CENTRO DE TRAUMATOLOGIA, ORTOPEDIA Y MIROCIRUGIA ARTICULAR, S.C.

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Extracorporeal Shock Wave Therapy (ESWT) in Orthopaedics and Traumatology

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1 ESWT, the powerful approach to musculoskeletal diseases

Extracorporeally generated shock waves were first used for kidney stone fragmentation in the early eighties. The treatment modality revolutionized urological stone management and developed into today's method of choice. Since the mid nineties shock waves are also used for several kinds of musculoskeletal applications such as tennis elbow, calcified shoulder, heel spur and nonunions.

Analgesic effects as well as healing effects due to enhanced metabolism, circulation and revascularization are reported. Astonishingly, significant improvements up to complete reduction of pain even in chronic complaints and stable reunion of non-unions are gained. Using basically the same technology as for Stone fragmentation, extracorporeal shock wave therapy (ESWT) stands for shock wave application in general, with a specific impact on orthopaedic indications, both, non-unions and tendopathies as well as others.

Even in sports medicine ESWT becomes a valuable new therapeutic treatment modality. In 1996, for the first time, an orthopaedic shock wave device was used by the German team during the Olympics in Atlanta. Instead of Stone disintegration it was applied to several types of tendopathies and persistent close to bone soft tissue pain. Again at the World Cup 1998 in France, three of the participating teams including the winner France made use of shock wave machines (MINILITH SL1, STORZ MEDICAL AG, Switzerland) to keep the athletes on their top performance level on time. Today several sports teams make use of ESWT on a regular basis.

2 Shock waves for medicinal use

Shock waves in medicine are focussed high pressure acoustical waves of very short time duration. They are transmitted through soft tissue without major losses and reflected at interfaces of different organs. Shock waves are pulsed acoustic waves characterized by short time duration (< 1 microsecond) very high pressure amplitudes of several 10 - 100 MPa (100 -1000 bar) and relatively low tensile wave components (approx.

10% of maximum pressure). Shock waves are generated outside the human body in water and transmitted widely spread over a large skin transmission area onto the target region where the acoustic energy is concentrated to a focal area of 2.8 mm in diameter. Modern ESWT devices make use of coupling cushions instead of an open water bath to couple the shock waves into the body without significant losses. Targeting of the treatment region is done either by an isocentrically attached co-axial ultraound transducer or by a flouroscopic localization device such as mobile C-arms. Treatment of the affected tissue region is done by a sequence of 1000 a 4000 shock wave pulses fired with a repetition frequency of 1.4 pulses per second. The whole treatment lasts 15 a 30 minutes and is usually performed without or under consumption of very little local anaesthetic drugs.

3 Shock wave generation Technology

Within the last two decades several different methods of shock wave generation have been developed. There is no question, that electrohydraulic, piezo-electric and electro-magnetic techniques can generate shock waves for medicinal applications. There are technical benefits and some disadvantages of the accordingly generated shock

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waves, however, there is no "magic" feature which would qualify only one of the systems being effective. Possible differences in rise time of pressure increase are washed out by passing through living tissue, thus being of no relevance with respect to efficacy of the specific modality. Nevertheless, significant technical differences make certain systems more favourable than others.

3.1 Electro-hydraulic. Elipsoidal reflector, the historic method

The electro-hydraulic principle makes use of a spark plug like electrode configuration. A rapidly expanding plasma bubble heated by the spark channel repels the surrounding water volume. The thereby developing spherical shock wave is focussed by aid of a semi rotational elipsoidal reflector. The first kidney stone lithotripter was based on this historic principle, first invented for soft tissue treatment 50 years ago (Fig. 1). This type of shock wave generator is still in use, however, it features some significant drawbacks compared to modern shock wave devices such as costly wear of electrodes, extraordinary noise level, non-uniform energy delivery etc.

3.2 Electro magnetic cylinder – parabolic reflector, present state of the art

The state of the art configuration of a shock wave device utilizes a cylindrical coil arrangement of an electrmagnetic generator with a parabolic reflector (Fig. 2). The cylindrical coil system provides significant improvements over flat coil arrangements with lens focussing. The cylindrical wave front is focussed virtually without energy loss by a rotational parabolic reflector.

Simultaneously, it provides the appropriate space on the central axis for implementation of either inline X-ray localization or inline ultrasound transducers.

Whatever technique of shock wave generation is used, to date, shock waves are always generated outside the human body, transmitted via a large skin area and concentrated by means of focussing reflectors to the area of interest within the selected tissue. In order to target the energy precisely to the desired location, imaging devices (ultrasound and/or X-ray) are used. The most precise method utilizes co-axially arranged (inline) configurationsof imaging modalities and shock wave devices.

Offline configurations (transducer outside the shock wave application head) suffer from reduced accuracy due to different tissue to be passed by shock waves and imaging energies.

Due to the technical benefits such as power, reproducibility, dynamic range and lifetime the electro-magnetic principle and i.e. the electromagnetic cylinder source with a parabolic reflector becomes more and more standard in high quality ESWT devices because of the additional benefit of inline localization features as discussed below.

4 Orthopaedic shock wave Devices

Although side effects of ESWT are usually negligible high energy shock waves may cause harm to certain organs if not applied properly. Precise targeting and avoiding critical tissue are mandatory. Apart from certain other organs especially lung tissue is sensitive to potential shock wave lesions and bony tissue may obstruct shock wave propagation. ESWT devices, therefore, require some kind of localization modality such as ultrasound and/or X-ray in order to clearly control the shock wave propagation pathway through the human body. Different device configuration are commercially offered wirh online or offline arrangements of shock wave applicator and localization modality.

A second tool to increase therapeutic shock wave efficiency is to concentrate the shock wave energy to a well confined treatment area and keeping the energy density as low as possible anywhere else.

This simple but efficient idea simultaneously reduces potential side effects. Technically, the goal is to use large aperture angels of the focussing device which also provide high energy concentration (therapeutic effect) and low energy density (low pain and tissue lesions) in the coupling area and anywhere else.

Due to the large variety of indications, the shock wave applicator needs to be coupled to a number of distinct areas of the human body from top to toe. This requires a high degree of mechanical flexibility of the shock wave head which usually cannot be provided by ordinary lithotripsy machines for urinary stone fragmentation.

Several companies developed specific orthopaedic devices with a flexible support of the shock wave head with or without inline ultrasound or X-ray argeting configurations.

Modern ESWT devices have all the beneficial features required by the specific needs of musculoskeletal indications. The latest generation also offers sufficient power and penetration depth up to 15 cm to fragmentize all kinds of human calculi. Such interdisciplinary devices as for example the MODULITH SLK Storz Medical, Switzerland (Fig 3.) contribute to significant cost reduction due to multiple use in different medicinal specialties.

5 Medicinal aspects

After its introduction in 1994, more than 100’000 shock wave treatments were successfully performed on various indications. Approximately 70 to 80% of the treated patients gained significant improvements of their complaints although - and this is worth to mention – their chronic disease was unsuccessfully treated before by several conservative treatment methods. Many thousands of patients could thus be released from their complaints without open surgery which would have been the next available treatment choice, also promising a limited success rate only.

Apart from treating chronic diseases after several months and years of frustrane conservative treatment approaches an interesting subgroup of indications is identified within sports medicine.

Top athletes need to be fit on time and do not like to undergo time consuming conservative herapies unless absolutely required. ESWT offers a simple, fast and effective therapeutic procedure which allows continuation of sports activities usually the following day after treatment. ESWT is a non-invasive therapy without significant side effects. Often immediate pain relief and muscle relaxation enables continuation of training and participation in sports events.

The situation for other than top athletes turned out to be different. Since some of the below listed indications may be successfully treated by conservative measures such as injections, massages etc. at lower costs the shock wave treatment was only applied after frustrane treatments (minimum 6 month) by conservative methods. Such persistent chronic pain indications feature the negative and most difficult selection of patients only suitable for open surgery. Even surgical methods promise an improvement in only 70 to 80% of the patients. Extracorporeal shock wave treatments are successful in a similar percentage of patients with the extraordinary advantage of being completely non-invasive.

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Most important also is the fact that patients may continue to work as usual the following day. Taking into account the significant reduction of the inability to work and the short headling time not only compared to open surgery, ESWT is generally cheaper tan several months of conservative treatment efforts.

6 Indication Range

The therapeutic potential of ESWT is by far not yet fully known. The working mechanism is still under discussion. Improvement of circulation and metabolism seems to be one of the most stringent mechanism responsible for muscle relaxation, pain reduction and enhanced heeling processes in case of non-unions.
The following four indications are considered well established due to thousands of successful treatments all over the world.

• Non-unions
• Tendinosis calcarea
• Plantar and dorsal heel spur
• Tennis elbow

All those indications are successfully treated by ESWT predominately in chronic stage. This does not mean that treatment in the acute phase will be less efficient. However, simple conservative treatment strategies may gain equally good results at lower costs. For financial reasons doctors restrict themselves to use ESWT only for the previously frustrane treated chronic diseases.Further indications such as hip necrosis and others are under investigation. Preliminary results are promising.

7 Financial Aspects

Due to the high success rate and the almost complete lack of side effects ESWT became a frequently used treatment alternative for tennis elbow, heel spur, tendinosis calcarea and others. Surprisingly, this seems to be the reason for preventing a wide acceptance of the method in some countries. In spite of all over excellent medicinal success, published in several hundreds of papers, statistically proven evidence supported by prospective double blind studies is still lacking.

Several studies are currently performed and FDA approval for several different indications is pending in the US. Interestingly, most of all other accepted conservative and reimbursed medicinal procedures are also lacking statistically proven evidence. At the first glance, ESWT seems to be costly due to expensive technical equipment.

In times of lack of financial resources and cost explosion in medicinal care, this is an extremely sensitive issue. Whenever a fixed amount of money is shifted from one medicinal speciality to another concerns and growing suspicion of the affected medicinal group and health care authorities are generated. Taking into account not only reimbursement costs of public health care systems, but all recovery costs including convalescence time, the financial benefit is obvious.

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8 Conclusion

ESWT has proven to be a new and very effective treatment modality based on the shock wave technology established since 20 years in urological stone therapy. In addition to its fragmentation power shock waves turned out to provide significant therapeutic effects in various musculoskeletal diseases. There is no doubt about final acceptance of this technology by the medicinal community even if financial restrictions and inertia of health care systems presently prevent ESWT from being as well accepted as it deserves to be.

Focus
Shock wave therapy
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Orthopedic trigger point shock wave therapy with focused and radial shock waves: a review of the current situation

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Introduction

Myofascial pain syndromes are among the most frequent orthopedic disorders. However, efforts to treat these syndromes often show limited success. This is confirmed by the multitude of competing therapy options available today.

According to the theory established by *Travell* and *Simons* in their Trigger Point Manual (1992), muscular trigger points are one of the main causes of myofascial pain. Clinical observations and experimental examinations conducted by *Travell* and *Simons* have corroborated this theory, demonstrating that muscular trigger points cause diverse functional disorders. These findings coincide with the information provided by patients on pain development and progression. Despite the impressively detailed description of muscle-associated pain syndromes in the Trigger Point Manual (1992), trigger point therapy is still only rarely used in orthopedic practice.
The role of trigger points in causing pain and discomfort is evidenced by the clinical symptoms they may generate: formation of muscle knots with local and referred pain, muscular taut bands, twitch response, reduced range of motion (ROM) of joints, formation of satellite trigger points, development of pseudoradicular dysesthesia and vegetative accompanying reactions.

