ESWT Guidelines

English version

Updated and agreed from the ISMST Managing Board, in close cooperation with the Germanspeaking Society for Extracorporeal Shockwave Therapy (DIGEST)

Daegu, South Korea July 20th, 2023

Content

Introduction

ISMST Guidelines aim to assist healthcare providers in delivering high quality care to patients, based on the most current and reliable medical research and evidence available at the time of their development.

The ISMST guidelines were developed on the basis of the DIGEST guidelines, the German speaking Society for Extracorporeal Shockwave Therapy (Deutschsprachige Internationale Gesellschaft für Extrakorporale Stosswellentherapie, DIGEST) published at the homepage www.digest-ev.de.

The ISMST Managing Board has reviewed and released these Guidelines in accordance with the DIGEST authors, they are adapted to be disseminated internationally by the ISMST Managing Board.

This 3rd edition of the ISMST Guidelines is an update of extracorporeal shockwave treatment applied to a wide range of pathologies of diverse origins and localizations in many medical fields, evidence based with a view to the published literature, keeping the basic principles **as a non-invasive, safe and effective** therapy.

On behalf of the ISMST, a working group for this edition has been established, the chapters were divided among experts, who largely worked out the explanations independently, but all members of this working group were able to participate in each chapter.

The ISMST Guidelines' Editorial Board in alphabetical listing:

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1. Physical basics

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Why is it important for physicians to have knowledge about shockwave physics?
Shock waves are special acoustic waves generated in a medical device applicator by various physical principles. The device head must be acoustically coupled to the patient to deliver energy to the target region where a therapeutic effect is desired.
Shock wave generation and propagation is subject to the governing laws of acoustics. They are characterized among other parameters by a very steep shock front. Due to the associated large pressure amplitudes, nonlinear sound propagation phenomena also play a role.
The physics section of these guidelines is intended to provide clinicians with a foundational understanding of shock waves relevant to their daily practice. Described are interactions of the shock wave along its path in a typical clinical setting, which may significantly alter the shock wave and thus no longer correspond to the values from the manufacturer's data sheet (typically measured in an undisturbed water bath).
Shock waves and their associated spatial distribution (often referred to as the sound field) can be described by different technical parameters. It is important to understand how to interpret these parameters and their interplay.
In order to better compare clinical studies with different devices, it is helpful to understand the main differences of the generation principles, sound field characteristics, and key parameters.
Ultimately, it should be clear, we can only understand and optimize the effect of a shock wave if we know how it arrives at the target zone. In the following sections, the sound wave propagation from generation via tissue interaction to the targeted therapy zone is described.

Shock wave generation

Over the years, three primary shock wave generating mechanisms have been adopted by the medical device manufacturers. While the underling technologies which are discussed subsequently differ, the unifying principle is the effective conversion of electrical energy into targeted acoustic shock wave energy.

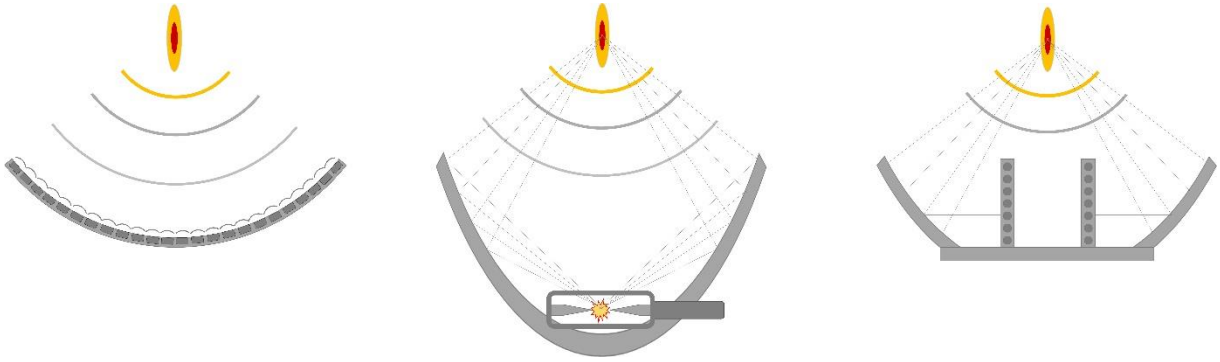

Fig. 1: Schematic illustrations of (left) piezoelectric, (center) electrohydraulic, (right) electromagnetic shock wave generation principle. ©RWTH Aachen University, Germany

Piezoelectric generation principle

Piezoelectric generated sound waves have been used in diagnostic medical ultrasound devices since the early 1940s to generate reproducible pressure pulses that are being reflected at different tissue interfaces for diagnostic anatomical imaging. The generation principle is based on the inverse piezo-effect where a brief high voltage pulse causes an elongation of the piezo crystal.

The piezo crystals in diagnostic ultrasound devices are designed to emit very small pressure pulses. In contrast, for shock waves high amplitudes are required. To achieve these high amplitudes, piezoelectric transducers, in contrast to other technologies, require larger sound emitting areas. This is achieved by combining a large number of powerful small piezo ceramics and focusing the pressure pulses, thus increasing the pressure, either by orientating the crystals in a spherical shell or by using acoustic lenses (more details about focusing in 0). Alternatively, a large single crystal can be used. Alternatively, the piezo crystals can also be stacked in double layers to achieve even higher summative amplitudes.

Electrohydraulic generation principle

The electrohydraulic generation principle was first experimentally implemented in the late 1940s, with shock waves generated by a high voltage discharge in a spark plug.

In contrast to piezoelectric or electromagnetic shock waves, which start as low amplitude pressure waves and have to steepen up to form a shock front by wave-focusing, electrohydraulic shock waves maintain inherent shock wave characteristics from the point of generation.

The electric breakdown across the spark gap in the water filled transducer is inherently stochastic and a difficult to control physical process which may result in time-varying applicator output (pressure and focus position) from shot to shot.

Similar to the piezoelectric generation, electrohydraulic shock waves also need to be re-focused to achieve high energy wave pulses in the target zone. This can be achieved by using acoustic reflectors (more details in 1.2).

Electromagnetic generation principle

In electromagnetic shock wave generation, a brief high voltage pulse is sent through an electrical coil which results in a rapid displacement of an adjacent membrane, akin to the workings of a loudspeaker, but with much higher energy. This membrane can be designed to be either flat or cylindrical to create approximate planar or cylindrical pressure waves respectively.

Similarly to piezoelectric shock wave generation, electromagnetically generated shock waves have to be focused achieve the characteristic steep shock front pressure profile of a shock wave (more details in 1.2).

Ballistic generation principle

In contrast to the previously mentioned principles, ballistic devices generate a pressure wave by the collision of an accelerated projectile (either by compressed air or by electromagnetic induction) with an impact body (applicator). The collision generated pressure wave has a maximum amplitude on the applicator's surface and is directed radially from it. Hence, the intensity decreases with the distance. This is the reason why ballistic shock wave generators are commonly referred to as radial devices. It is more accurate to speak of pressure waves rather than shock waves when referring to this technique as the sound waves have a different shapes and propagation. However, in medical parlance the term radial shock wave therapy has become established but other names are also used ("Radial Shock Wave Therapy", RSWT; "Extracorporeal Pulse Activation Therapy", EPAT; "Radial Pressure Wave Therapy").

