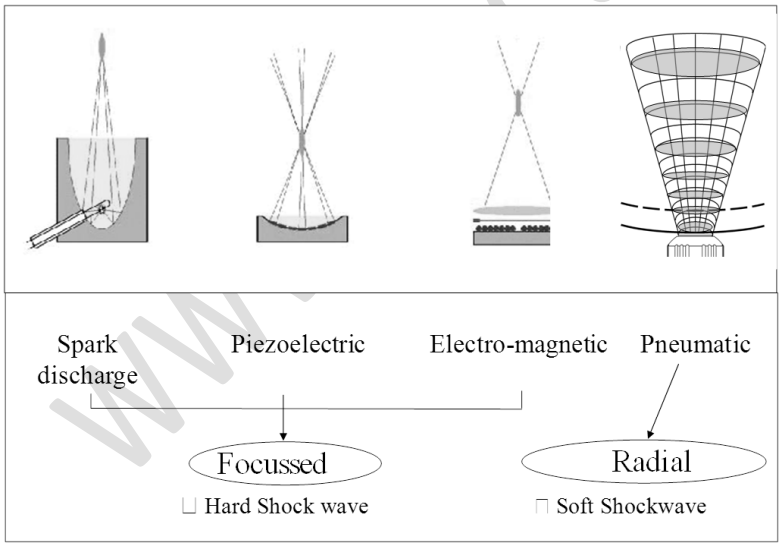
around the middle of that decade on delayed and non unions. By the early 1990's, reports start to appear in the journals and conference papers where shockwave is being employed to deal with soft tissue problems, most commonly calcific tendinitis in the first instance, and then on to a variety of other long term problems in tendon, ligament and similar tissues.

Although becoming much more popular (especially in Europe and to some extent, in the UK), it is still a relatively new technology for musculoskeletal intervention, and although the publication volume is steadily increasing, some of the published trials are of doubtful methodological quality and need to be considered with some caution.

The treatment goes by several names, the most popular being ***SHOCK WAVE THERAPY*** or ***EXTRACORPORAL SHOCKWAVE THERAPY***, though, as ever, there are several variations, often linked to the names of particular machines. Some have recently suggested that the therapy version of shockwave therapy might be usefully called ***RADIAL SHOCKWAVE THERAPY*** to distinguish the nature of the wave from the focused versions employed elsewhere in medical practice. A very readable but succinct history of the development of shock waves for medical applications can be found in Thiel (2001).

Shockwave - Principles of Production

There are basically four different way to produce the 'shock wave', which, without getting technical about it are : spark discharge; piezoelectric; electromagnetic and pneumatic (or electrohydrualic). The wave that is generated will vary in its energy content and also will have different penetration characteristics in human tissue. In therapy the most commonly employed generation method is based on the pneumatic system, and the key reason for this is that a radial (dispersive) wave results. The focussed waves are essential for 'surgical' interventions, but given their destructive nature, they are less appropriate for therapeutic uses. Focussed waves are sometimes also referred to as 'hard' shockwaves, the radial or dispersive wave sometimes called a 'soft' shockwave (another twist in the terminology).



ESSENTIAL SHOCKWAVE PRODUCTION METHODS (AFTER SPECTRUM TECHNOLOGY).

Shockwave - Characteristics

The characteristics of a shock wave are (typically) :

- Peak pressure - typically 50-80MPa (according to Ogden et al, 2001) and 35 - 120MPa (according to Speed, 2004)
- Fast pressure rise (usually less than 10 ns (nanoseconds)
- Short duration (usually about 10 microseconds)
- Narrow effective beam (2-8mm diameter)
  (more detailed descriptions can be found in Ogden et al 2001, Speed, 2004)