According to *Simons'* "integrated hypothesis of trigger point formation" (1996), trigger points are produced by muscular motor end-plate dysfunction which may be caused by various mechanisms, such as acute mechanical overstrain, including trauma, chronic overstrain caused by monotony of motion (repetitive strain injury), poor posture, cold, emotional distress, or result from articular, neurogenic, visceral, hormonal or remote muscular disorders.

The increased calcium release resulting from the above lesions causes a permanent contracture of the actin/myosin filaments (abnormally contracted sarcomeres) under the dysfunctional end-plate and thus leads to increased energy consumption. At the same time, the capillary compression caused by the contraction knots produces local ischemia. The concurrence of these two factors causes a local energy crisis. Local ischemia induces the release of bradykinine in the tissue and of other substances sensitizing muscle nociceptors and increases the tenderness to pressure of the trigger points (allodynia, hyperalgesia). Ischemia causes additional motor end-plate dysfunction and thus creates a vicious circle.

Muscles affected by trigger points exhibit changed properties. Apart from the typical contractures, these muscles are characterized by a reduced development of muscular force, delayed relaxation after activity, tendency to spasm and decreased fine motor skills (coordination). These conditions explain the muscles' susceptibility to additional lesions (muscle strain, torn fibers, etc.).

Trigger points cause alterations in the nervous system that contribute to the chronification of pain. These alterations include peripheral sensitization of muscle nociceptors, increased number of nociceptors, activation of the axon reflex, central sensitization (synaptic transmission) and failure of inhibiting interneurons of the supraspinal descending antinociceptive system (8).

If trigger points continue to exist over a prolonged period of time, they may activate satellite trigger points in other muscles. These satellite trigger points will develop their own pain patterns and functional disorders. This will eventually induce myopathic chain reactions (2) through GABAergic interneurons in the dorsal horn. In addition to this action, the pressure and vibrations of radial shock waves improve blood circulation and lymphatic drainage.

Indications and contraindications

Trigger point shock wave therapy can be used to treat all acute and chronic myofascial disorders, provided that no primary disease is present that causes the muscular trigger points and prevents their elimination. In the latter case, trigger points and entire trigger point chains must be seen as part of *complex disease patterns* such as visceral and psychic diseases, craniomandibular dysfunctions or foot deformations with proprioceptive control disorders. Such conditions should be treated by conducting a causal therapy of the primary disease on the one hand and by eliminating the trigger point syndromes on the other hand.

Trigger point therapy is most successful if the primary disease causing the trigger point symptoms can be entirely cured or if its intensity can at least be minimized. Despite causal therapy, trigger points are frequently found to persist or to develop independently. This condition, which is referred to as *autonomous trigger point syndrome*, can be well treated with trigger point shock wave therapy.

One example for this phenomenon is pseudosciatica after successful discectomy. The trigger points in the gluteal muscles, external rotators (e.g. piriformis muscle) and quadratus lumborum muscle that were activated by the original nerve compression continue to persist despite the fact that the root compression has been eliminated. Successful resolution of these trigger points is only possible by means of trigger point therapy.

Examples of poor indications for trigger point therapy are genuine radicular lesions or advanced spinal or foraminal stenosis in the lower lumbar segments, also with secondary trigger points in the gluteal or hip muscles. Although trigger point therapy of these conditions frequently provides alleviation of pain, this effect will only be of short duration owing to the dominant nature of the nerve compression.

Trigger point therapy is *not successful* in the treatment of the following disorders: all types of rheumatism with inflammatory activity, severe fibromyalgia and severe vegetative dystonia.

General contraindications for trigger point therapy include malignant tumors, primary myopathies, serious rheumatic diseases (e.g. rheumatic polymyalgia) or treatment areas above vulnerable structures. During shock wave therapy, it is crucial that pulmonary tissue is not within the target area of focused shock waves.
Relative contraindications include pregnancy and anticoagulant therapy.

Radial or focused shock waves?

The *combined use* of focused and radial shock waves is one of the recent developments in trigger point therapy. With this approach, focused shock waves are used to treat both tendon insertions and muscles.

The application of focused shock waves to tendon insertions is recommended whenever muscle shortening caused by trigger points has resulted in *secondary insertional tendinopathies*. In these cases, treatment of the muscular trigger points alone would not be sufficient to cure the disease as the tendon irritation is often responsible for the dominant pain symptoms and would persist as an independent cause of pain even after successful muscular trigger point therapy.

Focused shock waves applied to muscles are used for diagnostic and therapeutic purposes. On the one hand, they ensure precise localization of the trigger points as the typical referred pain can be induced more reliably than during manual examination. On the other hand, focused shock waves are used for the local treatment of individual trigger points. Thanks to the minimal irritation they cause, focused shock waves can also be used for the trigger point therapy of extremely painful muscles.

Radial shock waves are used for the local treatment of muscular trigger point areas and, subsequently, for smoothing the residual muscle. This method allows large muscle regions to be treated with radial shock waves.

When treating extremely painful myofascial syndromes, only focused shock waves should be used during the initial therapy sessions. Treatment can then be continued with radial shock waves at low therapy pressure (1.6 – 1.8 bar).

Promising experience has been gathered recently in the use of *defocused shock waves* for the treatment of trigger points or insertional tendinopathies. "Defocused" means that the generated waves are applied to the tissue not in a single spot but over a wider surface area.

Therapy planning

The muscles to be treated are selected on the basis of the following criteria: *patient's indication of pain*, diagnosis of *muscle knots* (manually or with radial shock waves), possible provocation of *referred pain* by palpation pressure or with focused shock waves and, where possible, *ROM testing* to identify the muscles affected by reductions in the range of motion.

The *anamnesis and description of the pain* with respect to the pain location and referral are of special importance. Detailed knowledge of muscle-specific pain patterns, which deviate entirely from classical neurological innervation patterns, allows early identification of the muscles involved in the pain syndromes. Descriptions of pain provided by patients, which do not make sense under neurological aspects, prove astonishingly coherent and informative when considered under trigger point aspects, all the more so because trigger points can also be responsible for dysesthesia, coordination disorders and loss of strength.

Knowledge of the *muscle-specific pain referral* described by *Travell* and *Simons* (1992) represents an indispensable requirement for every therapist. Increasing experience in trigger point therapy, especially in the use of focused shock waves, has shown that pain referral patterns and the location of muscle knots *vary in each patient* and need to be identified by *accurate examination*.

Localization of trigger points

The induced *referred pain* is a major criterion for the selection of the therapy region. Strong manual pressure is exerted on the muscle knots to cause referred pain. *Focused shock waves* can be applied to induce referred pain more easily and accurately. Depending on the muscle thickness and depth of the trigger point areas, focused shock waves with variable penetration depth are applied at an energy level of between 0.05 and 0.25 mJ/mm².

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Radial shock waves are less suitable for the localization of trigger points on the basis of referred pain. Radial shock waves are rather used to identify *indurations inside the muscles*. This is done by moving the applicator over a large muscle area during the therapy.

Therapy procedure

The trigger points to be treated are selected according to the criteria of short-term or long-term reduction of the pain symptoms. Therapy is started by treating the *active trigger points* which are responsible for spontaneous current pain or pain on exertion.

This is followed by the treatment of *satellite trigger points in the area of pain referral*. Similarly to secondary trigger points in the functional muscle chains of antagonists and synergists, satellite trigger points are responsible for the chronification process if they persist for a prolonged period of time.

Insertional tendonitis, which *Travell* and *Simons* (1992) describe as *peripheral trigger points*, should be given special attention. These trigger points must be treated with focused shock waves. However, contrary to the treatment of muscular trigger points, a reduction in pain is only perceived *several weeks* after the therapy. This is due to the slowness of the induced physiological repair mechanisms. In this context, the energy flux density is of major importance. Experience has shown that shock waves should be applied at a low energy level in order not to affect the cell recovery potential, that is the useful neurogenic immediate tissue response. Since treatment is performed on a biological system, the therapy intervals between the individual sessions should not be too short (at least 1 to 2 weeks) and the number of therapy sessions should be limited. It is also crucial that no local anesthetic be used prior to shock wave application (12).

Accompanying therapies

In principle, *no accompanying therapies* are required to achieve the desired therapy success. However, shock wave therapy can be supported by trigger point stretching in fiber direction. In the presence of severe joint blockage, the blockage may loosen as a result of muscle relaxation after shock wave therapy. If this is not the case, manual therapy can be performed to eliminate the blockage after the first two or three trigger point therapy sessions and after muscle tension has started to decrease. Additional therapies, such as massaging, should not be used.

Muscle strengthening therapy can be performed one to two days after the trigger point therapy. However, it is crucial that this therapy not be performed with maximum force or at the point of maximum muscle shortening.
In the treatment of chronic pain syndromes, ibuprofen or paracetamol should be administered at the beginning of the trigger point therapy to relieve the pain.

Treatment parameters and duration

The energy flux density of focused shock waves used in muscular trigger point therapy is between 0.05 and 0.25 mJ/mm^2. Higher energy levels should not be used to avoid tissue damage (11). Judging by the latest scientific research results, the shock wave frequency applied to the trigger point should not exceed 4 Hz.

The energy flux density (mJ/mm^2) is selected on the basis of the thickness and depth of the muscle and the patient's indication of pain during localization of the trigger points and provocation of referred pain. The energy flux density should be selected in such a way that the pain induced by the shock waves can still be *well tolerated* by the

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patient. Generally speaking, the energy level can be increased after each therapy session as the pain perceived during shock wave application gradually decreases if the therapy progresses smoothly.

The same applies to radial shock waves. The therapy pressure of radial shock waves varies between 1.6 and 4 bar, depending on the shock transmitter size and the patient's indication of pain. Shock transmitters with a small surface should be used with extreme caution owing to the high peak pressures they may generate. Judging by our experience, such shock transmitters are generally not required for the muscles to be treated. The pressure applied should be adequate for the tissue properties to avoid hematomas. The shock wave frequency is 10 to 15 Hz, where the 15 Hz frequency is generally perceived as causing less pain. This effect may be attributable to the *physiological intrinsic muscle oscillation* stimulated by the radial shock waves.

In the *combined use* of focused and radial shock waves in trigger point therapy, the trigger points are first treated locally, applying 200 to 400 focused shock waves.

This step is followed by muscle smoothing of the agonists, antagonists and synergists with the radial shock wave transmitter, applying 3000 to 4000 radial shock waves.

If muscles are treated with radial shock waves alone, the trigger point area is treated locally with 500 to 1000 shock waves and without applying manual pressure. This step is then followed by *muscle smoothing* with up to 4000 shock waves at a frequency of 15 Hz, in accordance with the stretch-and-spray technique developed by *Travell* and *Simons* (1992).

Treatment frequency

A therapy frequency of *one session per week* has shown to be ideal for most patients. These intervals enable the muscles to recover from the irritation, which may initially persist for up to three days. Shorter intervals might cause additional muscle irritation before the irritation from the previous session has actually disappeared and thus increase pain. Insertional tendonitis should not be treated at shorter intervals in order not to affect the aforementioned regeneration potential that results from the local neurogenic tissue response. Pain modulation aspects, too, suggest that the treatment intervals in trigger point shock wave therapy, similarly to acupuncture, should not be too short. The following general principle applies: *longer therapy intervals and lower treatment intensities should be used for more serious and chronic pain syndromes.*

Therapy progress: pain relief, side effects and complications

In the treatment of most trigger point syndromes, a reduction in pain is generally perceived after 4 to 6 therapy sessions, or even after as little as 1 to 2 sessions in the case of short-term conditions. Chronic syndromes with many different affected muscles require 6 to 10 or even more therapy sessions to eliminate the pain. If the therapy proves unsuccessful after this many sessions, treatment should be interrupted and the indication should be checked.