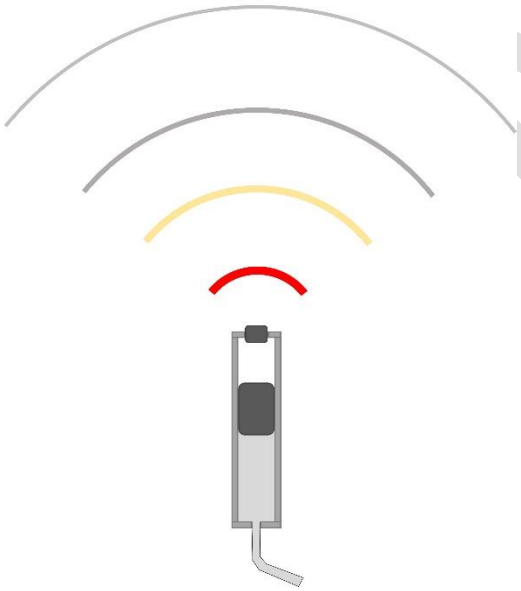

Fig. 2: ballistic (radial) generation principal

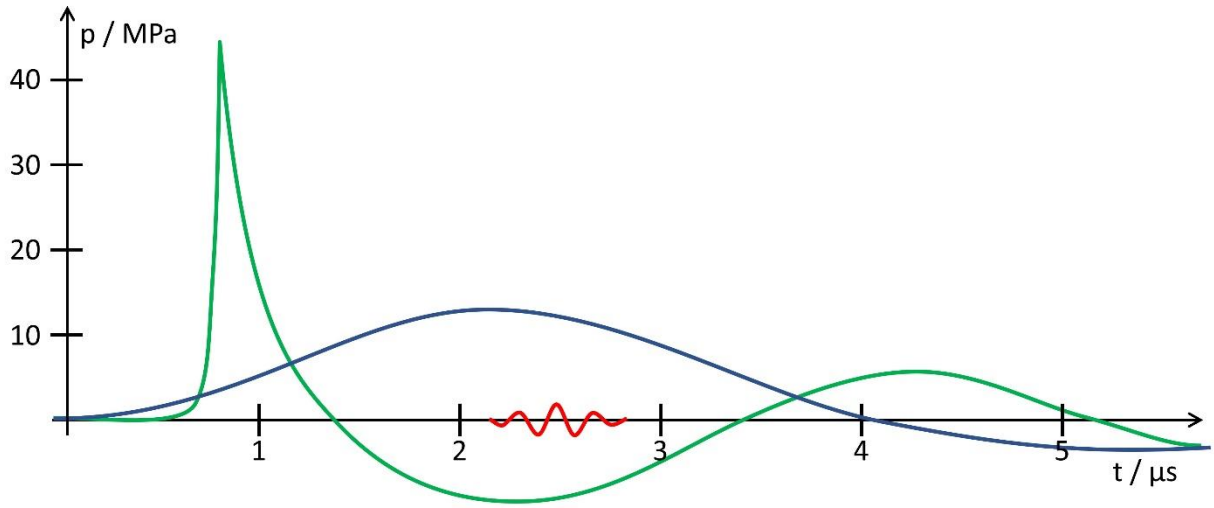

Fig. 3: Comparison of wave forms based on medical utilization: Shock wave (green) with the characteristic short rise time as measured in the focal point of piezoelectric, electrohydraulic, or electromagnetic devices, ballistic pressure wave (blue), and a 5 MHz diagnostic ultrasound pulse (red).

Shock wave focusing

All of the principles mentioned generate different types of pressure waves, of which only the electrohydraulic principle has the characteristic shape of a shock wave from the outset. To achieve shock waves in the target zone inside the body all generation principles need an appropriate focusing principle. All generated pressure waves fall off rapidly with distance and the sound field rapidly takes a radial form. This requires the collection of the spreading wavefronts by a focusing mechanism (or self-focusing) to achieve high intensity shock waves.

For piezoelectric and electromagnetic generators focusing is necessary to achieve the typical shock wave shape. They start as pressure pulses and only become shock waves in the focal zone. Focusing of the initially generated pressure wave results in a steepening of the pulse front due to nonlinear acoustic wave propagation effects resulting in the typical shock wave form in the focal zone.

Whether or not focusing is necessary depends on the indication and the target zone to be treated. While superficial targets can be easily treated with any type of device, focused or unfocused, targets with a penetration depth of a few centimeters require focusing to deliver sufficient acoustic energy to the target zone.

Technically, focusing can be achieved by either direct geometry based self-focusing (e.g. placing piezo crystals on a spherical transducer), lens focusing (e.g. converting a planar electromagnetic wave to a point focused field), or focusing via a reflector (e.g. converting a radial electrohydraulic field or cylindrical electromagnetic field to a point focused field).

How well focusing can be achieved depends mainly on the signal waveform (fundamental frequency) of the initially generated pressure wave and on the aperture (diameter and angle) of the device (what percentage of a sphere's surface area around the focus is used to generate pressure) and cannot be controlled by the user.

Besides strong point- focused devices there also exist alternative focusing strategies commonly named line-focused, unfocused or weakly focused to extend the focal zone to larger treatment zone which results in reduced focal energy.
In contrast to focusing shock wave devices (fESWT), there exist another class of ESWT devices often called radial extracorporeal shock wave therapy devices (rEWST). Common for all rESWT devices is that the initial, mostly by ballistic principle, generated pressure pulse is not focused but propagates radially defocusing from the applicator.

Wave Propagation

The generated pressure wave has to be transmitted from the transducer to the acoustically coupled (i.e. ultrasound gel) body where it propagates through different tissues and interacts with it. The following phenomena can be observed: Acoustic wave transmission, reflection, refraction, scattering, attenuation, and nonlinear steeping effects occur.

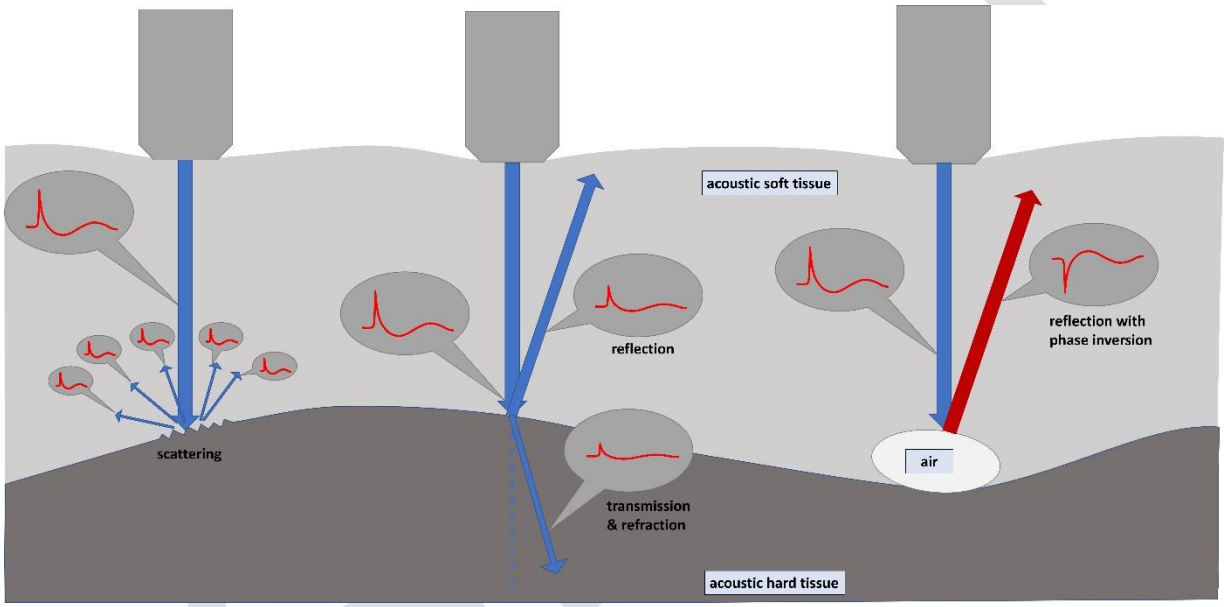

Fig. 4: Graphical illustration of different interaction of ultrasound with tissue. (left) scattering at rough surfaces, (middle) reflection and transmission at acoustic hard tissue (e.g., bone interface), (right) reflection at acoustic soft interface (e.g. air) with phase inversion (change from positive to negative pressure).

The following is a compilation of various observations on the physical mechanisms of action that might be useful for shock wave users.

Velocity and acoustic impedance of shock waves in different media.

The elasticity and the density are the most important material parameters for the determination of acoustic wave propagation. Different media in the propagation path of the wave, like water, fat, muscle, ... have different material properties, as listed in table 1. The propagation of an incoming wave is opposed by any media's acoustic impedance - a product of the material's density and speed of sound. These three acoustic material parameters determine the behavior of acoustic waves at media interfaces.

Material	Density kg/m^3	Speed of sound (m/s)	Acoustic impedance (as fraction of water)
Air	1.2	330	1.11 x 10^{-5}
Water	1000	1437	1.00
Fat	970	1480	1.00
Muscle	1060	1570	1.15
Bones:			
Cortical	1700	3600	4.25
Spongy	1000	1450	1.01

Table. 1: Impedance properties of different media

The acoustic wave interacts with surfaces between different media resulting in transmission, reflection and refraction (change of direction). Furthermore, scattering and diffraction occurs depending on the structure of the interfaces (at small interfaces or rough surfaces).
All shock wave devices need to maintain an uninterrupted acoustical path from the point of generation to the treatment zone. To achieve best transmission of the generated acoustic pulse into the body, good acoustic wave coupling between the applicator and patient is needed. The aim is to minimize acoustic reflections/scatters and maximize the acoustic transmission at the various interfaces. For one, the large contact area between the transducer and the skin or about optionally added spacers (water filled bags or a “water-like” gel pads) should be completely and continuously covered by a thin layer of ultrasound gel or similar substances (such as castor oil). This is to expel any air pockets (micro- and macroscopic air) potentially trapped in the interface (in skin crevices or about body hair) which would block transmission of the acoustical wave.
For two, spacers used to adjust the penetration depth of the applicator need to be impedance matched to the applicator itself. Using materials of different acoustical properties will decrease transmission and affect focusing, thus reducing the efficiency of the device. It is recommended to stick with manufacturer recommended spacers approved for your device.