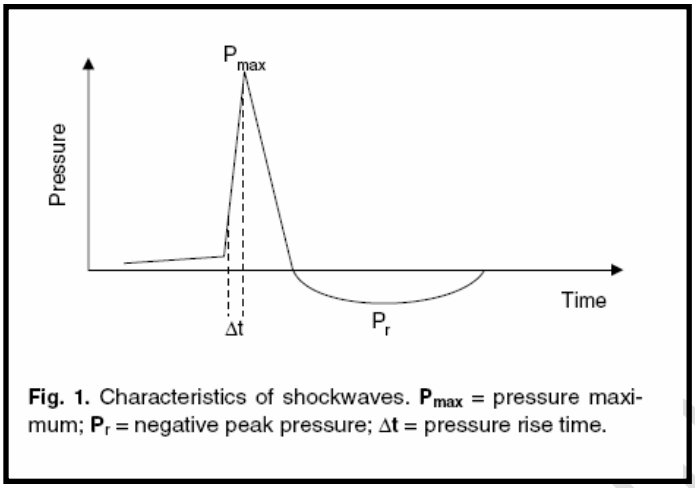


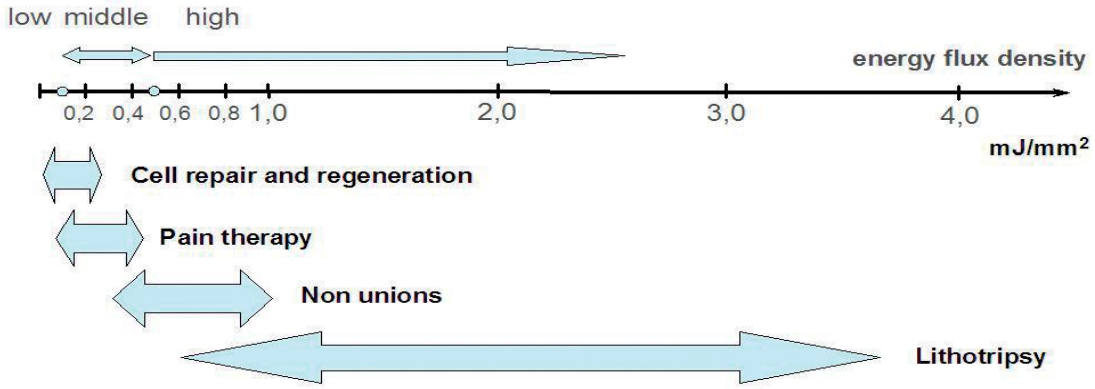
Fig. 1. Characteristics of shockwaves. P_{max} = pressure maximum; P_r = negative peak pressure; Δt = pressure rise time.

SHOCKWAVE CHARACTERISTICS AFTER CHUNG AND WILEY, 2002

Shockwaves are divided in terms of their energy content and although there is some controversy, it is generally accepted that the following groups would be reasonable (after Rompe et al, 1998):

LOW (up to 0.08mJ/mm^2)
MEDIUM (up to 0.28mJ/mm^2 - though some authorities elect for a higher value)
HIGH (over 0.6mJ/mm^2)

Though almost all authors, manufacturers and others divide the range into these energy bands, there is (as yet) no universal agreement with regards the boundary values.



PRINCIPAL ENERGY DIVISIONS FOR SHOCKWAVE USE IN MEDICAL PRACTICE

Shockwave - Physiological Effects and Mechanisms of Action

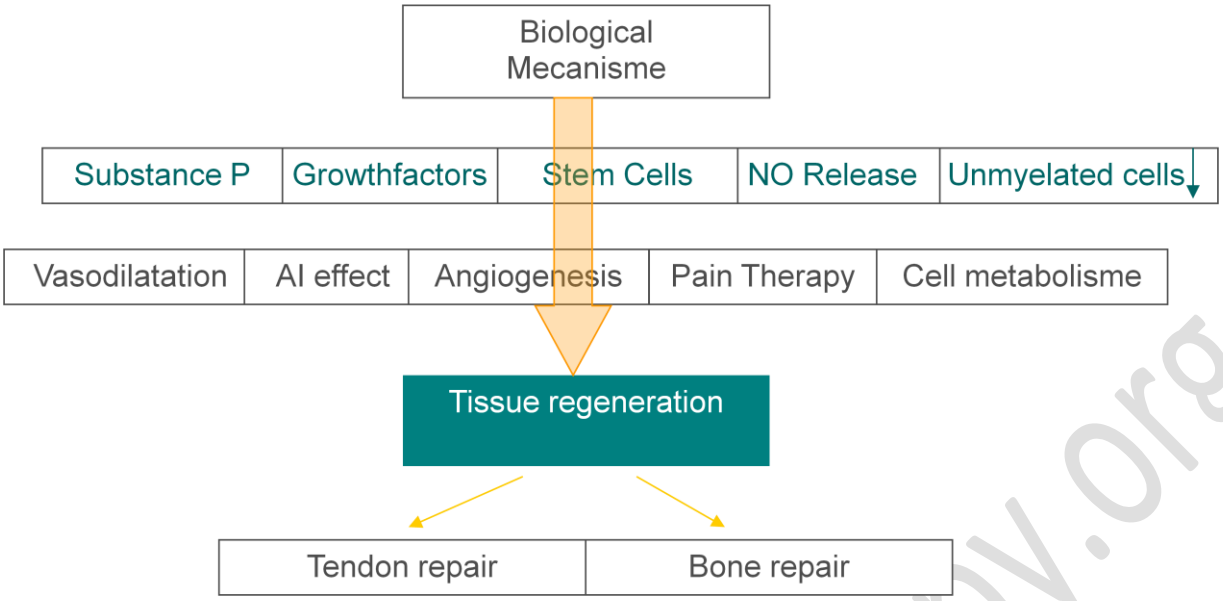
The pressure wave causes direct effects (as one would expect) and also 'indirect' effects associated with the subsequent low pressure part of the cycle (often referred too as the tensile phase), and during this phase, cavitation will occur (as with therapeutic ultrasound). The collapse of these cavitations (bubbles) is in part at least, responsible for the efficacy of the therapy. The waves are focused in order to achieve the effects in a volume limited zone of tissue, though the focus does not actually come to a 'point' in therapy devices - more like a zone or small volume typically several mm across (2 - 8mm), and thus the destructive effects are eliminated. There is no evidence of tissue destructive effects at therapy level doses.