A *short-term increase* in the original pain and, in very rare cases, the *manifestation of other muscular disorders* may occur after the initial sessions. Shock wave application to the cervical spine may cause headache and temporary buzzing in the ears, especially when radial shock waves are used. Patients who are suffering from migraine or are susceptible to tinnitus must be informed about these possible side effects. In these cases, the shock waves should be applied at a low pressure (1.6 bar), and patients should wear ear protection. The same applies to the application of focused shock waves.

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No serious complications will occur if the shock waves are applied correctly in terms of the shock wave energy levels and penetration depth. The most frequent side effects include *local hematomas*, especially in the gluteal muscles, caused by radial shock waves.

Should a temporary interruption of the therapy prove necessary due to the aggravation of pain or the extent of the hematoma, the therapy intensity (energy flux density, treatment pressure and total number of shock waves applied) should be reduced when treatment is continued. The intensity can then be increased again during the following therapy sessions.

Therapy success

Trigger point shock wave treatment is considered successful if *over 80 %* of the original pain has been eliminated at the end of the therapy. The residual 20 % may well disappear during the three months following the therapy, which means that it does not make sense to permanently continue treatment. A successful therapy should provide *lasting pain relief or at least eliminate the pain for 6 to 12 months*.

If the original pain is reduced by as little as 50 %, additional trigger points are likely to exist in the functional muscle chain. These trigger points, which may be latent in nature, should be identified.

If pain reduction rates of only 20 to 30 % are achieved at the end of the therapy or if the pain relief lasts only a few weeks, additional differential diagnostics of the disorder will be necessary.

Orthopedic disorders with high therapy success rates

The recommendations below are based on several years of experience acquired by the authors in the field of orthopedic trigger point shock wave therapy.

Cervicalgia, cervical cephalalgia, cervicobrachialgia

These indications respond particularly well to trigger point shock wave therapy as the affected muscles (except for the trapezius muscle) are rather small and located close to the body surface. The local pain, which climbs up into the head, is primarily caused by the descending and horizontal parts of the trapezius muscle and by the semispinalis muscle, splenius muscle, levator scapulae muscle and sternocleidomastoideus muscle.

Apart from the scaleni muscles, the muscles that are responsible for pseudoradicular brachialgia are all located in the shoulder girdle region (subscapularis muscle, infraspinatus muscle, teres, muscles, serratus posterior superior muscle, pectoralis muscle). A reduction in pain is achieved after 6 to 8 therapy sessions, along with a lasting increase in mobility of about 20 degrees rotation, 17 degrees inclination/reclination and 17 degrees lateral inclination.

If no improvement is achieved, examinations should be conducted to find out whether the patient suffers from temporomandibular dysfunctions or psychovegetative exhaustion.

Lumbalgia, pseudoradicular lumbosciatica

These indications can also be treated successfully, provided that the patient does not suffer from dominant radicular irritations (prolaps, foraminal stenosis with segmental deficiencies), arthrogenic irritations (activated facet syndrome, spondylolysis) or discogenic irritations (erosive discopathy). Local pain in the lumbar spine is caused by trigger points in the segmental muscles (multifidi and rotator muscles), in the dorsolumbar junction (iliocostalis lumborum and thoracis muscle) and in the iliopsoas muscle. Referred pseudoradicular pain is caused by trigger points in the gluteal muscles (gluteus minimus and medius muscles), in the external hip rotators and in the quadratus lumborum muscle. In these cases, referred pain (in the lower leg and foot) can be easily induced by applying focused shock waves.

Dorsalgia

The primarily local pain is caused by trigger points in the multifidi and rotator muscles and, in the interscapular region, by trigger points in the rhomboidei muscles, serratus posterior superior muscle and in the ascending part of the trapezius muscle.

Periarticular shoulder pain and restricted mobility

The term "periarthritis", often reluctantly used, plays a major role in the description of these conditions as many types of shoulder pain originate in the periarticular muscles and cause restricted mobility (infraspinatus muscle with reduced internal rotation and anterior shoulder pain, subscapularis muscle with reduced external rotation and posterior shoulder pain). Referred pain in the lateral upper arm is caused by trigger points in the horizontal part of the trapezius muscle, in the supraspinatus muscle and in the deltoid muscle. Insertional inflammations of the supraspinatus tendon have to be treated separately with focused shock waves.

Frozen shoulder, a condition characterized by painful shoulder stiffness and pain caused by capsular contracture, cannot be treated successfully with trigger point shock wave therapy.

Radial and ulnar epicondylopathy

In general, these indications are no promising candidates for trigger point therapy. Most disorders are caused by local insertional tendinopathy, and not by referred pain. However, early stages of these conditions, which are caused by muscular overstrain of the forearm flexor and extensor muscles, can be treated successfully. In the case of chronic pain syndromes, treatment of the muscle chains is a viable attempt. Radial epicondylopathy: scaleni muscles, horizontal part of trapezius muscle, supraspinatus muscle, lateral part of triceps brachii muscle, anconeus muscle, supinator muscle, brachioradialis muscle including forearm extensor muscles. Ulnar epicondylopathy: serratus posterior superior muscle, infraspinatus muscle, pectoralis muscle, medial part of triceps brachii muscle, pronator teres muscle and forearm flexor muscles. Local insertional tendinopathies have to be treated with focused shock waves.

Wrist tendonitis

Wrist tendonitis is caused by overstrain of the forearm muscles involved in wrist movement. Accompanying trigger point shock wave therapy must be performed by applying shock waves to the affected forearm muscles.

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Pelvic/hip pain

Pelvic/hip pain can be successfully treated with trigger point shock wave therapy. The frequently diagnosed trochanteric bursitis is often caused by trigger points in the gluteal muscles and the external hip rotators. Local trochanteric pain has to be treated with focused shock waves. These trigger points may have been caused by previous lumbar spine pain syndromes or by a developing coxarthrosis and residual conditions after total endoprosthetic surgery.

Sciatic pain, which is caused by trigger points in the gluteus maximus muscle and in the ischiocrural muscles, responds well to trigger point shock wave therapy.

Tensor fasciae latae syndrome

Overstrain of the tensor fasciae latae muscle is very common among runners and causes lateral hip and thigh pain. This condition is often accompanied by trigger points in the gluteal muscles and vastus lateralis muscle.

Adductor tendinopathies

Although adductor muscles can be easily reached with shock waves, they are still difficult to treat. This is due to the fact that, in addition to trigger points, there are insertional tendinopathies in the proximal and medial third of the muscles on the pelvic insertion.

Shortening of thigh flexor and extensor muscles

The most frequent symptom of this condition is recurrent muscle sprain caused by increased muscle tension. It can be treated successfully with shock wave therapy, but requires a high number of shock waves due to the large size of the muscles involved.

Patellar chondropathy

This condition is often characterized by a shortened quadriceps and by trigger points in the medial and lateral vastus muscles near the knee joint. Quadriceps shortening can be reliably objectivated by measuring the heel-to-buttock distance in prone position. Successful results are achieved after only two to four therapy sessions. Moreover, parapatellar pain often manifests itself after total endoprosthetic surgery and can be well treated with trigger point shock wave therapy.

Patellar tendonitis

In addition to the symptomatic tendonitis, which can be treated locally with focused shock waves, this condition is often characterized by a shortened quadriceps muscle. Although trigger point shock wave therapy provides excellent quadriceps relaxation, the tendonitis often takes several months to cure completely.

Shin splint

Tendons and the periosteum are the dominant pathological features of shin splints and must be treated with focused shock waves. Accompanying radial shock wave therapy can be performed to eliminate indurations in the medial calf muscles and in the flexor hallucis longus muscle.

Anterior tibial syndrome

Trigger point irritation of the anterior tibial muscle is encountered among runners and after mountain descents due to muscular overstrain. Shock waves are exclusively applied to the muscles.

Achillodynia

The dominant pain symptoms in achillodynia are caused by tendonitis, which is treated locally with focused shock waves. Achillodynia is frequently accompanied by calf muscle shortening. Shock wave therapy should be extended to treat these contractures as a reduction in the calf muscle tension by trigger point therapy will also relieve the Achilles tendon (similarly to raising the heel) and is reported by patients to provide rapid alleviation of pain. The experience gathered by the authors has shown that trigger point therapy ensures a lasting improvement in the frequently restricted active ankle joint extension from 16 degrees to 25 degrees after 4 to 5 sessions.

Plantar fasciitis of the heel (plantar calcaneal spur)

In most cases, sonographic diagnosis reveals that the frequent X-ray diagnosed calcaneal spur is a severe plantar fasciitis below the calcaneus, characterized by fascial swelling of 4.5 to over 12 mm (normal value < 4.0 mm). This means that on the one hand local therapy is required, applying focused shock waves to below the calcaneus. On the other hand, the therapy should also focus on eliminating muscle contractures of the calf muscles and plantar muscles, which form a functional chain.

Metatarsalgia

Pain in the forefoot is frequently caused by splay foot related overstrain of the longitudinal and transverse muscles. This pain can be reliably eliminated with radial shock waves in 4 to 5 sessions, provided that it is not accompanied by periosteal irritations of the metatarsals and that Morton's neuromas are excluded.

Discussion

The many different types of disorders described above have shown that the combination therapy with focused and radial shock waves can be successfully used for a variety of indications in the treatment of myofascial pain syndromes. It has been pointed out that an *accurate anamnesis*, especially with respect to the *patient's indication of pain*, is of special importance. Extensive differential diagnostics is, of course, required, which means that extracorporeal shock wave therapy is and will continue to be a *medical procedure* to be performed by doctors. Even if radial shock wave therapy is delegated to a physiotherapist, the diagnosis must still be made by the physician. If no lasting improvement in the condition is achieved or in case of a poor therapy success, the physician will be required to re-examine the patient.

Palpation or pinch test diagnosis with provocation of the typical referred pain and local twitch response of the muscle, which is sometimes impossible to induce, continue to play a major role in clinical screening. Functional

and stretching tests are performed to complement clinical examinations. The *use of focused shock waves for the localization of muscular trigger points* has proved its worth as a new diagnostic procedure. This method is more accurate than localization by dry needling. The characteristic referred pain can be reliably induced. Pain localization with focused shock waves is performed at a low frequency (3 Hz) to ensure successful feedback from the patient. Treatment is started after having successfully localized primary, satellite or secondary trigger points.
The precise mode of action of shock waves applied to muscular trigger points has not been defined to date. However, the shock wave mechanism can be explained on the basis of known theories (1).

The *pain relief* provided by shock waves is due to counter-irritation and pain modulation comparable to dry needling. Owing to the specific physical properties of shock waves, this therapy can be described as needle-free acupuncture which induces a down-regulation of nociceptive afferents through enkephalinergic interneurons in the dorsal horn of the spinal cord. The pain modulation achieved with radial shock waves through the activation of A-beta fibers in the muscle, which then provide pain inhibition through GABAergic interneurons in the dorsal horn, can be explained in a similar manner. This would confirm the findings of *Travell* and *Rinzler* (1952), who observed many years ago that pain is relieved and trigger points are eliminated after pressure and stretching. The vibration (15 Hz) of radial shock waves also seems to have a favorable effect on muscular structures. The physiological intrinsic oscillations of 15 to 30 Hz have been described by *Nazarov* (1988) as important for muscular blood circulation and lymphatic drainage.