For shock wave users the following points need to be known:

- The higher the difference of the impedance between two media, the greater sound reflections at the media interfaces are.
- When the wave travels from an acoustically soft material (e.g., soft tissue) to a hard material (e.g. cortical bone) there is an acoustically hard reflection (lower-to-higher impedance) - up to 50% of the energy is reflected, and only the remaining 50% is transmitted.
- When the wave travels from an acoustically hard material to a soft material, there also is reflection – i.e. acoustically soft reflection (higher-to-lower impedance). Since gases have a vanishingly low impedance compared to soft or hard tissue, almost

100% of the energy is reflected. This is why ultrasound gel coupling is necessary to avoid air between the applicator and the skin.

- When the shock wave is acoustically soft reflected, there is also a phase inversion. This means that in the reflected wave, the positive pressure of the incoming wave becomes negative, and the negative pressure becomes positive. This means that within a few nanoseconds after reflection, previous compressive forces now become tensile forces increasing the risk of tearing and cavitation.
  Therefore it should be avoided to treat any regions with air inclusions with high intensity shock waves!!! Even for diagnostic ultrasound there exist different recommendations of threshold of the mechanical index for tissue with tiny gas filled nuclei. Whereas for general tissue there is a limit of MI=1.9, for intestine the recommendation is to not exceed MI=1.4, for lung ultrasound to not exceed MI=0.4 or eye ultrasound 0.23.

Attenuation / Damping

As the acoustic wave propagates through tissue, it loses not only energy through reflection and scattering but also by frequency-dependent attenuation. The higher the signal frequency is, the more it gets absorbed by tissue resulting in reduced amplitudes. This effect is also known from diagnostic ultrasound where the penetration depth (i.e. depth at which most of the wave has vanished) of low-frequency devices is much greater than that of high-frequency devices.

With shock waves, it is important to consider the attenuation effect, as it alters the shape of the wave, in particular the shock front. Usually shock waves have a ground frequency (the change rate from positive to negative pressure) in the 100-200kHz range determined by the generated pressure pulse at the transducer. But in the characteristic shock front, the pressure rises rapidly from zero to peak pressure within a few nanoseconds (rise time) and therefore contains frequencies up to 20MHz and more. Thus, the shock front gets absorbed much stronger than the ground frequency of the pressure pulse.
Depending on the tissue type and on how deep the tissue is penetrated by the shock wave, the rise time could almost be double, and the peak positive pressure is almost halved (Cleveland 1998 - In Vivo Pressure Measurements of Lithotripsy Shock Waves in Pigs), and as a result, the delivered energy is also much lower than measured in a water bath.

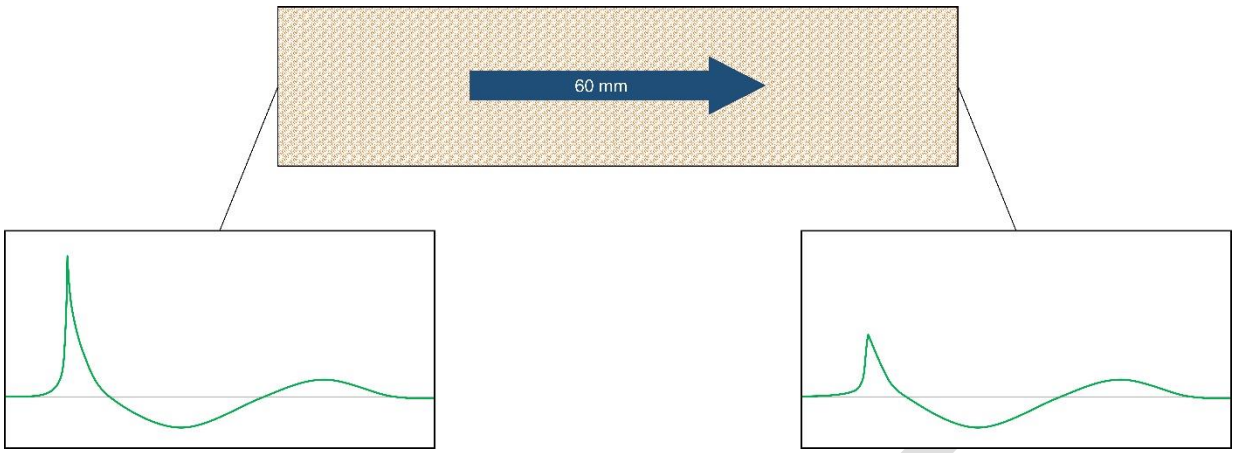

Fig. 5: When a shock wave travels through soft tissue, the high frequency parts of it get attenuated more than the lower frequencies resulting in significantly lower peak-pressure and significantly higher rise time

Characteristic properties of the focal sound field and shock wave parameters

The technical approaches to generating shock waves differ in many aspects like generation principle, generation surface area, pressure pulse form and amplitude at the transducer, shot-to-shot pulse reproducibility and stability with higher pulse repetition rates and the focusing principle.

To date, the significance of the various parameters in shock wave therapy remains unclear, but it is useful to document as many a possible established parameters to facilitate the correlation between physical parameters and clinical outcomes.

Whereas non- or weakly-focused shock wave parameters are regulated by the newly published IEC 63045:2020 standard, focused devices are still regulated by the old lithotripsy standard IEC 61846:1998, which is currently in a review process of getting updated.

As an acoustical wave propagates through the various tissues, it is subject to repeated acoustical interaction which affect its local properties. This spatial distribution of the acoustic parameters of the wave (also referred to as the sound-field) is an important factor in describing a shockwave therapy. Note, at each position the shock wave may have entirely different temporal shapes.

The following is a short summary of physical parameters used to characterize a shock wave sound field for a specific a device.

Local parameters (e.g. at focal point)

The pressure over time curve (also previously referred to as the wave form) is the evolution of the instantaneous pressure p(t) minus the ambient pressure at a particular position within the sound field.

Usually, the parameters published by the manufactures are the local parameters at the center of the focus or for radial devices at the transducers surface.

At the beginning of a shock wave there is the characteristic shock front where the pressure rises within few nanoseconds (the rise time r_s defined as the time to go from 10% to 90%) to the maximum compressional pressure defined as the peak-positive pressure (p_+). There clearly is a spatial distribution of the peak-positive pressure (p_+), but it is usually only provided at the position with maximum pressure (the focal position).

Analogously, the peak-negative pressure (p_-) is the maximum (absolute value) of the tensile pressure at any point in the pressure field.

Each shock wave carries a certain amount of energy through the target tissue. The energy of a single shock wave can be estimated by the pulse intensity integral (PII), many times also called energy flux density (EFD) or energy density (ED). The EFD is an often-used parameter for comparing ESWT devices or to transfer clinical settings from one device to another. Here it is important to know that the EFD gives you the maximum local EFD value of the shock wave field measured at the focal position. Not more! At any other position in the sound field, you have completely different (smaller) values of EFD, and the spatial distributions are substantial different across the devices. It is also important to note that EFD is a summative parameter over the entire pulse and therefore many, vastly different wave forms may still have the identical energy value.

It is of utmost importance to understand that all local, temporal parameters mentioned above only describe the pressure p(t) at a single position with a diameter of approx. 200 µm (1/5 of a millimeter), depending on the hydrophone used. At any other position in the sound field the p(t) distribution has a completely different shape and therefor parameters.