As the shock wave travels through a medium and comes to an interface, part of the wave will be reflected and part transmitted. There are equations around for calculating this proportional relationship, but effectively, the dissipation of the energy at the interface is almost certainly responsible for the generation of the physical, physiological and thus the therapeutic effects.

The full details of physiological and therapeutic mechanisms are yet to be identified, though a range of effects have been confirmed and several others postulated. Some of the effects relate to an increase in local blood flow which has been clearly evidenced, even in relatively avascular tissues. It is suggested that the beneficial effects are partly also due to a stimulation of an inflammatory response – therefore enhancing tissue repair responses, which is especially relevant when dealing with recalcitrant tissues, such as some chronic tendinopathies and delayed and non unions in bone.

One of the strongest arguments for the use of shockwave in therapy is that it effectively takes a Tissue from a more chronic to a more acute state, and in doing so, provides a stimulus (trigger) to a 'stalled' repair sequence. This is actually consistent with other approaches employed in therapy - such as some manual therapies (e.g. transverse frictions), some exercise based approaches (e.g. eccentric loading) and some electrotherapy interventions (e.g. provocative ultrasound or laser treatments). The following are the most strongly established treatment effects at therapy shockwave levels.

- Mechanical stimulation
- Increased local blood flow
- Increase in cellular activity – release of substance P, prostaglandin E2, NO, TGF β, VEGF, and almost certainly other inflammatory cytokines
- Transient analgesic effect on afferent nerves
- Break down calcific deposits (primarily, but not exclusively in tendon)



PROPOSED MECHANISMS HIERARCHY (AFTER GYMNA UNIPHY, 2010)

Energy Levels for Detrimental Effects

High energy shockwave (considered to be over 0.6 mJ/mm2) have been shown to have detrimental effects in soft tissues, though it is proposed that this is not a dose that would normally be employed in therapy, and is likely to require at least some form of local analgesia to be able to tolerate the treatment! There is some evidence that energy densities greater than 0.4 mJ/mm2 may have detrimental effects, though this has yet to be confirmed. In tendon *(using an animal model), shockwave at 0.6 mJ/mm2 was demonstrated to have a damaging effect on local blood vessels (Rompe et al 1998).

Adverse Effects

Provided that the applied energy levels are in the therapy range (LOW and ?possibly MEDIUM), there have been no significant adverse effects reported. Some reports of pain or discomfort during, and sometimes after the treatment, but this usually subsides within a relatively short period (1-2 days). It is worth advising the patient of this possibility when discussing the treatment, prior to application. There can be minor skin irritation, and sometimes numbness or paraesthesia, but all are temporary. The potential for and the incidence of adverse effects is included in the Wang et al (2012) review.

Shockwave - Clinical Applications

[a range of clinical application trials and literature is included in the reference list at the end of this material]

Treatment Dose Issues

- In addition to the applied energy (mJ/mm^2) – in therapy we are using the LOW (up to $0.08mJ/mm^2$) and possibly the MEDIUM (up to $0.28\ mJ/mm^2$) energy levels, the other significant factors are
- a) number of shocks and
- b) number of treatment session repetitions

Shock Number

- Shock number usually between 1000 and 1500, though some authorities suggest up to 2000
- Some research has tried as few as 100 and also 500
- 500 more effective than 100
- 1000 – 1500 have been used in the clinical trials with the best (most significant) outcomes
- Anecdotally, 1000-2000 shocks per session appears to be the most commonly applied range

Number of Treatment Sessions

- Some evidence for a single session BUT only for High level treatment – using local anaesthesia – not physiotherapy
- Most clinical research has used between 3 – 5 sessions at low energy levels (typical therapy application), suggested up to 7 may be needed in the more recalcitrant lesions
- There have been no RCT trials yet to determine the maximally effective therapy session number (or interval)
- Typically 3 - 5 session appears to be effective for the majority of patients, spaced such as to let the tissue 'reaction' at least partly subside from the first session before the next treatment is delivered. Optimal treatment spacing has yet to be identified in the published research evidence.

In terms of specific lesions that have been supported by the research evidence, the tendinopathies are certainly the most frequently reported in the literature, though open wounds and bone union (delayed and non union) problems are also found. Of the chronic and especially recalcitrant tendon lesions, those with strongest research and anecdotal support include :
Plantar fasciitis
Achilles tendinopathy
Patellar tendonipathy
Tennis and Golfers elbow (medial and lateral epicondylalgia)
Biceps tendinopathy
Supraspinatus tendinopathy

Other include trochanteric bursitis, though it is appreciated that this is clearly not a tendinopathy type lesion.