On the basis of *Simons' integrated hypothesis of trigger point formation* (1996), according to which muscular end-plate dysfunction and an energy crisis caused by local ischemia are the central features of trigger point pathologies, the following additional *shock wave mechanisms* are discussed: mechanical resolution of permanent actin/myosin contractures through local transverse stretching of the sarcomeres by the application of shock waves perpendicular to the fiber orientation up to the destruction of abnormally contracted sarcomeres through the energy applied, reactive local tissue hyperperfusion and angioneogenesis (18), which would eliminate the ischemia responsible for the energy crisis, and eventually thinning of vasoneuroactive substances by the pressure exerted on the tissue by shock waves. All these mechanisms could explain the clinically observed reduction in muscle tension and muscular contracture.

Judging by the results of recently conducted animal tests, the effects of focused shock waves in the treatment of insertional tendinopathies, referred to as "attached trigger points" by *Travell*, are molecular, biochemical and cellular in nature (6, 10). Neurogenic messenger substances such as substance P or CGRP are considered to induce plasma extravasation, angiogenesis and neurogenic inflammation. Similarly to the chemical stimulus produced by capsaicin, shock waves used to induce a mechanical stimulus can cause immediate local tissue response, which would explain the regeneration of tendon tissue.
While the results of the aforementioned animal tests and pain therapy considerations may explain the effects of extracorporeal shock wave therapy in the treatment of trigger point syndromes associated with insertional tendinopathies, no clinical confirmatory studies have been conducted to date to verify the experience gathered in practical application. Further research is therefore required by university scientists and by the shock wave study group of the DGOOC (German Society for Orthopedics and Orthopedic Surgery).

Literature

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ABSTRACTS
2003 – 2008

English

Dr. Markus Gleitz

Luxembourg

2003
Presentation
51st Annual Meeting of the Association of Southern German Orthopaedists e.V. (Baden-Baden)
Shock waves for the treatment of myofascial pain in orthopaedics: A new treatment option
Dr. M. Gleitz, Luxembourg

Introduction: Myofascial pain is treated in many different ways, although all methods share the therapeutic goal of reducing pain by alleviating muscle tension and eliminating contractures. Therapies performed directly at the muscle, including conventional trigger point treatment using infiltration and dry needling, have not become widely accepted due to a lack of efficacy, variation among treatment providers and a lack of objectivity in comparison with competing methods. Manual pressure treatment of trigger points (gelotripsy) can only be used in a limited extent due to its significant side effects (severe treatment pain, haematoma). According to the current state of knowledge, trigger points represent local muscle contractures that are created by an energy crisis at the neuromuscular end plate. They cause palpable contracture bands (taut bands), limit the elasticity of the affected muscle and cause a referred pain, which can range up to pseudoradicular paresthesia in terms of severity.

Problem: Can extracorporeal shock wave therapy (ESWT) provide effective treatment of trigger points with improvement of the above-mentioned clinical findings? Material and method: The investigation studied 93 patients with chronic (>6 months) cervical spine pain with headache and pseudoradicular cervical / brachial pain and an average age of 48 years. The active range of motion of the cervical spine was measured in 3 planes using CROM goniometers before and after treatment, as well as the VAS pain intensity. After differentiated palpation, the affected trigger areas were treated based on muscle thickness using low to moderate energy shock waves once weekly with 1000-4000 shocks over 3-10 weeks. No more than 12,000 shocks were administered per treatment session. Results: After an average of 5.6 treatments, the patients achieved a reduction in pain of 80%.

The active ROM in the cervical spine also improved, with additional rotation of +21.2°, anterior/posterior flexion of +11.3° and lateral flexion of +13.1°. Aside from low-grade local haematomas, no side effects were observed. In particular, no elevations of muscle enzymes or myoglobinuria were observed.

Conclusion: ESWT of muscle trigger points leads to a measurable improvement of range of motion of the cervical spine and to a significant reduction in pain. This method has been used for more than 3,000 treatments as a routine treatment in an orthopaedic practice. Based on its mechanism of action, the method can also be used on other orthopaedic problems caused by muscle contractures.

2004
Presentation
52nd Annual Meeting of the Association of Southern German Orthopaedists e.V. (Baden-Baden)
Introduction to the diagnosis and therapy of myofascial trigger points using extracorporeal shock waves
Dr. M. Gleitz, Luxembourg

Introduction: Myofascial pain syndromes are a routine problem for orthopaedists, but often can not be treated satisfactorily. This is confirmed by the large number of competing methods of treatment. Trigger points are an important problem due to the clinical symptoms they cause: node formation in muscles with local and referred pain, cord-like strands of contractures in muscle (taut bands), limited joint range of motion (ROM), formation of satellite triggers, activation of pseudoradicular dysesthesia and accompanying autonomic nervous reactions.

Every muscle has characteristic pain patterns. According to the current state of knowledge, trigger points are caused by a local energy crisis at the neuromuscular end plate, which can be caused by various mechanisms: acute mechanical overexertion, including trauma, chronic overexertion due to repetitive strain, malposition, and exposure to cold or emotional stress. If a trigger exists for a longer period of time, even if subclinical, satellite triggers can be activated, which then develop their own pain patterns and functional disorders. After some time, muscle chain disorders develop with complex pain patterns. The most effective classical treatment option for trigger points is direct pressure applied to the muscle node in order to mechanically interrupt the actin-myosin connections, which cannot brake down spontaneously because of a lasting energy deficiency.

Material and method: Based on the mechanism of action of direct pressure application on muscular trigger points, the author has performed more than 7000 treatments using low to medium energy radial shock waves for a wide variety of myofascial orthopaedic disorders in an empiric fashion and with documentation of treatment outcomes. The selection of the muscle to be treated was based on the patients' reported pain localization and mechanism of formation, taking the muscle-specific referred pain into account. Palpation of the muscle in question for taut bands and contractures and, if possible, ROM testing with correlation to the muscles causing decreased mobility were also taken into account. Treatments were continued until improvement of at least 80% of the original pain was achieved.

Results: The treatments were successful with the following diseases: cervical spine pain, back pain and low back pain (including pseudoradicular irrradiation), coxalgia (so-called trochanteric bursitis and post-operative gluteal pain), radial and ulnar epicondylopathy including distal forearm tendinopathies, shoulder periarthropathy, patellar chondropathy, achillodynia and plantar fasciitis. Depending on the treated muscles and the patients' reported pain during treatment, device pressure between 1.8 and 4.0 bar was selected with 1000 to 4000 shock impulses per muscle per therapy session, with a maximum of 10,000 shocks per therapy session.

For the vast majority of patients in which therapy was properly indicated, trigger symptoms were cleared up within 6-8 treatments (1 treatment per week) in a sustained fashion (>6 months) with measurable improvement in ROM. Side effects included temporary haematomas and temporary pain increases. The percentage of patients who stopped therapy was <1%. Conclusion: Treatment of myofascial trigger points with radial shock waves represents a new therapy method. Based on the practical experience of the author, the method is extremely effective for everyday use in an orthopaedic clinic. Muscle tissue has an inherent diagnostic and therapeutic potential that, in addition to the classical arthrogenic and neurogenic perspectives, should in future be more effectively used for myofascial disorders in orthopaedics.

2004
Presentation
52nd Annual Meeting of the Association of Southern German Orthopaedists e.V. (Baden-Baden)
Age-dependency of cervical range of motion increases with treatment of myofascial trigger points using extracorporeal shock waves
Dr. M. Gleitz, Luxembourg

Introduction: Limitations in Rang of Motion (ROM) of the cervical spine with increasing age have classically been regarded by orthopaedists as arthritis-related (degenerative) with limited chances for improvement using conservative therapies. Active device-based muscular strengthening and mobilization methods for the back (DBC, MedX, FPZ), which are often successfully implemented to treat chronic muscular deconditioning syndromes, also do not show any or show only minimal improvement in ROM in the cervical spine after 12-24 treatments. Reduced mobility in the cervical spine can also be caused by formation of trigger points in the cervical muscles. These trigger points are formed due to an energy crisis at the neuromuscular end plate, causing local muscle contractures. Based on clinical experience, direct mechanical pressure to the trigger points with release of actin-myosin connections is one of the most effective forms of treatment. This raises the question as to whether radial extracorporeal shock waves are suitable for treatment of trigger points with improvement of muscle flexibility and joint mobility and to what extent the patient's age is a factor in the success of treatment.

Material and method: The investigation comprised 156 patients of an orthopaedic practice with chronic (>6 months) cervical spine pain and pseudoradicular cervical/brachial pain with an average age of 52.9 years (19-84 years). The radiological extent of degenerative changes was not taken into account. Active mobility (ROM) of the cervical spine was measured in 3 planes using a CROM goniometer before and after shock wave treatment, as well as at a 3-months follow-up. Following differentiated palpation and functional examination, the affected muscular trigger points were treated with radial shock waves for 3-10 weeks once weekly with a maximum of 8000 shocks per session.

Results: After an average of 6.6 treatments an improvement in active ROM of the cervical spine was seen in the patient collective, with improvement in rotation of +21.2°, lateral flexion of +16.8° and anterior/posterior flexion of +16.1°, whereby posterior flexion was particularly improved by +10.2°. At a follow-up examination 3 months after the final therapy session, range of motion measurements had only worsened by 1° each. After dividing the patient collective into 2 age groups (Group 1: 19-50 years old with an average age of 38.8 years, Group 2: 51-84 years old with an average age of 61.3 years), Group 2 showed decreased initial rotation (121.7° in Group 2 compared to 142° in Group 1), but no statistically significant differences were seen in the absolute increases in ROM at the end of therapy: Rotation: Gr.1 +20.4°, Gr.2 +21.6°, Lateral flexion: Gr.1 +17.6°, Gr.2 +16.3°, Anterior/Posterior flexion: Gr.1 +14.2°, Gr.2 +17.2°.

Furthermore, no correlation was seen between the patient age and the improvement in ROM in the cervical spine. Conclusion: The musculature plays an important role in the treatment of limited ROM of the cervical spine. Patient age and the accompanying degree of degenerative change have no influence on the results of treatment. Based on the fact that the range of rotation in the cervical spine decreases by 6° every 10 years after the age of 20, the increased ROM of >20° at the end of therapy represents the same cervical spine mobility as the patient enjoyed 30 years ago. Based on this practical experience, radial extracorporeal shock waves represent an appropriate means of therapy and should be used more frequently for treatment of myofascial orthopaedic disorders.

2004
Presentation
52nd Annual Meeting of the Association of Southern German Orthopaedists e.V. (Baden-Baden)
Improvement of calf muscle elasticity using extracorporeal shock waves with chronic achillodynia
Dr. M. Gleitz, Luxembourg

Introduction: Contracture of the calf musculature is a primary risk factor for recurrent achillodynia. Patient histories often include reports of limited movement (such as lifting the heel from the ground when squatting) that date back many years. Usually no actual cause for the muscle contracture is to be found. Stretching exercises are generally not sufficient to reduce complaints. However, wearing heel lifts quickly leads to improvement, confirming the importance of reducing tension in the Achilles tendon for its healing. The existence of muscle trigger points is a possible cause of calf contractures. Due to an energy crisis at the neuromuscular end plate the trigger points lead to permanent shortening of actin-myosin connections, causing remarkable muscle contractures. If the number of trigger points is sufficient, this can lead to measurable shortening of the affected muscle. There are many different causes of trigger point formation, ranging from acute mechanical overexertion and trauma to malpositions or even complication of articular, neurogenic or muscular problems in other parts of the body (satellite triggers). One of the most efficient treatments for trigger points involves the application of direct mechanical pressure. This raises the question as to whether radial extracorporeal shock waves are capable of improving the elasticity of the calf muscles by applying pressure to them.