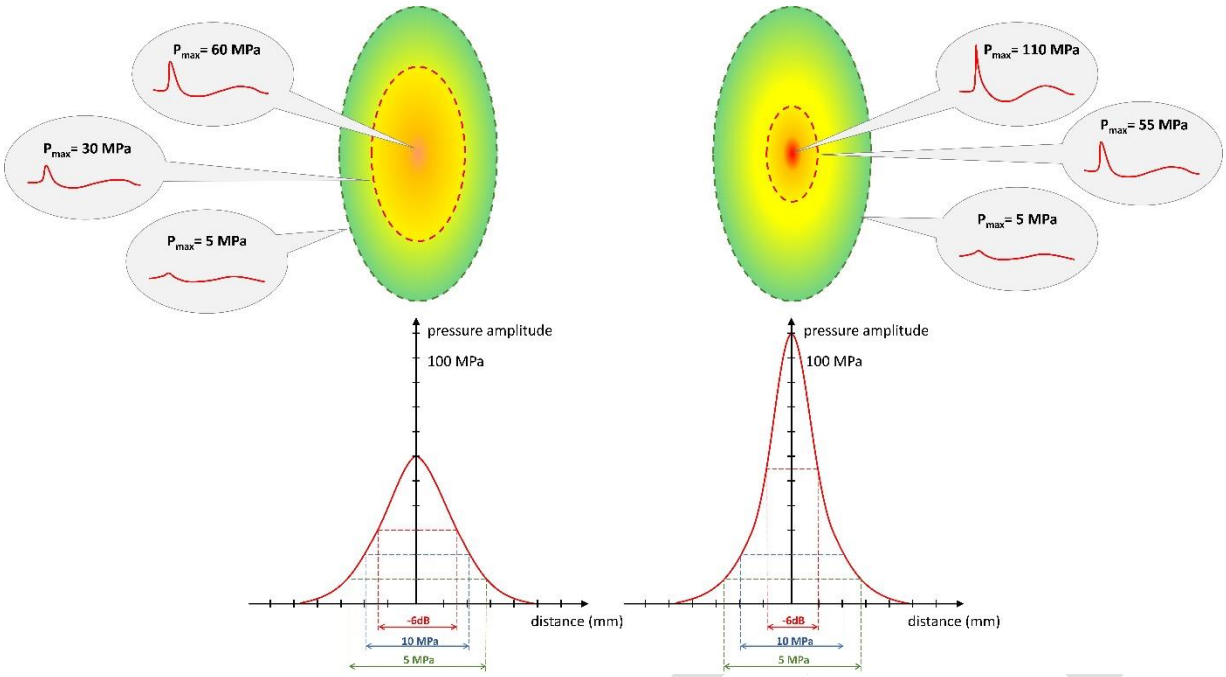

Fig. 6: Graphical illustration of two differently focused shock wave devices, both having the same 5MPa focal size, but due to focusing having different -6dB focus size. You can see that the -6dB zone is a relative magnitude (in excess of 50% of the maximum peak pressure), while the 5 MPa or 10 MPa zones are absolute magnitudes. At any position the sound field has a differently shaped p(t) curve.

Spatial parameters and pulse energy

Depending on the generation principle and focusing mechanism, shock wave devices can have varied pressure distributions in axial and lateral direction, ranging from sharply focused to non-focused radial. For focused devices there exist one position in the sound field, where the pressure accumulates to a maximum peak pressure whereas radial devices have the maximum pressure at the device's surface and the pressure radially decreases from there.

For focused devices, the size of the focal zone and the pulse energy in the surrounding of the focus can be characterized as follows:
Currently most times the -6dB zone is used to describe the size of the focus where the pressure amplitude reaches at least 50% of the maximum pressure given at the focal point.

Another possibility to describe the focal zone is the volume, where the pressure amplitude reaches at least n MPa. For example, n = 5 MPa describes the zone where the maximum pressure is at least 5 MPa at any position.
The shock wave (SW) focal zone parameters used are the extent of the axial and one for the lateral part of the assumed ellipsoidal shaped focus zone. Due to physical reasons and focusing strategies the lateral focal diameter is often 3-10 times smaller than the axial dimension.

It is important to understand the difference between these two definitions of the focal size. The -6dB zone defines a relative value as it depends on the peak-maximum pressure. Hence, it describes how good a device can focus. It gives no information about the zone the shock wave is therapeutically effective absent knowledge of the peak pressure. Hence, the -6dB zone alone is not suitable to compare therapeutic effectiveness of different devices.

In contrast, the 5 MPa zone has an absolute defined limit and may therefor better suited to compare different devices. However, since we don't know yet whether 5 MPa or e.g., 10 MPa are necessary to get a therapeutic effect, we also cannot describe a therapeutically effective zone with this parameter.
Finally, an example of why the 6-dB zone is totally unsuitable to describe a therapeutically effective zone: If one increases the intensity of a device, more energy is emitted and focused. Due to nonlinear effects, the peak pressure in the focus increases more than at other locations, which results in the -6dB zone becoming smaller with increasing intensity, while the 5MPa zone becomes larger.

Besides the dimension of the focal zone, the energy within the zone can also be similarly described. A number of different SW pulse iso-energetic bounding values E6dB, E5MPa, E5mm, and E12mm are commonly found. All energy values stand for an acoustic pulse energy, which propagates through a circular area inside the lateral focal plane. The difference is in the definition of the boundary, inside which the measured lateral energy flux density distribution is calculated. E5mm and E12mm have a fixed diameter circular transverse region of 5mm and 12mm respectively, while the E6dB and E5MPa depends on the extend of the lateral -6dB or 5MPa zone dimensions.

It is important to recognize, that all common SW-parameters mentioned are just acoustical-technical envelope parameters (absent the full individual wave forms) which roughly describe the pressure distribution of a shock wave device in a water bath.
As we have learned, the wave propagation through tissue may alter the sound field significantly. The focal in-situ SW field in tissue can thus be dramatically different resulting in entirely different SW-parameters from their manufacturer reference values.
It is important to note that no single SW-parameter is suitable to be used exclusively as therapeutically effective parameter and are furthermore insufficient for reporting of therapy settings. Neither the often used -6dB zone diameter nor the EFD value of the focal point.
Finally, it should be reiterated here that not only the device used for shock wave treatment should be recorded in the documentation, but as many of the settings as possible: the used device and applicator, the coupling, the energy levels, the number of pulses at the individual energy levels and how the shock waves where applied (distributed on the target zone). Only by preserving as much of the information of the total applied SWs over the treatment zone do we preserve our ability to can be retrospectively calculate dosing and allow for reproducibility.

On the homepage of the ISMST (International Society for Shockwave Treatment) you find a corresponding recommendation for good practice in ESWT documentation. This recommendation was developed in cooperation with the DIGEST and applies to all devices!
→ https://shockwavetherapy.org/wp-content/uploads/2023/11/20151021-ISMST-Physics-Working-Group-Recommendation-statement-20160620-sign.pdf

Physical Mechanisms of Action:

The aim of applying shock waves to the patient is to elicit a positive therapeutic effect from the applied sound field in the target zone. Simplified, one can separate the process into 2 steps. In a first step, the spatially inhomogeneous and highly dynamic pressure field physically interacts with the tissue in the target zone: this leads to high dynamic mechanical compression forces, shear forces and pressure gradients in the tissue and to mechanical impulse transmission to the tissue. High mechanical tensile forces lead to a secondary physical phenomenon, cavitation, which has its own complex behavior and significant additional mechanical impact on tissue. In contrast, thermal effects and tissue heating can be neglected for the shock wave pulses and pulse repetition rates (i.e. comparable to extremely low ultrasound duty cycles) used in ESWT.
In a second step, these different mechanical stressors may lead to different biological cell responses. For example, depending on the strength and type of mechanical cell stress, one can achieve a destructive cell/tissue effect by immediately destroying and killing the cell (e.g., cell membrane rapture), or one can stimulate the cell/tissue to regenerate. An awareness of both is important for all ESWT users. The destructive effects usually correspond to side effects, while the stimulatory effects are desired biological outcomes of ESWT. The mechanisms resulting in these stimulating effects are often summarized under the term mechanotransduction.
In the following sections, only the first step, the physical mechanisms of action, will be further discussed in detail. The biological cellular reactions in ESWT are very diverse and complicated and will be discussed in a separate chapter.

Direct, mechanical action

We know the direct, mechanical effect of high-energy shock waves from nature; part of the energy of a lightning bolt is also emitted to the surroundings as a shock wave, which can be heard as thunder at a further distance and can certainly have a destructive effect; the bang of an airplane when it breaks the speed of sound is also a shock wave.
In medicine, we use the destructive effect of shock waves for disintegration of calculi (kidney, bladder, ureter, gall or salivary stones) in lithotripsy or rupturing of tissue in surgery by histotripsy.
At very high shock wave pressure amplitudes even the connective tissue parts of the body such as skin, muscle, lungs, parenchymatous organs or blood vessels can tear. This effect is not sought in ESWT and that is why such high levels are not used.
However, as we lower the peak pressure levels, the resulting compressional and the tensile parts of the shock wave compress and stretch tissue down to a cellular level. At the

cellular level this can lead to mechanotransduction releasing growth factors and other markers initiating the know therapeutic effect of shock waves.

Cavitation

When a shock wave travels through a liquid medium, the elongated tensile portion of the wave temporarily lowers the local static pressure resulting in the creation of cavitation effects. The size of the induced bubbles depends on the effective wavelength of the tensile-wave as well as the type of liquid, the amount of gas dissolved in it, and temperature. After the shock waves relatively quick transition past the fluid, the newly formed bubbles collapse, oscillate, and dissolve again in the fluid over the timespan of approximately half a millisecond.

Cavitation excited bubbles will, when unable to maintain spherical shape due to external factors, collapse asymmetrically and generate strong micro-jets. These destructive forces can be seen in the abrasive impact on ship propellers or the disintegration of kidney stones. Predicting detailed outcomes of complex inter-bubble interaction within a cloud of many bubbles is however difficult and practitioners should focus on limiting excessive cavitation.