Interestingly, this 'problem' list closely mirrors the clinical presentations identified by Poltawski, Watson and Byrne (2008) as those identified by therapists as being 'highly problematic'.

Shockwave - Research Evidence

The attached reference list identifies a range of research and review papers which have been published. Not all are strongly conclusive, and some of the reviews are less enthusiastic than others - but that largely depends on when the review was carried out, which literature was included, and conversely, which papers were excluded from the review.

The weight of the evidence is more supportive of the intervention than not, with the anecdotal evidence being even stronger. If one were to deliver an evidence based approach to the clinical management of a chronic tendinopathy, it would be difficult to justify the exclusion of shockwave as a therapy. It is not suggested that it is best used instead of other (effective) interventions, but as an adjunct to overall management (see for example the papers by Rompe et al with regards Achilles problems, shockwave and eccentric loading).

Additional references are added as they appear to the www.electrotherapy.org web pages which is a non commercial, non partisan, free/open access internet resource.

Shockwave - Contraindications, Dangers and Precautions

Whilst not intended to constitute a definitive list, there are several areas/pathologies where concern has been expressed with regards the use of shockwave, and until further clarification has been obtained, some of the

key issues are identified below. This list is compiled from the best (currently) available evidence and expert advice/opinion. It may be that this is an over conservative approach, but as with many 'new' or 'emerging' therapies, it is normal to err on the side of caution in the initial stages of clinical application.

- Lung tissue appears to be damaged unequivocally and should be avoided
- The epiphysis has been considered and whilst some experiments demonstrate a detrimental outcome, others do not. Whilst clarification is being obtained, it would make sense to avoid epiphyseal regions
- Patients who are haemophiliac or who are on anticoagulant therapy are best not treated with shockwave given that some visible tissue damage (skin petechiae and disruption of the microvasculature) has been noted in several studies.
- Malignancy remains on the contraindication list, though, as with other modalities, some experimental work is ongoing whereby shockwave therapies are being employed to try and minimise the growth and spread of malignant tissue. Given the unknowns at the moment, it is considered best to avoid such areas.
- Metal implants appear to be OK with regards bone based treatments, but implanted cardiac stents and implanted heart valves have not been fully evaluated. If however, one is avoiding the lungs, then they should not be exposed anyway.
- Infection in the local area should be treated with strong caution given the as yet unknown effect of the therapy in this field.
- Joint replacements - interestingly - come up with a mixed result. Some have used the therapy experimentally as a means to help with the removal of prostheses, making extraction easier. Given this, it would seem wise to avoid cemented implants. On the other hand, it is suggested that several researchers have actually used shockwave as a means to stimulate bone growth around an already lose prosthesis (osseous ingrowth). It would seem prudent to avoid the area given the possible loosening effect which, unless desired, would certainly constitute a detrimental outcome.

References

(2005). "Extracorporeal shock wave treatment for chronic plantar fasciitis." Technol Eval Cent Asses Program Exec Summ 19(18): 1-4.

Albert, J. D. et al. (2007). "High-energy extracorporeal shock-wave therapy for calcifying tendinitis of the rotator cuff: A RANDOMISED TRIAL." J Bone Joint Surg Br 89(3): 335-41.

Alper, B. S. (2007). "Evidence-based medicine. Extracorporeal shock wave therapy appears ineffective for lateral elbow pain." Clinical Advisor 10(3): 181.

Aqil, A. et al. (2013). "Extracorporeal Shock Wave Therapy Is Effective In Treating Chronic Plantar Fasciitis: A Meta-analysis of RCTs." Clinical Orthopaedics and Related Research 471(11): 3645-3652.

Bisset, L. et al. (2005). "A systematic review and meta-analysis of clinical trials on physical interventions for lateral epicondylalgia." Br J Sports Med 39(7): 411-22; discussion 411-22.

Borchers, J. R. and T. M. Best (2006). "Corticosteroid injection compared with extracorporeal shock wave therapy for plantar fasciopathy." Clin J Sport Med 16(5): 452-3.

Buchbinder, R. et al. (2005). "Shock-wave therapy for plantar fasciitis." J Bone Joint Surg Am 87(3): 680-1; author reply 682-4.

Buchbinder, R. et al. (2005). "Shock wave therapy for lateral elbow pain." Cochrane Database Syst Rev(4): CD003524.

Buchbinder, R. et al. (2006). "Systematic review of the efficacy and safety of shock wave therapy for lateral elbow pain." J Rheumatol 33(7): 1351-63.

Buchbinder, R. et al. (2006). "Shock wave therapy for lateral elbow pain." The Cochrane Library 4.