Material and method: The investigation studied 86 patients (average age 46.4 years) in an orthopaedic practice with chronic achillodynia (>6 months) who had previously had unsuccessful conservative treatment. The inclusion criterion was a clinically notable limitation of dorsal extension in the ankle joint caused by soft tissue. In addition to local treatment at the Achilles tendon, patients were treated with 4000-6000 pulses of radial shock waves per calf and treatment session for 4-6 treatments (1 / week) using a device pressure of 2.5-4.0 bar. Active dorsal extension of the ankle joint was measured using a gravity goniometer under standard practice conditions before and after completing shock wave therapy (one investigator) as well as during a follow-up 3-6 months afterwards.

Results: Before shock wave treatment the average measured active dorsal extension was 17.0°. After an average of 4.4 treatments and until the end of treatment, dorsal extension of 25.8° was achieved. A follow-up at an average of 4.4 months later showed average dorsal extension of 26.3°. Side effects included small local haematomas. Therapy stoppage was not necessary for any patient.

Conclusion: Based on these results, treatment with radial shock waves leads to long-lasting improvement of calf muscle elasticity within a short therapeutic period, making it an alternative to wearing heel lifts, which may cause increasing muscle shortening, for the treatment of chronic achillodynia. Although the trigger point theory appears to be sound, additional research for clarification of the mechanism of action is needed.

2005
Paper presented at a symposium on tendon problems ("Den Bogen überspannt – Sehnenprobleme von A-Z" – "Overstretched – tendon problems from A-Z") held at the Orthopaedic University Clinic of Mainz
The importance of the flexor chain for the results of treating chronic plantar fasciitis with pressure waves
Dr. M. Gleitz, Luxembourg

Introduction: Plantar fasciitis is the expression of an imbalance between the load on the tendón insertion at the calcaneus and its load carrying capacity. It is attributed to a local exaggeration of mechanical stress. One possible cause that should be discussed is an increased tensile load on the plantar fascia due to a hypertonus in the flexor chain. The present study aims at clarifying whether a treatment of the muscles of the calf and the sole with radial pressure waves in addition to an isolated local treatment of the tendon insertion at the calcaneus produces better therapeutic results.

Material and method: Out of an overall number of 124 patients suffering from chronic plantar fasciitis (> 6 months) with a proven retraction of the calf muscles (active extension of the talocalcanean joint < 18°), 2 groups of 62 patients each were treated with radial pressure waves in 5 weekly sessions: group 1 was only treated locally at the heel with 2000 shots, whereas group 2 additionally received 4000 shots in the muscles of the calf and 2000 shots in the muscles of the sole. In order to objectify the therapeutic process, the intensity of pain (VAS) was documented 3, 6 and 12 weeks after the end of the treatment, and the thickness of the tendon insertion at the calcaneus was measured by sonography.

Results: The initial values for both groups were comparable before the treatment: the average pain intensity was 7.1 (VAS), and the mean tendon thickness amounted to 6.7 mm (normal value 3.6 mm). 3 weeks after the end of the treatment, the average pain intensity of group 1 had sunk to 5.1, whereas group 2 had reached the significantly ($p<0.05$) lower value of 4.2. The thickness of the tendon had not changed. After 6 weeks the pain intensity indicated by group 1 was 3.9, whereas group 2 stated an intensity of 3.0 ($p<0.05$). The thickness of the tendon amounted to 5.4 mm in group 1 and to 4.9 mm (ns) in group 2. After 12 weeks, group 1 showed a pain intensity of 2.2 and group 2 of 1.9 (ns). The thickness of the tendon was 4.8 mm in group 1 and 4.0 mm ($p<0.05$) in group 2. The active extension capacity of the talocalcanean joint had not changed in group 1, whereas an improvement of 9.1 degrees ($p<0.01$) on average could be noted in group 2.

Conclusion: The better intermediate results obtained with patients who were treated both locally and in the muscular chains prove the hypothesis of an excessive load on the plantar fascia due to retracted flexor chains. However, further studies are needed to show if the improved stretchability of the calf muscles will reduce the number of recurrences in the future.

2005

Paper presented at the 53rd annual meeting of the Association of Southern German Orthopaedists (Baden-Baden)

The importance of trigger point pressure wave therapy in the treatment of pseudoradicular cervicobrachialgia

Dr. M. Gleitz, Luxembourg

Summary: The trigger point pressure wave therapy allows an effective and lasting treatment of pseudoradicular irradiation in the upper extremity and prevails clearly in efficiency over physiotherapy.

Problem: Distal pain irradiating into the arm and hand together with temporary paresthesia is one of the most frequent clinic complaints of patients with cervicobrachialgia. In most cases, the objective electro-neurological examination shows no radicular or peripheral nerve compression syndromes. Diagnostic imagings most often fail identifying the causes. The main clinic symptom of such patients is paravertebral cervical myogelosis of the cervicodorsal transition region as well as of the muscles that stretch towards the shoulder and the adjacent muscles, accompanied partly by a distinct formation of muscle knots.

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Since muscular trigger points are ascribed the properties of "referred pain" and dysesthesia, the present study aims at clarifying how far these complaints can be treated by applying trigger point pressure wave therapy.

Material and method: A total of 86 patients with recurrent pseudoradicular cervicobrachialgia (duration > 6 months) were treated 6-8 times with radial pressure waves in the course of 4 weeks. After diagnosis by palpation, the treatment was directed at the noticeably hardened muscles of the cervicodorsal transition region, the trapezius and interscapular regions as well as the shoulder muscles, applying a maximum of 10,000 shots per session at an intensity of 2-4 bar.

Pain intensity (VAS) was documented before, immediately after and 3 months after the end of the pressure wave therapy. The frequency of pseudoradicular irradiation was also documented at the same intervals. A group of 86 patients with similar complaints who were treated 6-8 times with physiotherapy during 4 weeks served as control group. Results: In the trigger point pressure wave group, the pain intensity (VAS) sank from an average of 7.3 before the therapy to 1.4 at the end of the therapy, and to 1.3 after 3 months. In 81% of the patients, distal pain irradiation could not be detected any more at the end of the therapy, and in 76% after 3 months. In the group treated with physiotherapy the pain intensity sank significantly less ($p<0.01$) at the same times of measurement, namely from 7.2 before to 3.3 after the therapy, and to 3.5 after 3 months. The reduction of irradiating pain was also significantly lower ($p<0.01$) and amounted to 49% at the end of the therapy and to 43% after 3 months.

In the trigger point pressure wave group, the following muscles proved to be of therapeutic significance: Mm. trapezius transversus, scalenii, splenius, semispinalis, subscapularis, infraspinatus, teres major et minor, pectoralis, supraspinatus, deltoideus and triceps brachii.

2005
Paper presented at the 53rd annual meeting of the Association of Southern German Orthopaedists (Baden-Baden)
Limits of trigger point pressure wave therapy in pseudoradicular lumboischialgia
Dr. M. Gleitz, Luxembourg

Summary: Muscular trigger points are frequent in cases of pseudoradicular lumbalgia. However, their presence is not a reason to use this therapy in isolation. By diagnostic differentiation, several concomitant disorders cause trigger points and must therefore also be taken into consideration as they account for the failure of trigger point pressure wave therapy in 19% of the patients.

Problem: Pseudoradicular lumboischialgia is often caused by trigger points in the gluteal muscles, the external rotators of the hip, the M. quadratus lumborum, and the lumbar extensors.

The main criterion for proving their existence and the necessity of treatment is the "referred pain" produced by the pressure exerted on the muscles. Since the beginning of treating trigger points with pressure waves, the therapeutic success regarding these pain symptoms has increased strongly and led to real enthusiasm among therapists.

After many years of experience with this treatment, the author now asks where its limits are as well what its relative contraindications are.

Material and method: In the course of a study, 432 patients suffering from chronic pseudoradicular lumboischialgia on one or both sides (> 6 months), active trigger points and reproducible "referred pain" were treated in 6-10 sessions with radial pressure waves (a maximum of 10,000 shots / session, an intensity of 2.5-4 bar, 1-2 times a week). Standard radiography in upright position as well as MRI and CT examinations of the lumbar spine served for basic diagnostic. If necessary, extensive additional laboratory tests, bone scintigraphy and radiography of the adjacent joints (hip joint, sacroiliac joint, thoracic spine) were carried out. The progress of the treatment was evaluated by recording pain intensity (VAS) and irradiating pain before the therapy, at the end of the therapy, and 3 months later.

Results: In 19% of the patients the therapeutic goal was not reached. 15% did not report a sufficient improvement of pain (VAS before therapy of 7.3, after therapy > 4.0) at the end of the therapy, or showed a new deterioration after 3 months. 4% of the patients showed an increase of pain which led to a premature end of the therapy for 2% of the patients. After additional diagnostics, the following disorders were detected in those patients: inflammatory rheumatism, fibromyalgia, malfunction of the thyroid and parathyroid glands, mental stress. In the case of the following concomitant disorders, an insufficient or only short-term improvement of the complaints was stated: chronic nerval compression without neurological
failures (spinal stenosis, foraminal stenosis, large protrusio, post-operative fibrosis), active spondylarthritis proved by bone scintigraphy, osteoid osteoma in the facet joint, spondylolysis on both sides (also without listhesis), erosive osteochondrosis, sacroileitis, progressive coxarthritis, severe coxa valga, thoracolumbal scoliosis > 20°, severe static disorders of the pelvis as well as diseases of organs in the abdomen and pelvis.

2005
Presentation
8th International Congress of the International Society for Musculoskeletal Shockwave Therapy (ISMST) (29.05.-01.06.2005, Vienna)
Gluteal trigger points as a common source of pseudo sciatic pain and their therapy with radial shockwaves
Dr. M. Gleitz, Luxembourg

Introduction: Patients with chronic low back pain often complain about pain irradiation in their legs although they have no objective neurological deficit. These irradiations are called "pseudo sciatic" and are mostly explained by the muscle trigger point theory of Travell & Simons. Pseudo sciatic pain is mostly due to trigger points in the gluteal muscles.

The trigger point theory further includes the possibility of secondary insertion tendinosis due to an increase of intramuscular tension over longer periods. In this clinical study the frequency and localisation of musculotendinous pathologies amongst chronic low back pain patients were examined and the results of a radial shockwave therapy described.

Material and method: In a group of 184 patients with chronic pseudo sciatic pain (>12 months) the gluteal muscles and their insertion at the ilium and the greater trochanter were examined by palpation and the correlation to the duration of pain calculated (1 examiner).

The trigger point areas in the gluteal muscles were treated with radial shockwaves (Masterpuls, Storz) during 6-8 sessions and the result of therapy documented over 6 months.

Results: 92% of all patients with chronic pseudo sciatic pain showed trigger points in the gluteal muscles and described a typical referred pain in the lower extremities during high pressure on these areas. Amongst these 184 patients 61% showed muscular trigger points only (average pain duration 1.8 years, VAS 7.3), whereas additional insertion tendinosis was found in 31% of the patients (average pain duration 3.7 years, VAS 7.6). The difference in pain duration was statistically significant ($p<0.01$), whereas the intensity of pain was not.

The treatment with radial shockwaves resulted in a significant reduction of pain after 6 months in the subgroup of pure muscular trigger points in 84% of patients (VAS 1.9) and a relief of the referred pain in 69%. In the subgroup with additional insertion tendinosis only 49% of patients profited from the trigger shockwave therapy (VAS 3.4) and described a relief of the pseudo sciatic pain in 35%.

Conclusion: Muscular gluteal trigger points are a common source of pseudo sciatic low back pain and are a risk factor for secondary insertion tendinosis. Whereas muscular trigger points respond well to the radial shockwave therapy, insertion tendinosis does not improve equally. Under practical considerations we recommend an early treatment of muscular trigger points in patients with pseudo sciatic low back pain to prevent later tendinosis which is much more difficult to treat.