As the bubbles may have a lifetime of few hundreds of microseconds and even after that still some cavitation nuclei are remaining, the amount of cavitation depends on the pulse repetition rate. For higher rates, still existing bubbles will on one hand scatter the shock wave thus reducing the energy. On the other hand, still existing nuclei increase the amount of new, additional cavitation bubbles in the path of subsequent shock waves. It remains however unclear what if any, role cavitation plays in the observed biological effects.

2. Mechanism of action of shock waves

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Biological effects of shock waves[1]

The clinical effect of shock wave therapy has been known for several decades, and the indications for regenerative treatment are constantly expanding due to continuous research activity and clinical necessity. Initially, there was a hypothesis that mechanical stimulation leads to micro-lesions in tissues, and that subsequent repair processes are the main regenerative component of SWT. In recent years, however, it has become increasingly clear that the mechanical stimulus induces very specific signaling pathways in treated cells through mechanotransduction (=the cellular translation of a mechanical stimulus into a biological response), which ultimately results in the well-known regenerative effects of shock wave therapy.

Cell integrity

No cellular damage is evident in the therapeutic range after SWT. Tissue examined after SWT shows no signs of apoptosis or necrosis, and analysis by transmission electron microscopy showed no change in cellular ultrastructure after SWT[2]. The angiogenic and proliferative effect of SWT is dose-dependent up to 0.15 mJ/mm^2 EFD, and at energies higher than this, cell viability is negatively affected in vitro. Moreover, the shock wave source, the geometry of the culture vessel, and the number of pulses also affect viability[3].

Angiogenesis

Induction of new vessel formation (=angiogenesis) is a central mechanism of action of SWT. In angiogenesis, new capillaries sprout from existing vessels. This process is initiated by angiogenic factors. The best known angiogenic factor is the Vascular Endothelial Growth Factor (=VEGF). This is present in 4 different isoforms: VEGF-A, VEGF-B, VEGF-C, and VEGF-D. These proteins can activate their specific receptors (VEGF receptor (VEGFR) 1-3) and thus exert their biological effect. VEGFR3 is mainly present on lymphatic endothelial cells and is activated by VEGF-C and VEGF-D. VEGFR2 binds the major isoform of VEGF, namely VEGF-A, and leads to proliferation, migration, and survival of endothelial cells. SWT

[1] Graber M, Nagele F, Hirsch J, Polzl L, Schweiger V, Lechner S, Grimm M, Cooke JP, Gollmann-Tepekoylu C, Holfeld J. Cardiac Shockwave Therapy - A Novel Therapy for Ischemic Cardiomyopathy? *Front Cardiovasc Med* 2022;**9**:875965.
[2] Liu B, Zhang Y, Jia N, Lan M, Du L, Zhao D, He Q. Study of the Safety of Extracorporeal Cardiac Shock Wave Therapy: Observation of the Ultrastructures in Myocardial Cells by Transmission Electron Microscopy. *J Cardiovasc Pharmacol Ther* 2018;**23**:79-88.
[3] Polzl L, Nagele F, Hirsch J, Graber M, Lobenwein D, Kirchmair E, Huber R, Dorfmuller C, Lechner S, Schafer G, Hermann M, Fritsch H, Tancevski I, Grimm M, Holfeld J, Gollmann-Tepekoylu C. Defining a therapeutic range for regeneration of ischemic myocardium via shock waves. *Sci Rep* 2021;**11**:409.

leads to the release of VEGF from the extracellular matrix and stimulation of VEGFR2[4]. This, in turn, stimulates endothelial nitric oxide synthase (eNOS) to produce nitric oxide (NO), a potent vasodilator that further promotes endothelial proliferation and thus capillary formation[5]. The potent angiogenic effect has been described in epigastric skin flap models, in hindlimb ischemia, and also in ischemic myocardium and represents a central mechanism of the regenerative component of SWT.

Recruitment of progenitor cells

In contrast to angiogenesis, vasculogenesis refers to the formation of new blood vessels from progenitor cells. Shock wave therapy leads to the release of stromal-derived factor 1 (SDF-1). This represents the most important "attractant" for endothelial progenitor cells from the bone marrow. It attracts progenitor cells from the bloodstream to the treated area via its receptor CXCR4. The newly migrated progenitor cells differentiate into blood vessels and thus play an important role in tissue regeneration. The concentration of SDF-1 in treated tissue is increased after SWT, as is the concentration of progenitor cells in the blood of treated mice[6]. Treatment of ischemic myocardium also leads to recruitment of endothelial progenitor cells to the heart[4].

SWT can also attract stem cells, which are injected, to treated tissue in increased numbers[7] or increase the regenerative potential of treated stem cells[8].

Inflammation

Inflammatory processes and the precise orchestration of the immune system play a central role in regenerative processes. Pro-inflammatory stimuli remove cellular debris, anti-inflammatory processes pave the way for subsequent regeneration. The mechanical stimulus of shock wave therapy leads to the release of intracellular RNA. A specific receptor of the innate immune system (Toll-Like Receptor 3=TLR3) is specialized to recognize released RNA.

After all, since it could be viral RNA, activation of the receptor by RNA induces a strong

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[4] Gollmann-Tepeköylü C, Lobenwein D, Theurl M, Primessnig U, Lener D, Kirchmair E, Mathes W, Graber M, Pölzl L, An A, Koziel K, Pechriggl E, Voelkl J, Paulus P, Schaden W, Grimm M, Kirchmair R, Holfeld J. Shock Wave Therapy Improves Cardiac Function in a Model of Chronic Ischemic Heart Failure: Evidence for a Mechanism Involving VEGF Signaling and the Extracellular Matrix. *Journal of the American Heart Association* 2018;**7**.

[5] Yan X, Zeng B, Chai Y, Luo C, Li X. Improvement of blood flow, expression of nitric oxide, and vascular endothelial growth factor by low-energy shockwave therapy in random-pattern skin flap model. *Ann Plast Surg* 2008;**61**:646-653.

[6] Tepeköylü C, Wang F-S, Kozaryn R, Albrecht-Schgoer K, Theurl M, Schaden W, Ke H-J, Yang Y, Kirchmair R, Grimm M, Wang C-J, Holfeld J. Shock wave treatment induces angiogenesis and mobilizes endogenous CD31/CD34-positive endothelial cells in a hindlimb ischemia model: implications for angiogenesis and vasculogenesis. *The Journal of thoracic and cardiovascular surgery* 2013;**146**:971-978.

[7] Aicher A, Heeschen C, Sasaki K, Urbich C, Zeiher AM, Dimmeler S. Low-energy shock wave for enhancing recruitment of endothelial progenitor cells: a new modality to increase efficacy of cell therapy in chronic hind limb ischemia. *Circulation* 2006;**114**:2823-2830.

[8] Priglinger E, Schuh C, Steffenhagen C, Wurzer C, Maier J, Nuernberger S, Holnthoner W, Fuchs C, Suessner S, Rünzler D, Redl H, Wolbank S. Improvement of adipose tissue-derived cells by low-energy extracorporeal shock wave therapy. *Cytotherapy* 2017;**19**:1079-1095.

inflammatory response. On the other hand, the release of RNA after tissue stress, the activation of TLR3 and the subsequent immune response also represents an innate mechanism of tissue regeneration. The receptor leads to the release of important cytokines that orchestrate the immune response. SWT stimulates this receptor via released RNA, inducing angiogenesis and regeneration. In animals lacking the receptor (so-called TLR3 knock-out animals), SWT no longer shows a regenerative effect[9]. Subsequent cytokine release also results in increased macrophages as anti-inflammatory M2 macrophages, further supporting tissue regeneration[10].

The activation of TLR3 also leads to the DNA of treated cells becoming more accessible, i.e., the epigenetic plasticity of treated cells increases. This favors the so-called "transflammation": SWT leads to fibroblasts in the tissue becoming functional endothelial cells again through epigenetic processes, which also contribute to tissue regeneration.

Mechanotransduction

Cells have their own organelles and receptors that are responsible for sensing mechanical stress and converting it into a biological response. Important receptors for this are integrins. These are located on the cell surface, are activated by proteins from the extracellular matrix and are intracellularly connected to the cytoskeleton of the cell. SWT leads to the activation of integrins with subsequent activation of AKT/ERK, a specific signaling pathway of integrins[11].

In addition, SWT causes the membrane to invert into small microvesicles. These vesicles are controlled by caveolin 1 and also trigger important signaling cascades in the cell[11]. However, the mechanical impulse of shock wave therapy also causes very small vesicles (= exosomes) to be sheared off the cell surface. These contain angiogenic RNA (especially miRNA 19a-3p). Treating ischemic heart or muscle with these exosomes leads to the same regenerative effect as shock wave treatment. Conversely, the effect of SWT is extinguished if one inhibits the release of exosomes or the formation of miR19a-3p[12].