Burton, A. M. and T. J. Overend (2005). "Low-energy extracorporeal shock wave therapy: a critical analysis of the evidence for effectiveness in the treatment of plantar fasciitis." Phys-Ther-Rev. 10(3): 152-62.

Buselli, P. et al (2010). "Shock waves in the treatment of post-traumatic myositis ossificans." Ultrasound Med Biol 36(3): 397-409.

Cacchio, A. et al. (2006). "Effectiveness of radial shock-wave therapy for calcific tendinitis of the shoulder: single-blind, randomized clinical study." Phys-Ther. 86(5): 672-82.

Cacchio, A. et al (2011). "Shockwave Therapy for the Treatment of Chronic Proximal Hamstring Tendinopathy in Professional Athletes." Am J Sports Med 39(1): 146-153.

Chow, I. H. W. and G. L. Y. Cheing (2007). "Comparison of different energy densities of extracorporeal shock wave therapy (ESWT) for the management of chronic heel pain." Clinical Rehabilitation 21(2): 131-41.

Chung, B. et al. (2005). "Long-term effectiveness of extracorporeal shockwave therapy in the treatment of previously untreated lateral epicondylitis." Clin J Sport Med 15(5): 305-12.

Cook, J. (2007). "Eccentric exercise and shock-wave therapy benefit patients with chronic Achilles tendinopathy." Aust J Physiother 53(2): 131.

Costa, M. L. et al. (2005). "Shock wave therapy for chronic Achilles tendon pain: a randomized placebo-controlled trial." Clin Orthop Relat Res 440: 199-204.

Crawford, F. and C. Thomson (2006). "Interventions for treating plantar heel pain." The Cochrane Library 4.

Csaszar, N. B. and C. Schmitz (2013). "Extracorporeal shock wave therapy in musculoskeletal disorders." J Orthop Surg Res 8(1): 22.

Dizon, J. N. et al. (2013). "Effectiveness of extracorporeal shock wave therapy in chronic plantar fasciitis: a meta-analysis." Am J Phys Med Rehabil 92(7): 606-620.

Dorotka, R. et al. (2006). "Location modalities for focused extracorporeal shock wave application in the treatment of chronic plantar fasciitis." Foot Ankle Int 27(11): 943-7.

Foldager, C et al (2012). "Clinical Application of Extracorporeal Shock Wave Therapy in Orthopedics: Focused versus Unfocused Shock Waves." Ultrasound in Medicine & Biology 38(10): 1673-1680.

Fridman, R. et al (2008). "Extracorporeal shockwave therapy for the treatment of Achilles tendinopathies: a prospective study." J Am Podiatr Med Assoc 98(6): 466-468.

Furia, J. F. (2005). "The safety and efficacy of high energy extracorporeal shock wave therapy in active, moderately active, and sedentary patients with chronic plantar fasciitis." Orthopedics 28(7): 685-92.

Furia, J. P. (2005). "Safety and efficacy of extracorporeal shock wave therapy for chronic lateral epicondylitis." Am J Orthop 34(1): 13-9; discussion 19.

Furia, J. P. (2005). "The safety and efficacy of high energy extracorporeal shock wave therapy in active, moderately active, and sedentary patients with chronic plantar fasciitis." Orthopedics 28(7): 685-92.

Furia, J. P. et al. (2013). "A single application of low-energy radial extracorporeal shock wave therapy is effective for the management of chronic patellar tendinopathy." Knee Surgery Sports Traumatology Arthroscopy 21(2): 346-350.

Greve, J. M. et al (2009). "Comparison of radial shockwaves and conventional physiotherapy for treating plantar fasciitis." Clinics (Sao Paulo) 64(2): 97-103.

Griffin, X et al (2012). "Ultrasound and shockwave therapy for acute fractures in adults." Cochrane Database Syst Rev 2: CD008579.

Gur, A. et al. (2013). "Comparison of the Efficacy of Ultrasound and Extracorporeal Shock Wave Therapies in Patients with Myofascial Pain Syndrome: A Randomized Controlled Study." Journal of Musculoskeletal Pain 21(3): 210-216.

Haake, M. and L. Gerdesmeyer (2005). "Fasciitis plantaris. Frequency, symptoms, pathogenesis and therapy." Internistische-Praxis. 45(1): 97-104.

Ho, C. (2007). "Extracorporeal shock wave treatment for chronic lateral epicondylitis (tennis elbow)." Issues Emerg Health Technol(96 (part 2)): 1-4.

Ho, C. (2007). "Extracorporeal shock wave treatment for chronic plantar fasciitis (heel pain)." Issues Emerg Health Technol(96 (part 1)): 1-4.

Ho, C. (2007). "Extracorporeal shock wave treatment for chronic rotator cuff tendonitis (shoulder pain)." Issues Emerg Health Technol(96 (part 3)): 1-4.