2006
Presentation
German Congress for Orthopaedics and Trauma Surgery 2006 (05.10.2006, Berlin)

Continuing education course for shock waves by DIGEST (Deutschsprachige Internationale Gesellschaft für Extrakorporale Stosswellentherapie)

Trigger point shock wave therapy
Dr. M. Gleitz, Luxembourg

Introduction: Trigger point shock wave therapy takes advantage of a less well-known property of the muscle: that of a central pain organ.

As this has been an empirical therapy until now, the following descriptions of therapy modalities are to be seen as recommendations of an experienced therapist.

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History: From a historical perspective, this therapy is a recent development. The first publications on this topic cited in MEDLINE were published in the late 90s. These publications reported reduction in pain (Kraus M. et al., 1999) as well as reduced muscle tone (Lohse-Busch H. et al., 1997) after the application of low-energy focused shock waves to the muscle.

In the field of orthopaedics, trigger point treatment only begun when radial pressure wave devices were introduced, which were originally developed for the classical shockwave indications (treatment of tendons and calcifications). Based on the experiences of trigger point therapists, which indicated that firm pressure on the muscle nodes caused them to disappear or become less painful, radial pressure wave devices were used "off-label" to treat muscles using mechanical pressure.

In additional to the above-mentioned treatment of local pain and reduction of muscle tone, treatment of clinically-variable referred pain became a primary objective. This was based on the extensive publications of Travell and Simons in the 80s.

Pathophysiology of muscular trigger points: Based on the investigations performed by Simons and Travell, trigger are sarcomere contractures in the µm range which, if a large number of them occur in the same area, can lead to locally painful and palpable nodes with cord-like contractures in muscle.

The causes for triggers can include trauma or overexertion, leading to dysfunction at the end plate with an overriding muscle contraction. An energy crisis due to ischemia and the release of vasoneuroactive substances then starts a vicious circle. The temporary contraction becomes a long-lasting contracture that can not be relieved without an external influence, thus establishing itself as an autonomous illness (Simons DG, Travell J, 1999).

The characteristic referred pain for trigger points is due to the activation of one spinal neuron by two or more different peripheral nociceptive afferent neurons in different muscles (Mense S., 1990). Muscles do not have 1-to-1 neural connections, meaning that pain is not correlated to a specific muscle.

Clinical consequences: The autonomous trigger points often cause complications if left untreated for long periods: Due to weakness, spasm and coordination problems, the musculature often suffers additional injury. The long-term muscle contracture leads to therapyresistant insertion tendinosis. Trigger points can also lead to central pain chronification (Mense S., 2001).

Therapy planning: The patients' description of their pain regains significance for therapy planning, as reported pain patterns that would seem illogical from a neurological perspective often exactly correlate with referred pain from affected muscles. The muscles that are suspected causing the problems are palpated for local nodes and referred pain elicited by pressure. In ideal cases, this pain correlates with the pain described by the patient. A focused shock wave is even more effective for provoking referred pain. An examination for muscle contractures and the information regarding the activities that could be causing overexertion are also valuable for determining the localisation of trigger points.

Therapy is started at the clinically-relevant active trigger, followed by the satellite and secondary triggers and finally the triggers in the muscle chain. Radial pressure waves: In our experience up to this point it has been shown that the radial pressure waves produced by projectile impact are highly effective, although their physical properties are only partially correlated with the trigger point theory. The pressure waves are neither point-shaped nor do they radiate from the skin into muscle in a radial fashion. They also do not reach into the deep layers of thick muscle groups due to their maximum penetration depth of 30 mm.

Nevertheless, they can be used to treat muscle nodes and reduce muscle tone in thin muscles eliminating local and referred pain. They present the advantage of being suitable for treating large muscle areas.

Possible mechanisms of action currently under discussion for superficial pressure wave therapy include: PAIN MODULATION caused by anti-irritation effects of excitation of a-delta nociceptors in and below the skin, stimulation of high-frequency MUSCLE OSCILLATIONS and THREEDIMENSIONAL EFFECTS within sarcomers.

Additional hypothetical mechanisms of action for pressure and shock waves include: Elimination of ISCHEMIA and MODULATION OF VASONEUROACTIVE SUBSTANCES (two major causes of trigger pathophysiology) and MECHANICAL TRANSDUCTION as a cellular response to external stimulation. DESTRUCTION OF DAMAGED MUSCLE FIBRES by shock waves (Mense S, 2001) does not appear likely, as I have never observed enzyme elevation following therapy.

Based on these mechanisms of action, wide-area shock transmitters of 15, 20 and even 35 mm in diameter are increasingly being used with shock frequencies of 15 Hz and more. Lower shock frequencies have the disadvantage of increased pain during treatment. Shock transmitters with a diameter of less than 10 mm can produce enormous peak pressures, which often lead to haematomas and skin lesions.

During treatment, several hundred shocks are first applied locally to each of the identified trigger areas using a punch technique. After this, the muscle is treated over a wide area using long strokes. The total number of shocks per muscle is between 500 and 4000, depending on the size of the muscle. The treatment pressure selected in each case ranges near the pain threshold and varies between 1.0 and 3.5 bar, depending on the muscle thickness. The pressure is increased from treatment to treatment. The treatment frequency is between 4 and 8 treatments once or twice weekly.

After this, complaints should improve by 80%. If results are significantly lower than this value, extended diagnostics are indicated for finding underlying disorders that are continuously irritating the muscle.

Focused shock waves: As the effects of radial pressure waves are limited to a superficial area, focused shock waves have been used increasingly in recent years. These waves have a penetration depth of more than 5 cm, making it possible to reach deeper triggers, such as those in the gluteal muscles. Their small focus also allows for point-shaped therapy. This often provokes referred pain, which is rarely possible using radial pressure waves.
For this reason focused shock waves are also suitable in diagnostic terms for precise localisation of trigger points. After diagnostic triggering of referred pain, local treatment is performed with 200 to 500 shocks per trigger node. Unlike radial pressure waves, the shock frequency should not exceed 4 Hz. Research performed by NEULAND regarding mechanical transduction indicate that this is due to the refractory period of the cells. The energy flux density is between 0.05 and 0.25 mJ/mm² and is selected depending on the pain intensity during treatment.

In this case complaints should also have improved by 80% after a maximum of 6-8 treatments (1- 2/week). Combination of radial pressure waves - focused shock waves: The most recent development is that the combination of both types of waves during treatment has been found to be helpful. After localisation of the painful trigger points by causing referred pain with the focused shock wave, local treatment is performed with the focused shock wave in the described manner. The trigger point is then treated with several hundred shocks of radial pressure waves and the entire muscle is relaxed using long strokes over a wide area.

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The results of combined treatment are better than either of the respective individual therapy methods alone. Clinical example 1: Acute and chronic pseudoradicular low back pain The investigation of trigger points is imperative in cases of irradiating lumbar pain without paresis. Irradiation of pain into the gluteal region can be caused by trigger points in the extensor muscles at the thoracolumbar transition as well as in the quadratus lumborum muscle. These muscles are located in the cranial subcostal region and directly above the distal region of the iliac crest.

In contrast, true irradiation into the lower extremity is often caused by deep trigger points in the gluteal muscles, particularly in the gluteus minimus. Patients often describe additional dysesthesia of the heel and toes as well as unstable gait due to a loss of control over the muscles of the lower extremity. All of these symptoms are reversible with the combined application of shock and pressure waves.

Clinical example 2: Acute and chronic cervical spine pain, cervical spine pain with headache and cervical/brachial pain The trigger-related irradiation of pain from the cervical spine is often felt as a headache. A typical muscle that can cause this is the middle part of the trapezius muscle. The pain is described as hood-shaped and extends to the temporal region and behind the eyes. In this case the best results are also achieved with combined application of shock and pressure waves.

Other muscles that can be responsible for headache include the splenius muscles, the semispinalis capitis muscles and the sternocleidomastoid muscles. The levator scapulae muscle is more often responsible for local pain at the lateral base of the neck with associated limitation of rotation.

Brachial pain can be caused at the cervical spine due to problems with the scalenus anterior and medius muscles. All other muscles responsible for brachial pain are located in the shoulder and thorax.

Clinical results:
With accurate diagnostics, significant pain relief (VAS < 2) can be achieved in 80% of cases and lasts for at least 6-12 months, if not permanently. No improvement is possible in 20% of all cases, and increased pain is observed in 2% of the patients. An increased range of motion at the cervical spine was also achieved, which remained constant after 3 months: +20° of rotation, +16° of anterior and posterior flexion and +17° of lateral flexion.

These increases in range of motion are identical for patients of middle age (40 years) and older age (60 years).

Complications:

Complications are minimal with correct usage of the devices. In addition to haematomas caused by radial pressure waves, primarily when used on the gluteal musculature, the patient should be advised of a temporary increase in pain lasting 1-2 days.

For treatment of the cervical spine, headaches and temporary worsening of existing tinnitus may occur. Resistance to therapy: Insufficient or only short-term improvement was seen with the following underlying conditions: chronic nerve compression without neurological deficits (spinal or foraminal narrowing, large protrusions, post-operative fibrosis or radiculitis), psychovegetative exhaustion, severely por posture, inflammatory rheumatoid diseases, fibromyalgia, hormonal disorders with involvement of muscle metabolism (hypothyroidism, hyperparathyroidism) and long-term inadequate ergonomics.

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Contraindications: Treatment over the lung using focused shock waves with an excessively deep focus and high energy is absolutely contraindicated.

Relative contraindications include diseases in the above-mentioned group of therapy-resistant diseases, medication with anticoagulants and treatment over the thoracic spine, lumbar spine or abdomen in pregnant women.

Summary and outlook: Based on the current state of knowledge, shock waves function by stimulation of the muscle and not by damaging it. As a result of research carried out by Neuland (2006), it is known that focused shock waves can cause a migration of mesenchymal stem cells, the extent of which depends on the treatment parameters. Excessive impulse counts have led to poorer results.

This research and personal clinical experience indicate that the selection of treatment parameters is of decisive importance for therapeutic success.

For the future, we should strive to determine the best parameters for energy, number of shocks, shock frequency, treatment frequency and the type of wave source with regard to the ability of the treated tissue to respond to therapy.

2006
Journal publication
Orthopaedic trigger shock wave therapy with radial and focused shock waves: Current Status

Orthopädische Praxis 42, 5 (2006), 303-12

Dr. M. Gleitz, Luxembourg

The trigger point theory of Travell and Simons represents the basis for diagnostics and therapy of myofascial pain syndromes. This therapy is however not in wide use, due to the difficulty of identifying trigger points and its lack of efficiency.

Application of shock waves to trigger points represents a new therapy method. Combined use of radial and focused shock waves allows for efficient local treatment and wide-area treatment of the affected muscles. In particular, focused shock waves can be used to activate referred pain, providing a reliably precise diagnostic method.

Based on the authors' experience, trigger shock wave therapy is indicated for a number of functional disorders. Reported success confirms the concept of the muscle as a pain organ and therefore lends this therapy high relevance among conservative methods.

Scientific evidence of the mechanism of action has to be defined.

2007
Presentation
55th Annual Meeting of the Association of Southern German Orthopaedists e.V. (Baden-Baden)
Treatment results for combined radial and focused shock wave therapy for chronic cervical spine pain
Dr. M. Gleitz, Luxembourg

Introduction:
Radial pressure waves play an important role in muscle shock wave therapy. Focused shock waves have recently been used for treatment of muscle trigger points in addition to their original use for the treatment of tendons. The advantage of this method is attributed to the fact that the focused nature of the waves allows for more precise identification of muscle triggers due to provocation of characteristic referred pain, resulting in an improved treatment.