Another important aspect of mechanotransduction after SWT is the release of adenosine triphosphate with subsequent activation of purinergic receptors[13]. 3.-**3. 3.**

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[9] Holfeld J, Tepekoylu C, Reissig C, Lobenwein D, Scheller B, Kirchmair E, Kozaryn R, Albrecht-Schgoer K, Krapf C, Zins K, Urbschat A, Zacharowski K, Grimm M, Kirchmair R, Paulus P. Toll-like receptor 3 signalling mediates angiogenic response upon shock wave treatment of ischaemic muscle. *Cardiovasc Res* 2016;**109**:331-343.

[10] Tepekoylu C, Lobenwein D, Urbschat A, Graber M, Pechriggl EJ, Fritsch H, Paulus P, Grimm M, Holfeld J. Shock wave treatment after hindlimb ischaemia results in increased perfusion and M2 macrophage presence. *J Tissue Eng Regen Med* 2018;**12**:e486-e494.

[11] Hatanaka K, Ito K, Shindo T, Kagaya Y, Ogata T, Eguchi K, Kurosawa R, Shimokawa H. Molecular mechanisms of the angiogenic effects of low-energy shock wave therapy: roles of mechanotransduction. *Am J Physiol Cell Physiol* 2016;**311**:C378-385.

[12] Gollmann-Tepekoylu C, Polzl L, Graber M, Hirsch J, Nagele F, Lobenwein D, Hess MW, Blumer MJ, Kirchmair E, Zipperle J, Hromada C, Muhleder S, Hackl H, Hermann M, Khamisi HA, Forster M, Lichtenauer M, Mittermayr R, Paulus P, Fritsch H, Bonaros N, Kirchmair R, Sluijter JPG, Davidson S, Grimm M, Holfeld J. miR-19a-3p containing exosomes improve function of ischemic myocardium upon shock wave therapy. *Cardiovasc Res* 2019.

[13] Weihs AM, Fuchs C, Teuschl AH, Hartinger J, Slezak P, Mittermayr R, Redl H, Junger WG, Sitte HH, Runzler D. Shock wave treatment enhances cell proliferation and improves wound healing by ATP release-

3. Contraindications and adverse effects of ESWT

The following list gives the contraindications for which ESWT is not performed:

For radial technique and focused technique with low energy (focused and defocused):

- Malignant tumor in the shockwave field (not the tumor disease itself)
- Fetus in the shockwave field (not the pregnancy itself)
- Pacemaker/defibrillator in the shockwave field

Relative contraindication:

- Brain tissue/CNS in the shockwave field (at high energy)
- Vertebral bodies, skull bones and ribs

For focused sources with high energy, the following contraindications apply:

- Lung tissue in the shockwave field
- Malignant tumor in the shockwave field (not the tumor disease itself)
- Significant coagulation disorder
- Fetus in the shockwave field (not the pregnancy itself)
- Pacemaker/defibrillator in the shockwave field

There is no definite evidence of persistent complications from ESWT, however, tendon ruptures did occur after ESWT, for example, and ESWT was blamed for this. Rompe and Maier had performed impressive experiments with tendons, showing that such tendons suffer damage at energies > 0.6 mJ/mm2. The described tendon ruptures always occurred after repeated cortisone infiltration, so ESWT might not have been able to prevent the rupture rather than being the cause.

Among other things, **pain** (including headaches - migraines), **reddening of the skin (**blistering) and **bruising** (hematomas) can usually occur during and after treatment. **Tendon loosening** (edema, occasionally tendon rupture) has been observed after treatment. Complications not previously known may also occur. Although it has only been described in Lithotripsy, an increase of Hypertension might occur. Also, Tinnitus could appear in sensitive patients has been related.

Literature

- Rompe - 1997 Orthopaede - Extrakoporale Stosswellentherapie
- Durst - 2002 JBJS br – Case report - Osteonecrosis of the humeral head after ESWL
- Erduran - 2013 Am Orth Foot Ancle Soc - A complication due to SWT resembling calcaneal stress fracture.
- Haake - 2002 AOTS - Epicondylitis-ESWT-side-effects
- Kiessling - 2015 Sci Rep - Radial extracorporeal shock wave treatment harms

coupled extracellular signal-regulated kinase (ERK) activation. *J Biol Chem* 2014;**289**:27090-27104.

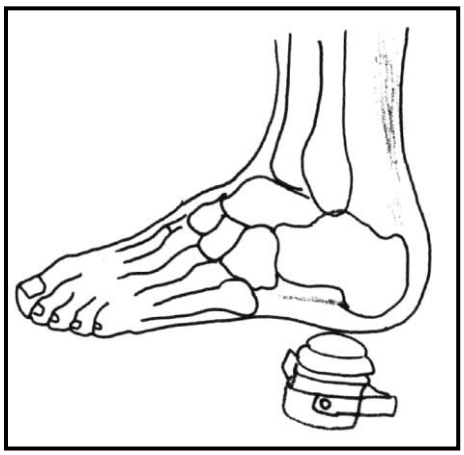
developing chicken embryos

- Lin - 2012 Phys Ther Sport - Achilles tendon tear following SWT for calcific tendinopathy of the Achilles tendon _ case report.
- Maier – Z Orthop Ihre Grenzgeb 2003; 141(2): 223-226 Vortrag Nr 432 beim Süddeutschen Orthopäden-Kongress in Baden-Baden 2003: Nachweis von Knochenfragmenten in Lungengefässen nach hochenergetischer Stoßwellenapplikation am distalen Femur in einem in-vivo Tiermodell. (English: Detection of Bone Fragments in Pulmonary Vessels Following Extracorporeal Shock Wave Application to the Distal Femur in an in-vivo Animal Model.)
- May - 2004 Akt Uro - Eine seltene Komplikation der ESWL - Nierenruptur mit nachfolgender Nephrektomie
- Moya - 2021 Rehabilitación - Malos resultados y complicaciones en el uso de ondas de choque
- Roederdink - 2017 IJSU - Complications of ESWT in plantar fasciitis - Systemic Review
- Shim - 2015 PMRJ - Ulnar Neuropathy After ESWT _ A Case Report
- Sistermann - 1998 Z Orthop - Komplikationen Nebenwirkungen u Kontraindikationen von ESWT

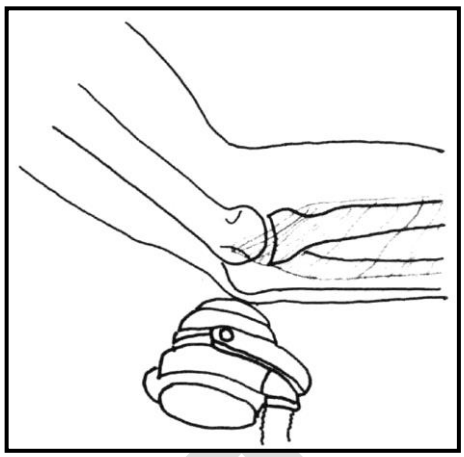
4. Shock wave treatment procedure:

- ⇨ The patient is informed about alternative treatment options, risks and prospects of success.
- ⇨ Patients consent to ESWT in writing.
- ⇨ The treatment with focused shock waves is carried out exclusively by trained physicians, who underwent additional education in shockwave treatment! The treatment with radial pressure waves can be performed also by well trained, certified physiotherapists and nurses after the necessary and essential diagnostic and prescription by a physician has been made.
- ⇨ The treatment can be painful! Usually analgesia (anesthesia or local anesthesia) is not necessary for treatment. Labek et al., Z Orthop 2005 and Rompe et al. JOrthopResearch 2005 demonstrated that the use of local anesthesia might decrease the efficacy of the ESWT in various locations.
- ⇨ The shock waves are introduced via an applicator through the skin using a coupling medium (contact gel/oil). The treatment parameters are set before and during the treatment by means of the patient's pain description (biofeedback). The location of the treatment area is determined clinically or by means of imaging techniques (ultrasound, X-ray). A calm positioning of the patient is important, an interruption of the treatment e.g., in case of pain is possible at any time. The number of impulses and treatments is based on the indications and is presented in the individual chapters.
- ⇨ It is mandatory, that the used device and all variable parameters are listed in the treatment protocol, such as:
    - Name and date of birth and sex of the patient, if applicable comorbidities and pretreatments.
    - The indication of the ESWT.
    - Name of the device (eventually with the manufacturer and the exact designation, so the treatment can be retracted later on).
    - Number of impulses and the energy level indicated on the device and the frequency of impulses per second (not the frequency levels of the shock waves, as they could be described in a Fourier's analysis).
    - If there are additional information available, it should be reported, such as total energy applied, and it has to be announced, how the aiming of the target has been performed.