Hsu, C. J. et al. (2007). "Extracorporeal shock wave therapy for calcifying tendinitis of the shoulder." J Shoulder Elbow Surg.

Ioppolo, F. et al. (2013). "Clinical Improvement and Resorption of Calcifications in Calcific Tendinitis of the Shoulder After Shock Wave Therapy at 6 Months' Follow-Up: A Systematic Review and Meta-Analysis." Archives of Physical Medicine and Rehabilitation 94(9): 1699-1706.

Iserentant, C. and J. M. Crielaard (2006). "[Extracorporeal shock wave therapy value in calcific soft tissue pathologies]." Rev Med Liege 61(5-6): 341-4.

Kersh, K. D. et al. (2006). "The evaluation of extracorporeal shock wave therapy on collagenase induced superficial digital flexor tendonitis." Vet Comp Orthop Traumatol 19(2): 99-105.

Khan, K. (2005). "Best of the literature. Can shock-wave therapy help relieve 'tennis elbow' pain?" Physician and Sportsmedicine 33(7): 8.

Khan, K. (2005). "Can Shock-Wave Therapy Help Relieve 'Tennis Elbow' Pain?" Physician-Sports-Med. 33(7): 8.

Krasny, C. et al. (2005). "Ultrasound-guided needling combined with shock-wave therapy for the treatment of calcifying tendonitis of the shoulder." Journal of Bone and Joint Surgery 7(36 ref).

Kudo, P. et al. (2006). "Randomized, placebo-controlled, double-blind clinical trial evaluating the treatment of plantar fasciitis with an extracoporeal shockwave therapy (ESWT) device: A North American confirmatory study." J Orthop Res 24(2): 115-123.

Lebrun, C. M. (2005). "Low-dose extracorporeal shock wave therapy for previously untreated lateral epicondylitis." Clin J Sport Med 15(5): 401-2.

Lebrun, C. M. (2005). "Shock-wave treatment for chronic lateral epicondylitis in recreational tennis players." Clin J Sport Med 15(3): 198-9.

Lebrun, C. M. (2006). "Needling combined with shock-wave therapy for calcifying tendonitis of the shoulder." Clin J Sport Med 16(4): 375-6.

Lee, J.-H. and E.-Y. Han (2013). "A Comparison of the Effects of PNF, ESWT, and TPI on Pain and Function of Patients with Myofascial Pain Syndrome." Journal of Physical Therapy Science 25(3): 341-344.

Lee, S. et al. (2014). "Effects of extracorporeal shockwave therapy on patients with chronic low back pain and their dynamic balance ability." J Phys Ther Sci 26(1): 7-10.

Liang, H. W. et al. (2007). "Thinner Plantar Fascia Predicts Decreased Pain After Extracorporeal Shock Wave Therapy." Clin Orthop Relat Res.

Liu, S. et al (2012). "Radial Extracorporeal Pressure Pulse Therapy for the Primary Long Bicipital Tenosynovitis a Prospective Randomized Controlled Study." Ultrasound in Medicine & Biology 38(5): 727-735.

Martinez. M. E. and A. A. Pena (2005). "Treatment of tendinitis and calcified subacromiodeltoid bursitis with shock waves." Rehabilitacion. 39(1): 2-7.

Marwan, Y. et al. (2014). "Extracorporeal shock wave therapy relieved pain in patients with coccydynia: a report of two cases." Spine Journal 14(1): e1-e4.

Moretti, B. et al. (2005). "Medium-energy shock wave therapy in the treatment of rotator cuff calcifying tendinitis." Knee Surg Sports Traumatol Arthrosc 13(5): 405-10.

Moretti, B. et al. (2006). "Extracorporeal shock wave therapy in runners with a symptomatic heel spur." Knee Surg Sports Traumatol Arthrosc 14(10): 1029-32.

Moretti, B. et al (2009). "Shock waves in the treatment of stress fractures." Ultrasound Med Biol 35(6): 1042-1049.

Moretti, B. et al (2009). "A volleyball player with bilateral knee osteochondritis dissecans treated with extracorporeal shock wave therapy." Chir Organi Mov 93(1): 37-41.

Mouzopoulos, G. et al. (2007). "Extracorporeal shock wave treatment for shoulder calcific tendonitis: a systematic review." Skeletal Radiol.

NICE (2009). Extracorporeal shockwave therapy for refractory Achilles tendinopathy. Interventional Procedure Guidance. London, NICE. Interventional procedure guidance 312.

NICE (2009). Extracorporeal shockwave therapy for refractory plantar fasciitis. Interventional Procedure Guidance. London, NICE. Interventional procedure guidance 311.

NICE (2009). Extracorporeal shockwave therapy for refractory tennis elbow. Interventional Procedure Guidance. London, NICE. Interventional procedure guidance 313.

Norris, D. M. et al. (2005). "Effectiveness of extracorporeal shockwave treatment in 353 patients with chronic plantar fasciitis." J Am Podiatr Med Assoc 95(6): 517-24.