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Material and method:

To determine the treatment efficiency of various shock waves, a prospective randomized study was performed on 150 patients with chronic cervical spine pain (>6 months, VAS 7.2) during an observation period of 3 months. Three comparable groups of 50 patients each were treated in 6 sessions as follows: Group 1 (RPW) was only treated with radial pressure waves (8000 shocks/session, 1.8-3.5 bar). Group 2 (RPW-FSW) was treated with radial pressure waves (4000 shocks/session) and also with focused shock waves (1200 shocks/session, 0.05-0.15 mJ/mm², 300 shocks/trigger area). Group 3 (FSW) was only treated with focused shock waves (2100 shocks/session). Therapeutic success was measured by evaluating range of motion (CROM) and VAS before therapy, after therapy and at a 3-month follow-up.

Results:

Group 1 (RPW) confirmed increases in ROM as reported in earlier studies (Gleitz, 2004) of +20° rotation, +17° anterior/posterior flexion und +16° lateral flexion at the end of treatment and at a 3-month follow-up. Pain intensity (VAS) dropped from 7.2 to 2.1.

Group 2 (RPW-FSW) achieved a comparable increase in mobility. The reduction in pain, however, started significantly earlier than in Group 1 and lower long-term pain intensity was achieved (VAS 1.7, $p<0.05$).

Group 3 (FWS), in comparison to the other groups, achieved a significantly lower ($p<0.05$) increase in ROM of only +13° of rotation, +17° of anterior/posterior flexion and +16° of lateral flexion. Pain intensity fell to VAS 2.2, a significantly lower decrease than in Group 2 (RPW-FSW), but not significantly lower than in Group 1 (RPW).

Conclusion:

Combined treatment of muscle triggers with both radial pressure waves and focused shock waves achieved better results with the selected therapy parameters than either therapy alone. Compared to purely radial treatment, the addition of focused shock waves to therapy showed the benefit of a more rapid and effective reduction in pain, but did not show greater improvement of ROM. The reduced increase in ROM with sole application of focused shock waves despite the improved local effects could be due to the relatively smaller muscle area that was treated in each session.

2007
Presentation
55th Annual Meeting of the Association of Southern German Orthopaedists e.V. (Baden- Baden)
Diagnostic value of focused shock waves for pseudoradicular low back pain
Dr. M. Gleitz, Luxembourg

Introduction:
Pseudoradicular low back pain is one of the most common symptoms of chronic lumbar problems. According to Travell & Simons, it can be caused by trigger points in the Mm. Gluteus minimus and medius. In addition to the patient's pain report, manual pressure diagnostics with firm palpation are recommended, which may result in replication of the pain described by the patient. This type of examination is however very subjective.

This study seeks to examine the option of pain provocation with focused shock waves, which provide the technical advantages of a deeper penetration and a precise localisation.

Material and method:

Manual and shock wave-guided trigger point diagnostics were performed in the gluteal musculature of 117 patients with chronic (>6 months) pseudoradicular low back pain (negative CT or MRI findings) and the reproducibility of the patients' reported spontaneous irradiating pain was registered. For manual examination, a pressure bar with a rounded pressure surface of 1 cm in diameter was used to apply pressure up to the pain threshold in the gluteal muscles. As a shock wave a focused Duolith (Storz) shock transmitter was used to apply shock waves with a penetration depth of 5 cm. The used energy ranged from 0.10 to 0.35 mJ/mm². The gluteus minimus and medius muscles were scanned for trigger points along longitudinal and transverse lines.

Results:
Manual pressure diagnostics triggered the patients' pain in 64% of cases. Due to the high level of pressure applied, 53% of patients developed multiple haematomas.

Shock wave diagnostics resulted in reproduction of the patients' pain in 92% of cases, significantly better (p<0.01) than with the manual technique. Patients reported that the triggered radiating pain was more precise and irradiated further distally. In addition, irradiation into the inguinal region, lumbar spine, gluteal and parasacral regions and along the anteromedial thigh was provoked, which patients had previously experienced only as a dull spontaneous pain. Side effects such as haematomas or skin lesions were not observed with shock wave diagnostics.

Conclusion:
Focused shock waves are highly superior to the manual method for the diagnosis of pseudoradicular radiated pain and provide reproducible results. Due to the lack of side effects and precise localisation, shock waves represent an ideal diagnostic instrument for wide-area examination of the gluteal musculature, which is responsible for the vast majority of cases of pseudoradicular pain. Shock waves should be included in diagnostics in a more systematic fashion in the future.

2007
Presentation
10th International Congress of the International Society for Musculoskeletal Shockwave Therapy, ISMST, (Toronto, Canada)
Results of the combined treatment with radial and focused shockwaves in patients with chronic cervical pain
Dr. M. Gleitz, Luxembourg

Introduction:
The radial shockwaves have already received acknowledgement in the treatment of myofascial pain. Presently the focused shockwave that was known from the treatment of tendons is now used more and more in the treatment of muscular trigger points. By being able to regularly provoke the characteristic referred pain of muscular trigger points with the focused shockwave one can presume that this treatment will have more advantages.

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Material and method:
To evaluate the efficiency of the different shockwaves a prospective randomized study was executed on 150 patients with chronic cervical pain (> 6 months, VAS > 6) during an observation interval of 3 months. 3 comparable groups of 50 patients each were treated 6 times with shockwaves: Group 1 (RSW) was treated with the radial shockwaves (8000 impulses/session, 1.8- 3.5 bar). Group 2 (FSW-RSW) received a combined treatment starting with the focused shockwaves (1200 impulses/session, 0.05-0.35 mJ/mm²) and than continuing during the same session with the radial shockwaves (4000 impulses). Group 3 (FSW) was only treated with the focused shockwave (2100 impulses/session).

As clinical parameters we measured the mobility of the cervical spine (CROM) and the pain level (VAS) before and after the treatment and 3 months later.

Results:
Group 1 (RSW) achieved an increase of +20° in rotation, +17° in ante-retro flexion and +16° in Lateroflexion after treatment and 3 months later. The pain level was reduced from VAS 7.2 to 2.1.

Group 2 (FSW-RSW) showed a slightly larger increase in mobility than group 1 (but was not statistically significant). The reduction of pain was the greatest (VAS 1.7, p<005) and appeared earlier than in the other 2 groups.

Group 3 (FSW) gained less mobility (+13° in rotation, + 10° in ante-retro flexion, + 11° in latero flexion, p<0.05) but achieved the same pain reduction as group 1.

Conclusion:
The combined treatment of the focused and the radial shockwaves (group 2) achieves better results as the monotherapies in group 1 and 3. The big advantage of this combined treatment seems to be the amount and speed of pain reduction. The smaller gain in mobility after treatment with the focused shockwaves alone could be explained by the fact, that the treatment area of this precise shockwave is too limited and that the flexibility of muscles can also be increased by treating painless muscle areas, as has been done using the imprecise radial shockwave.

2007
Presentation
German Congress for Orthopaedics and Trauma Surgery 2007 (10/27/2007, Berlin)

Continuing education course for shock waves by DIGEST (*Deutschsprachige Internationale Gesellschaft für Extracorporeal Stosswellentherapie*)
Trigger point shock wave therapy
Dr. M. Gleitz, Luxembourg

Introduction:

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Trigger points are characterised by 2 properties: *pain* (local and referred pain) and *dysfunction* of the musculature (contracture, strength reduction, coordination deficit). They represent an autonomous illness that requires special treatment (Simons DG, Travell J, 1999).

Therapy planning:
The muscles to be treated are selected based on the following criteria: reported pain; palpation for locally hardened nodes; provocation of referred pain; identification of muscle contractures; knowledge of functional muscle chains.
Order of treatment: active triggers, satellite and secondary triggers and triggers in the muscle chain.

Radial pressure waves:
Advantages: wide-area treatment using large shock transmitters (15, 20 and 35 mm in diameter) and high impulse frequency (15-21 Hz).

Disadvantages: referred pain difficult to elicit, penetration depth of 30-40 mm. Treatment technique: Trigger areas are treated locally with several hundred shocks, followed by wide-area treatment of the muscle. The total number of shocks per muscle is between 500 and 4000, depending on the size of the muscle. Treatment pressure ranges up to the patient's pain threshold (1.0-3.5 bar). Number of treatments: 4-8, 1-2/week.

Focused shock waves:
Advantages: Penetration depth > 50 mm, referred pain can be precisely elicited Disadvantages: small treatment area
Treatment technique: After diagnostic triggering of referred pain, local treatment is performed with 200 to 500 shocks per trigger node until pain disappears. EFD: 0.05-0.30 mJ/mm^2, depending on pain intensity. Number of treatments: 4-8, 1-2/week.

Planar shock waves:
Focused shock waves are defocused with geometric changes to the shock wave head, resulting in parallel waves that enter the muscle.

Advantages: higher probability of reaching trigger points Combination of radial pressure waves - focused/planar shock waves: Better results than individual therapy methods.
Successful indications:
Acute and chronic pseudoradicular low back pain. Acute and chronic cervical spine pain, cervical spine pain with headache and cervical/brachial pain. Achillodynia, plantar fasciitis, forefoot pain (due to shortened calf muscles). Periarthritic shoulder pain. Acute muscular overexertion (tension in forearm extensors and flexors, tibialis anterior and peroneal muscles).
Complications:

Using proper technique, minimal complications. Apart from haematomas caused by radial pressure waves, primarily when used on the gluteal musculature, the patient should be advised of a temporary increase in pain lasting 1-2 days.

For treatment of the cervical spine, headaches and temporary worsening of existing tinnitus may occur.

Resistance to therapy:

Chronic nerve compression without neurological deficits (spinal or foraminal narrowing). Psychovegetative exhaustion. Improper posture. Inflammatory rheumatoid disease, fibromyalgia, hormonal disorders with involvement of muscle metabolism (hypothyroidism, hyperparathyroidism) and long-term inadequate ergonomics.

Contraindications:
Absolute: Treatment through the lungs, nerves and blood vessels with excessively deep focus and high energy.

Relative: Anticoagulants, pregnancy.

Summary and outlook:
The optimum parameters for energy, number and frequency of shocks, treatment frequency and type of wave source remain to be determined.

2008
Presentation
56th Annual Meeting of the Association of Southern German Orthopaedists e.V. (Baden- Baden)
The advantage of planar (defocused) shock waves over classical focused shock waves for pseudoradicular low back pain
Dr. M. Gleitz, Luxembourg

Introduction:
The treatment of gluteal trigger points using shock waves is one of the most successful indications for pseudoradicular low back pain. Insertion triggers located near the iliac crest are however difficult to treat, because they are usually spread out over an area of more than 10 cm in length and 3 cm in width. Experience has shown

that this area is too large for focused ESW because of their point-like focus. Planar shock waves, which are defocused shock waves, represent a technical alternative that allows for a wider treatment area due to the parallel path taken by the waves. The objective of this prospective, randomised study was to investigate this theoretical advantage.

Material and method:
Two groups of 30 patients each with chronic (>6 months) pseudoradicular low back pain (negative CT scan or MRI findings) caused by gluteal insertion triggers were treated at weekly intervals with either focused or planar shock waves for 6 sessions of 2000 shocks each. The treatment was performed by continuously and slowly moving the applicator over the treatment area that was characterised by severely increased pain and referred pain.

The Duolith (Storz) shock wave device with a focused shock transmitter (0.10-0.20 mJ/mm²) and planar shock transmitter (0.25-0.56 mJ/mm²) was used without local anaesthesia. Treatment energy was increased until the pain caused by the shock wave reached 6 on the visual analogue scale (VAS). Analysis of everyday pain intensity (VAS from 0-10) was performed 3 months after completion of the treatment.