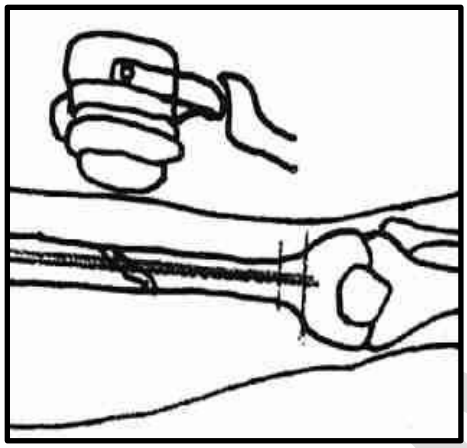
The use of simple drawings and schematics is helpful, but not mandatory.



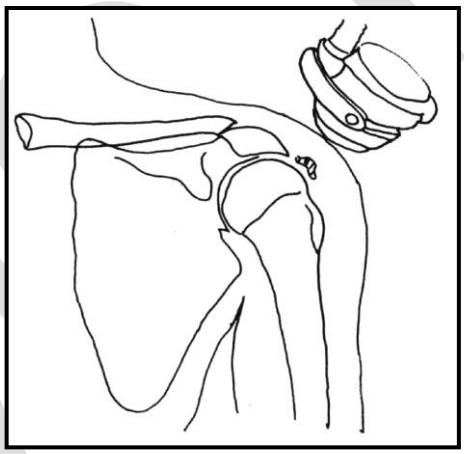
Sketch 4: ESWT for plantar fasciitis with/without calcaneal spur.



Sketch 3: ESWT at the elbow for epicondylitis humeri lateralis



Sketch 4: ESWT for pseudarthrosis



Sketch 3: ESWT at the shoulder in calcifying tendonitis

5. Tendinosis Calcarea – Calcific Tendinopathy of the Shoulder

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Synonyms

Calcifying shoulder, tendinitis/tendinosis calcarea, calcifying tendinitis, calcific lesion

Keywords

Painful shoulder, rotator cuff, calcium deposit, calcified shoulder, shock wave therapy, ESWT

Definition

Calcification in the rotator cuff secondary to dystrophic tendon disease with facultative chondroid metaplasia

Etiology

Tendinosis calcarea of the rotator cuff is a common cause of shoulder pain. Data on the incidence of the disease show considerable variation. It is reported to be between 2.5% and 20%. It is usually a self-limiting disease with high spontaneous recovery rates. In clinically symptomatic calcific shoulder with calcific deposits with radiologically sharp margins and a homogeneous or inhomogeneous structure (type Gärtner 1 and 2), spontaneous resorption occurs in 33% of cases within 3 years. The rate of spontaneous resorption is considerably higher in calcium deposits with soft margins and an inhomogeneous radiographic structure (type Gärtner 3) with up to 85%. Within one year, spontaneous resorption occurs in 6.4% of asymptomatic calcific shoulders. Data in chronic and conservatively unsuccessfully treated tendinosis calcarea are lacking. A coexistence of degradation and build-up is described in the literature and favors chronic courses.

There is no definite correlation between tendinosis calcarea and rotator cuff lesions. Bilateral occurrence is observed between 9% - 40% of cases. The supraspinatus tendon is affected in 82% - 94.5%. The classic calcareous deposit is located in the hypovascular zone, about 1.5cm proximal to the attachment zone.

Pathogenesis

An acute phase is distinguished from a chronic phase. The acute phase begins suddenly with severe pain over a period of 2-3 weeks with swelling, hyperthermia and marked pain at night and at rest. Thereafter, the pain gradually subsides to complete freedom from symptoms. Residual symptoms may persist for months (postcalcific tendinitis).

Macroscopically, a pasty milky emulsion is found, which mineralogically consists of poorly crystallized carbonate apatite. The crystals are resorbed in the tendon or after breakthrough into the subacromial/subdeltoid bursa (resorption stage).

The chronic phase of tendinosis calcarea is characterized by slowly increasing pain. The

self-limiting cyclic course of the disease, which leads via a pre-calcification phase to the calcification phase and finally to a post-calcification phase, is interrupted. Chronic patients are in the calcification phase for years. Mechanical, vascular and biochemical factors are discussed as possible causes of calcification.

Local pressure increases lead to reduced blood flow and hypoxia of the tendon tissue with degeneration of the tendon cells and dystrophic calcification.

Classification of the calcium deposit

The classification is based on size on the one hand, and on radiological criteria on the other. The classification according to Gärtner has become established.

Classification according to gardener

Grade I	Sharp edges, homogeneous structure, radiopaque
Grade II	Sharp edges, inhomogeneous structure, less radiopaque
Grade III	Unsharp edges, inhomogeneous structure, low radiopacity

Medical KeySystems

ICD10

M75.3 Tendinitis calcarea in the shoulder region

S46.0 Injury to a tendon of the rotator cuff

S46.7 Injury to several muscles and tendons at the level of the shoulder and upper arm

Medical history

Special anamnesis Duration of illness Accident anamnesis

direct, indirect force, pseudoparalysis

Pain

Localization, radiation, painful restriction of movement,

Night rest pain

Functional limitation mobility, functional grips,

General diseases and risk factors

Skeletal or connective tissue disorders, metabolic diseases,

Pretreatments

Diagnostics

Clinical diagnostics

Inspection: Muscle relief, symmetry, skin redness

Palpation: palpable resistance in the area of the attachment zone of the rotator cuff

Findings: Range of motion (active and passive), Pain on movement,

specific positive tests for differential diagnosis rotator cuff rupture and subacromial impingement (drop arm sign), Jobe test, Patte test,

Palm-up test, O`Brian test, lift off test, impingement sign according to Neer, Matsen, Hawkins.

Assessment of blood flow, motor function and sensitivity

Apparative diagnostics

Sonography of the shoulder

X-ray of the shoulder in 3 planes

y-view recording according to Neer

Optional Investigation:

MRI

X-ray of adjacent joints (e.g., cervical spine) Clinical chemical laboratory

Differential diagnoses

Impingement syndrome (mechanical outlet, secondary or functional

Impingement)

Pulley lesions

Frozen shoulder

Vertebra-genic, vascular, neurovascular shoulder pain Neuralgic shoulder amyotrophy

Rotator cuff lesions

Gouty arthropathy

Myofascial shoulder pain

Targets

Pain relief and restoration of shoulder function

Induction of lime resorption

Therapy principle

Treatment of tendinosis calcarea of the shoulder should initially be conservative. In case of insufficient or absent therapeutic success by conservative strategies, surgical measures can be discussed. Shock wave therapy is the method of first choice. Highly acute calcific shoulder is not an ESWT indication!

Conservative therapy

Best evidence for ESWT

Myofascial trigger point therapy

Active and passive movement exercises/physiotherapy

Active muscle strengthening to depress and center the humeral head,

Analgesics

Local infiltration

Surgical therapy

Sonographically or radiologically controlled needling of the calcium deposit

Arthroscopic resection

Open resection

Indication: indication by the expert physician

Contraindication: malignant tumor in focus, osteomyelitis.

Spatial requirements: Certification criteria of a medical practice e.g. hygiene plan, emergency management available according to DIN standard.

Preparation of the patient: differentiated and documented education and

Information (onset of action after weeks). Explicit information about the risk of tendon rupture in case of previous damage and premature sports load after treatment.

Physician and assistant personnel: ESWT is a service to be performed personally by the physician qualified by means of specialist knowledge.

Implementation of the therapy:

Focused shock wave is used for the treatment of tendinosis calcarea.

Locating:

The treatment is controlled by imaging techniques (X-ray or ultrasound). The treatment target area is the calcific deposit. If inline localization is not available, it is recommended to verify the calcific deposit sonographically. Care must be taken to ensure correct positioning.

In addition, co-treatment of myofascial trigger points.

Possible side effects, included: Hematoma discoloration, petechial skin bleeding, transient increase in pain,

EFD: 0.10-0.32mJ/mm². The energy flux density and is based on the patient's pain perception and the device technology.

Up to 5 treatment sessions are performed with an interval of between1- 2 weeks, depending on the device technology used. Around 2000 to 3000 shock waves with a frequency of up to 5Hz are applied per treatment session.

Literature:

Bosworth B.Calcium deposits in the shoulder and subacromial bursitis: a survey of 12122 shoulders. JAMA 1941; 116:2477-2489.

Uhthoff HK, Loehr JF Calcifying tendinitis. In: Rockwood CA, Matsen FA (eds): The shoulder.Saunders,Philadelphia(1998),989-1008.

Harmon PH. Methods and results in the treatment of 2580 painful shoulders with special reference to calcific tendinitis and the frozen shoulder. Am J Surg 1958; 95:527-544.

Gärtner J. Tendinosis calcarean: treatment results with needling. Z Orthop IhreGrenzgeb1993; 131:461-469.

Rompe JD, Buch M, Gerdesmeyer L, Haake M, Loew M, Maier M, Heine J. Musculoskeletal shock wave application- Current status of clinical research on standard indications. Z Orthop Your Bordergeb 2002; 140:267-274.