Notarnicola, A. et al (2010). "Shockwave therapy in the management of complex regional pain syndrome in medial femoral condyle of the knee." Ultrasound Med Biol 36(6): 874-879.

Pettrone, F. A. and B. R. McCall (2005). "Extracorporeal shock wave therapy without local anesthesia for chronic lateral epicondylitis." Journal of Bone and Joint Surgery 304(19 ref).

Qin, L. et al (2010). "Osteogenesis induced by extracorporeal shockwave in treatment of delayed osteotendinous junction healing." J Orthop Res 28(1): 70-76.

Radwan, Y. A. et al. (2007). "Resistant tennis elbow: shock-wave therapy versus percutaneous tenotomy." Int Orthop.

Rasmussen, S.et al (2008). "Shockwave therapy for chronic Achilles tendinopathy: a double-blind, randomized clinical trial of efficacy." Acta Orthop 79(2): 249-256.

Reznik, J. E. et al. (2013). "Extracorporeal shock wave therapy as a treatment for heterotopic ossification." Physical Therapy Reviews 18(4): 300-307.

Roehrig, G. J. et al. (2005). "The role of extracorporeal shock wave on plantar fasciitis." Foot Ankle Clin 10(4): 699-712, ix.

Romeo, P. et al (2011). "Extracorporeal shock wave therapy in pillar pain after carpal tunnel release: a preliminary study." Ultrasound Med Biol 37(10): 1603-1608.

Romeo, P. et al. (2014). "Extracorporeal Shock Wave Therapy in Musculoskeletal Disorders: A Review." Medical Principles and Practice 23(1): 7-13.

Rompe, J. D. et al. (2005). "Repetitive low-energy shock wave application without local anesthesia is more efficient than repetitive low-energy shock wave application with local anesthesia in the treatment of chronic plantar fasciitis." J Orthop Res 23(4): 931-41.

Rompe, J. D. (2005). "Shock-wave therapy for plantar fasciitis." J Bone Joint Surg Am 87(3): 681-2; author reply 682-3.

Rompe, J. D. (2005). "Effectiveness of extracorporeal shock wave therapy in the management of tennis elbow." Am J Sports Med 33(3): 461-2; author reply 462-3.

Rompe, J. D. (2006). "Shock wave therapy for chronic Achilles tendon pain: a randomized placebo-controlled trial." Clin Orthop Relat Res 445: 276-7; author reply 277.

Rompe, J. D. (2007). "Repetitive low-energy shock wave treatment is effective for chronic symptomatic plantar fasciitis." Knee Surg Sports Traumatol Arthrosc 15(1): 107; author reply 108.

Rompe, J. D. et al. (2007). "Shock wave therapy for chronic plantar fasciopathy." Br Med Bull.

Rompe, J. D. et al. (2007). "Eccentric loading, shock-wave treatment, or a wait-and-see policy for tendinopathy of the main body of tendo Achillis: a randomized controlled trial." Am J Sports Med 35(3): 374-83.

Rompe, J. D.et al (2008). "Eccentric loading compared with shock wave treatment for chronic insertional achilles tendinopathy. A randomized, controlled trial." J Bone Joint Surg Am 90(1): 52-61.

Rompe, J. D. et al (2009). "Eccentric loading versus eccentric loading plus shock-wave treatment for midportion achilles tendinopathy: a randomized controlled trial." Am J Sports Med 37(3): 463-470.

Rompe, J. D. et al (2009). "Home training, local corticosteroid injection, or radial shock wave therapy for greater trochanter pain syndrome." Am J Sports Med 37(10): 1981-1990.

Rompe, J. D.et al (2010). "Low-energy extracorporeal shock wave therapy as a treatment for medial tibial stress syndrome." Am J Sports Med 38(1): 125-132.

Sabeti, M. et al. (2007). "A comparison of two different treatments with navigated extracorporeal shock-wave therapy for calcifying tendinitis - a randomized controlled trial." Wien Klin Wochenschr 119(3-4): 124-8.

Sabeti-Aschraf, M. et al. (2005). "Extracorporeal shock wave therapy in the treatment of calcific tendinitis of the rotator cuff." Am J Sports Med 33(9): 1365-8.

Sarkar, B. et al. (2013). "Efficacy of low-energy extracorporeal shockwave therapy and a supervised clinical exercise protocol for the treatment of chronic lateral epicondylitis: A randomised controlled study." Hong Kong Physiotherapy Journal 31(1): 19-24.

Saw, A. (2005). "Extracorporeal shock wave therapy for musculoskeletal pathology--a literature review." Med J Malaysia 60 Suppl C: 8-10.

Schmitz, C. and R. Depace (2009). "Pain relief by extracorporeal shockwave therapy: an update on the current understanding." Urological Research 37(4): 231-234.