Results:
Before treatment was started, the intensity of pain (VAS) was 7.4 in the group treated with focused shock waves and 7.3 in the group treated with planar shock waves ($p=0.87$). Three months after treatment was completed, the pain intensity in the group treated with planar waves was significantly less (VAS of 2.6) than in the group treated with focused waves (VAS of
3.4, $p<0.05$).

No complications occurred in either group. The local and referred pain experienced during treatment was significantly more severe with focused shock waves than with planar shock waves.

Conclusion:
Defocused planar shock waves are superior to focused shock waves for pain reduction during treatment of wide-based insertion triggers. The decreased level of treatment pain is an additional advantage. Greater difficulty in activating referred pain is a disadvantage, but not a critical one. Despite the maximum EFD of 0.56 mJ/mm², no complications were observed.

2008
Presentation
11th ISMST Congress 2008 (05.06.-08.06.2008 Antibes, France)
Trigger point shock wave therapy: An Overview
Dr. M. Gleitz, Luxembourg

Introduction:
Trigger points are clinically characterised by 2 properties: *muscle pain* (local or referred pain) and *dysfunction* (contractures, reduction of strength and coordination). Classic trigger point therapies such as infiltrations, dry needling, stretching, friction massage has little significance in orthopaedics, in contrast to the frequency of

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myofascial pain. The rapid expansion in trigger point treatment with shock waves during recent years indicates the greater efficiency of this method. The recommended treatment methods are based on empiricism.

Chronology:
The first publications in MEDLINE on this topic were published in the late 90s. These publications reported reduction in pain (Kraus M. et al., 1999) as well as reduced muscle tone (Lohse-Busch H. et al., 1997) after the application of low-energy focused shock waves to the muscles.

In the field of orthopaedics, trigger point treatment only began later when radial pressure wave devices were introduced, which were originally developed for the treatment of tendons and calcifications. Based on the experience of trigger point therapists, they have indicated that firm pressure on muscle nodes caused them to disappear or become less painful, radial pressure wave devices were used "off-label" to treat muscles using increased mechanical pressure.

In addition to the treatment of local pain and reduction of muscle tone, treatment of clinicallyvariable referred pain developed into the primary objective. This was based on the extensive publications of Travell and Simons in the 80s.

Pathophysiology of muscular trigger points:
Based on the investigations performed by Simons and Travell, triggers are sarcomere contractures in the µm range which, if a large number of them occur in the same area, can lead to locally painful and palpable nodes with cord-like contractures in muscle.

The causes for triggers can include trauma or overexertion, leading to dysfunction at the end plate with an overriding muscle contraction. An energy crisis due to ischemia and the release of vasoneuroactive substances then starts a vicious circle. The temporary contraction becomes a long-lasting contracture that can no longer be relieved without an external influence, thus establishing itself as an autonomous problem (Simons DG, Travell J, 1999).

The characteristic referred pain for trigger points is due to the activation of one spinal neuron by two or more different peripheral nociceptive afferent neurons in different muscles (Mense S., 1990). Muscles do not have 1-to-1 neural connections, meaning that pain perception is not correlated to a specific muscle.Once the trigger point has been created, it can continue even after its cause has disappeared and can become an autonomous secondary problem that has to be treated separately.

Clinical consequences:
Triggers often cause complications if left untreated for long periods: Due to weakness, spasms and coordination dysfunction, the musculature often suffers additional injury. The long-term muscle contracture leads to therapy-resistant insertion tendinopathies. Triggers can also lead to a chronic central pain (Mense S., 2001).

Therapy planning:
The patients' description of their pain regains significance for therapy planning, as reported pain patterns that would seem illogical from a neurological perspective often exactly correlate with referred pain from muscles affected with triggers. The muscles that are suspected to be causing the problem are palpated for local nodes and

referred pain triggered by pressure. In ideal cases, this pain will correlate with the pain described by the patient. A focused shock wave is even more effective for provoking referred pain. A search for muscle contractures and information regarding activities that could be causing overexertion are also valuable for determining the localisation of trigger points.

Therapy is started at the clinically-relevant active trigger, followed by the satellite and secondary triggers and finally the triggers in the muscle chain.

Radial pressure waves:
Our experience up to this point has shown that the radial pressure waves caused by projectile impact are highly effective, although their physical properties only partially correlate with the trigger point theory. The pressure waves are not point-shaped and penetrate from the skin into muscle in a radial fashion. They also do not reach into the deep layers of thick muscle groups due to their maximum penetration depth of 30 mm. Nevertheless, they can be used to treat muscle nodes and reduce muscle tone in thin muscles as well as eliminating local and referred pain. They present the advantage of being suitable for treating large muscle areas.

Possible mechanisms of action currently under discussion for superficial and wide-based pressure wave therapy include PAIN MODULATION caused by anti-irritation effects of excitation of a-delta nociceptors in and below the skin, stimulation of high-frequency MUSCLE OSCILLATIONS and THREE-DIMENSIONAL EFFECTS OF SARCOMERES. Additional hypothetical mechanisms of action for pressure and shock waves include: elimination of ISCHEMIA and MODULATION OF VASONEUROACTIVE SUBSTANCES (two major causes of trigger pathophysiology) and MECHANICAL TRANSDUCTION as a cellular response to external stimulation.

Based on these mechanisms of action, wide-area shock transmitters of 15, 20 and even 35 mm in diameter are increasingly being used with shock frequencies of 15 Hz and more. Lower shock frequencies have the disadvantage of increased pain during treatment. Shock transmitters with a diameter of less than 10 mm can produce enormous peak pressures, which often lead to haematomas and skin lesions.

During treatment, several hundred shocks are first applied locally to each of the identified trigger areas using a punch technique. After this, the muscle is treated over a wide area using long strokes. The total number of shocks per muscle is between 500 and 4000, depending on the size of the muscle. The treatment pressure selected in each case ranges near the pain threshold and varies between 1.0 and 3.5 bar, depending on the muscle thickness. The pressure is increased from treatment to treatment. The treatment frequency is between 4 and 8 treatments once or twice weekly.
After this, pain should decrease by 80%. If results are significantly lower than this value, extended diagnostics are indicated for finding hidden illnesses that irritate the muscle continuously.

Focused shock waves:
As the effects of radial pressure waves are limited to a superficial area, focused shock waves have been used increasingly in recent years. These waves have a penetration depth of more tan 5 cm, making it possible to reach deeper triggers, such as those in the gluteal muscles. Their small focus also allows for point-shaped therapy. This often triggers referred pain which is rarely possible using radial pressure waves. For this reason focused shock waves are also suitable in diagnostic terms for precise localisation of trigger points.

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After diagnostic triggering of referred pain, local treatment is performed with 200 to 500 shocks per trigger node until pain disappears. The energy flux density is between 0.05 and 0.35 mJ/mm² and is selected depending on the pain intensity during treatment.

Under this treatment pain should also decrease by 80% after a maximum of 6-8 treatments (1- 2/week).

Planar shock waves
They are the most recent development. Focused shock waves are defocused with geometric changes to the shock wave head, resulting in parallel waves that enter the muscle. The objective is to reach a trigger point located at a depth in the muscle that cannot be measured, and to reach it with a greater degree of certainty than has been possible with the spatially restricted focus.

Combination of radial pressure waves – focused/planar shock waves:
The combination of both shock waves has been found to be helpful in practice. After localisation of the painful trigger points by provoking referred pain with the focused shock wave, local treatment is performed in the described manner. The trigger point is then treated with several hundred shocks of radial pressure waves and the entire muscle is relaxed using long strokes over a wide area.

The results of combined treatment are better than the individual therapy methods alone.
Clinical examples

1.- Acute and chronic pseudoradicular low back pain The investigation of trigger points is imperative in cases of radiating lumbar pain without paresis. Radiation of pain as far as the gluteal region can be caused by triggers in the extensors at the thoracolumbar transition as well as in the quadratus lumborum muscle. These muscles are located in the cranial sub costal region and directly above the distal region of the iliac crest. In contrast, referred pain into the lower extremity is often caused by deep triggers in the gluteal muscles, particularly in the gluteus minimus. Patients often describe additional dysesthesia of the heel and toes as well as unstable gait due to a loss of control over the muscles of the lower extremity. All of these symptoms are reversible with the combined application of shock and pressure waves.

2.- Acute and chronic cervical spine pain, cervical spine pain with headache and cervical/brachial pain The trigger-related radiation of pain from the cervical spine is often felt as a headache. A typical muscle that can cause this is the middle part of the trapezius muscle. The pain is described as hood-shaped and extends to the temporal region and behind the eyes. In this case the best results are also achieved with combined application of shock and pressure waves. Other muscles that can be responsible for headache include the splenius muscles, the semispinalis capitis muscles and the sternocleidomastoid muscles. The levator scapulae muscle is more often responsible for local pain at the lateral base of the neck with associated limitation of rotation.
Brachial pain can be caused at the cervical spine due to problems with the scalenus anterior and medius muscles. All other muscles responsible for brachial pain are located in the shoulder and thorax.

Results:
With accurate diagnostics, significant pain relief (VAS from 7 to < 2) can be achieved in 80% of cases and lasts for at least 6-12 months, if not permanently. No improvement is possible in 20% of all cases, and increased pain is observed in 2% of the patients.

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An increased range of motion at the cervical spine was also achieved, which remained constant after 3 months: +20° of rotation, +16° of anterior and posterior flexion and +17° of lateral flexion. These increases in range of motion are identical for patients of middle age (40 years) and older age (60 years).

3.- Achillodynia, plantar fasciitis, forefoot pain Contractures of the calf muscles are a primary risk factor for the aforementioned overexertion syndromes. Shock wave therapy can significantly increase the active elasticity of the calf, leading to a reduction in tension in the overstressed tendons and fascias.

4.- Periarthritic shoulder pain The important muscles in terms of function include the subscapularis, infraspinatus, deltoideus, trapezius, latissimus dorsi and pectoralis major muscles. Trigger points in these muscles are created by acute overloading in sport and as phenomena associated with structural shoulder lesions. Clinically, the most significant effects are rotation restrictions and local as well as referred pain in the elbow and hand.

5.- Acute muscular overexertion Tension in forearm extensors and flexors, tibialis anterior and peroneal muscles are well suited to shock wave therapy. Only 1-3 treatments are required if treatment is started in the early stages.

Complications:
Complications are minimal with correct usage of the devices. In addition to haematomas caused by radial pressure waves, primarily when used on the gluteal musculature, the patient should be advised of a temporary increase in pain lasting up to 1-2 days. For treatment of the cervical spine, headaches and temporary worsening of existing tinnitus may occur.

Resistance to therapy:
Insufficient or only short-term improvement was seen with the following underlying conditions: chronic nerve compression without neurological deficits (spinal or foraminal narrowing, large protrusions, post-operative fibrosis or radiculitis), psychovegetative exhaustion, severely por posture, inflammatory rheumatoid disease, fibromyalgia, hormonal disorders with involvement of muscle metabolism (hypothyroidism, hyperparathyroidism) and long-term inadequate ergonomics.

Contraindications:
Treatment over the lungs, main vessels, nerves using focused shock waves with a deep focus and high energy is absolutely contraindicated. Relative contraindications include illnesses in the above-mentioned group of therapy-resistant diseases, medication with anticoagulants and treatment over the thoracic spine, lumbar spine or abdomen in pregnant women.

Summary and outlook:
Our experience of trigger shock wave therapy up to this point has shown that it represents an enrichment of conservative orthopaedics.
The future task should be to determine the best parameters for energy, number of shocks, shock frequency, treatment frequency and the type of wave source with regard to the ability of the treated tissue to respond to therapy.