Schmitz, C. et al. (2013). "Treatment of chronic plantar fasciopathy with extracorporeal shock waves (review)." J Orthop Surg Res 8(1): 31.

Seco, J. et al (2011). "The efficacy, safety, effectiveness, and cost-effectiveness of ultrasound and shock wave therapies for low back pain: a systematic review." Spine J 11(10): 966-977.

Seil, R. et al. (2006). "Extracorporeal shock wave therapy for tendinopathies." Expert Rev Med Devices 3(4): 463-70.

Sems, A. et al. (2006). "Extracorporeal shock wave therapy in the treatment of chronic tendinopathies." J Am Acad Orthop Surg 14(4): 195-204.

Seok, H. and S. H. Kim (2013). "The effectiveness of extracorporeal shock wave therapy vs. local steroid injection for management of carpal tunnel syndrome: a randomized controlled trial." Am J Phys Med Rehabil 92(4): 327-334.

Spacca, G. et al. (2005). "Radial shock wave therapy for lateral epicondylitis: a prospective randomised controlled single-blind study." Eura Medicophys 41(1): 17-25.

Stasinopoulous, D. and M. I. Johnson (2005). "Effectiveness of extracorporeal shock wave therapy for tennis elbow (lateral epicondylitis)." British Journal of Sports Medicine 39(3): 132-6.

Taki, M. et al. (2007). "Extracorporeal shock wave therapy for resistant stress fracture in athletes: a report of 5 cases." Am J Sports Med 35(7): 1188-92.

Thomson, C. E. et al. (2005). "The effectiveness of extra corporeal shock wave therapy for plantar heel pain: a systematic review and meta-analysis." BMC Musculoskelet Disord 6: 19.

Trebinjac, S. et al. (2005). "Extracorporeal shock wave therapy in orthopaedic diseases." Bosn J Basic Med Sci 5(2): 27-32.

van der Worp, H. et al. (2013). "ESWT for tendinopathy: technology and clinical implications." Knee Surgery Sports Traumatology Arthroscopy 21(6): 1451-1458.

van Leeuwen, M. T., J. Zwerver and I. van den Akker-Scheek (2009). "Extracorporeal shockwave therapy for patellar tendinopathy: a review of the literature." Br J Sports Med 43(3): 163-168.

Vetrano, M. et al. (2013). "Platelet-Rich Plasma Versus Focused Shock Waves in the Treatment of Jumper's Knee in Athletes." Am J Sports Med 41(4): 795-803.

Vulpiani, M. C. et al (2009). "Extracorporeal shockwave therapy (ESWT) in Achilles tendinopathy. A long-term follow-up observational study." J Sports Med Phys Fitness 49(2): 171-176.

Wang, C. et al. (2006). "Long-term results of extracorporeal shockwave treatment for plantar fasciitis." American Journal of Sports Medicine 34(4): 592-6.

Wang, C. J. et al. (2007). "Extracorporeal shockwave for chronic patellar tendinopathy." Am J Sports Med 35(6): 972-8.

Wang, C. J. et al. (2007). "The effects of extracorporeal shockwave on acute high-energy long bone fractures of the lower extremity." Arch Orthop Trauma Surg 127(2): 137-42.

Wang, C. J. et al. (2007). "Treatment of osteonecrosis of the hip: comparison of extracorporeal shockwave with shockwave and alendronate." Arch Orthop Trauma Surg.

Wang, C. J. et al. (2005). "The effect of shock wave treatment at the tendon-bone interface-an histomorphological and biomechanical study in rabbits." J Orthop Res 23(2): 274-80.

Wang, C. J. (2009). "The effects of shockwave on bone healing and systemic concentrations of nitric oxide (NO), TGF-beta1, VEGF and BMP-2 in long bone non-unions." Nitric Oxide 20(4): 298-303.

Wang, C.-J. (2012). "Extracorporeal shockwave therapy in musculoskeletal disorders." Journal of Orthopaedic Surgery and Research 7(1): 11.

Wang, L. et al. (2008). "Extracorporeal shock wave therapy in treatment of delayed bone-tendon healing." Am J Sports Med 36(2): 340-7.

Wood, W. et al. (2006). "Lateral epicondylalgia: an overview." Physical Therapy Reviews 11(3): 155-60.

Yalcin, E. et al. (2012). "Effects of extracorporal shock wave therapy on symptomatic heel spurs: a correlation between clinical outcome and radiologic changes." Rheumatol Int 32(2): 343-347.

Zhu, F. et al. (2005). "Chronic plantar fasciitis: acute changes in the heel after extracorporeal high-energy shock wave therapy--observations at MR imaging." Radiology 234(1): 206-10.

Zwerver, J. et al (2011). "No effect of extracorporeal shockwave therapy on patellar tendinopathy in jumping athletes during the competitive season: a randomized clinical trial." Am J Sports Med 39(6): 1191-1199.