Green S, Buchbinder R, Glazier R, Forbes A. Systematic review of randomised controlled trials of interventions for painful shoulder: selection criteria, outcome assessment, and efficacy. BMJ 1998; 316:354-360.

Rochwerger A, Franceschi JP, Viton JM. Surgical management of calcific tendinitis of the shoulder: an analysisof26cases.ClinRheumatol1999;18:313-316.

Loew M, Daecke W, Kusnierczak D, Rahmanzadeh M, Ewerbeck V. Extracorporal shockwave application-an effective treatment for patients with chronic and therapy-resistant calcifying tendinitis? J BoneJointSurg1999 ;81-B:863-867.

Constant CR, Murley AHG.A clinical method of functional assessment of the shoulder. Clin Orthop1987; 214:160-164.

Rompe JD,Zoellner J,Nafe,B.Significance of calcium depo elimination in tendinosis calcarea of the shoulder.ZOrthop Your Grenzgeb 2000;138:335-339.

Daecke W, Kusnierczak D, Loew M: Importance of extra corporeal shockwave therapy (ESWT) in chronic calcific tendinitis of the shoulder. Orthopäde 2002;-31:645-651.

Gerdesmeyer L, Wagenpfeil S, Haake M, Maier M, Loew M, Wörtler K, Lampe R, Seil R, Handle G, Gassel S, Rompe JD: Extracorporeal shockwave therapy for the treatment of chronic calcifying tendonitis of the rotator cuff-a randomized controlled trial.JAMA(2003);290:2573-258.

Balajy Umamahesvaran, Calcifying Tendinitis of Shoulder: A Concise Review**,** J Orthop. 2018 Sep; 15(3): 776-782.

6. Radial epicondylopathy – Lateral Epicondylopathy of the Elbow

Sergej Thiele (Berlin, Germany)

Classification

M77.1ICD10

Synonyms

Radial: tennis elbow, epicondylitis, tennis elbow, mouse elbow
(Ulnar: golfer's elbow, golfer's elbow, epicondylitis humeri ulnaris)

Etiology

Chronic overload/misload, training errors.

Irritation of the tendinous origin of the extensors at the epicondyle humeri radialis

Chronic degenerative changes of the tendon-bone interface, repetitive microtrauma (repetitive strain injury)

Structural lesion with failure of tendon to complete the healing.

Symptoms

Local pressure pain, functional pain

Positive provocation tests, changing intensity mostly unilateral.

Typically localized at the common extensor origin

Occasional radiation to distal

Apparatus diagnostics:

Ultrasound - if necessary, also with FKDS for activity assessment

X-ray - rather only for chronic courses

MRI - assessment of capsular ligament injuries and associated pathologies.

Differential diagnosis

Radial tunnel syndrome, Supinator's Channel Syndrome

Compartment syndrome, Systemic diseases, Osteomyelitis, Osteoarthritis

Cervicobrachialgia, Myofascial pain of the upper extremity

DD regarding ulnar epicondylopathy:

Sulcus ulnaris syndrome (possibly concomitant)
Bursitis

Conservative Therapy

Physiotherapy and independent exercises, Orthotics, Infiltration, NSAID

Physical measures, Acupuncture, X-ray Irradiation

Immobilization/relief

Surgical therapy

Different surgical procedures (e.g., tendon notching-denervation) (open/ endoscopic)

Shockwave therapy

Indication: indication by the expert physician

Contraindication: malignant tumor in focus, osteomyelitis.

Spatial requirements: Certification criteria of a medical practice e.g., hygiene plan, emergency management available according to DIN standard.

Preparation of the patient: differentiated and documented education and information (onset of effect after weeks). Explicit information about the risk of tendon rupture in the case of previous damage and premature sports stress after treatment.

Physician and assistant personnel: ESWT is a service to be performed personally by the physician qualified by means of specialist knowledge.

Implementation of the therapy

Radial pressure wave and focused shock wave are used according to the possibilities and availabili
The treatment is performed without the use of local anesthesia, if necessary, cryotherapy can
performed.

The localization is done by means of patient-oriented Bio Feedback. Both the enthesis and the tonu
increased musculature are treated.

The patient's position should be comfortable and stable.

In addition, myofascial trigger points should be treated and, if necessary, chirotherapeutic treatment
the concatenation symptoms should be performed.

Possible side effects include Hematoma discoloration, petechial skin bleeding, transient increase in pain,

Up to 5 treatment sessions are performed, depending on the device technology used, with an interval between1- 2 weeks.

EFD: 0.10-0.32mJ/mm². The energy flux density and is based on the patient's pain perception and the device technology.

Electrohydraulic:

0.015-0.22 mJ/mm², single session

1500 pulses/session

Frequency: 4 Hz

Electromagnetic:

0.09/0.14-1.2 mJ/mm², 3 sessions

2000 pulses/session

Frequency 4-5 Hz

Radial:

1.4 - 2.5bar, 3-5 sessions

Frequency: up to 8 Hz

2000 pulses/session

Documentation: Designation of the shock wave source and the parameters used.

Post-treatment: avoidance of potential triggers and, if necessary, abstinence from sports for 4 weeks (individual sports adaptation)

Continue stretching exercises.

Clinical success control after 8-12 weeks

Literature:

Rompe JD, Hopf C, Kullmer K et al. (1996) Analgesic effects of extracorporeal shockwave therapy on chronic tennis elbow. J BoneJointSurg,78-B,233- 237.

Crowther A, Bannister GC, Huma Hetal. (2002) A prospective study to compare extracorporeal shockwave therapy and injection of steroid for the treatment of tennis elbow. JBJS ,84-B,678-679.

Haake, M., Konig, I. R., Decker, T., Riedel, C., Buch, M., and Muller, H.-H. Extracorporeal shock wave therapy in the treatment of lateral epicondylitis: a randomized multicenter trial. J Bone Joint Surg Am 84-A, 11 (2002), 1982-1991.

Speed C, Nichols D, Richards C et al. (2002) Extracorporeal shockwave therapy for lateral epicondylitis: a double blind randomized controlled trial. J OrthopRes,20,895 898.

Mehra, A., Zaman, T., and Jenkin, A. I. R. The use of a mobile lithotripter in the treatment of tennis elbow and plantar fasciitis. Surgeon 1, 5 (Oct 2003), 290-2.

Melikyan EY, Shahin E, Miles K et al. (2003) Extracorporeal shockwave therapy for tennis elbow. A randomized double-blind study. JBJS,85-B,852-855.

Rompe JD, Decking J, Schoellner C et al (2004) Repetitive low energy shockwave treatment for chronic lateral epicondylitis in tennis players. Am J Sports Med, 32,734743.

Buchbinder, R., Green, S. E., Youd, J. M., Assendelft W. J. J., Barnsley, L., and Smidt, N. Shock wave therapy for lateral elbow pain. Cochrane Database Syst Rev, 4 (2005), CD003524.

Lebrun, C. M. Low-dose extracorporeal shock wave therapy for previously untreated lateral epicondylitis. Clin J Sport Med 15, 5 (2005), 401-402.

Chung B, Wiley JP, Rose MS. (2005): Long-term effectiveness of extracorporeal shockwave therapy in the treatment of previously untreated lateral epicondylitis. Clin J Sport Med. 2005 Sep;15(5):305-1.

Pettrone F, McCall B (2005) Extracorporeal shockwave therapy without local anaesthesia for chronic lateral epicondylitis. JBJS, 87-A,1297-1304.

Spacca G, Necozione S, Cacchio A (2005) Radial shockwave therapy for lateral epicondylitis: a prospective randomized controlled single-blind study. Eur Med Phys, 41,17- 25.

Radwan, Y., Elsobhi, G., Badawy, W., Reda, A., and Khalid, S. Resistant tennis elbow: shock-wave therapy versus percutaneous tenotomy. Int Orthop 32, 5 (2008), 671-7.

Staples MP, Forbes A, Ptasznik R, Gordon J, Buchbinder R (2008):A randomized controlled trial of extracorporeal shockwavetherapy for lateral epicondylitis(tennis elbow).J Rheumatology,2008;35:10;2038-46.

Ozturan, K. E., Yucel, I., Cakici, H., Guven, M., and Sungur, I. Autologous blood and corticosteroid injection and extracorporeal shock wave therapy in the treatment of lateral epicondylitis. Orthopedics 33, 2 (Feb 2010), 84-91.

Vural M, Diracoglu D, Erhan B, Gunduz B, Ozhan G, Pekedis K. Efficacy of extracorporeal shock wave therapy and ultra- sound treatment in lateral epicondylitis: A prospective, randomized, controlled trial. Annals of Physical and Rehabilitation Medicine. 2014;57: e190.

Thiele S, Thiele R, Gerdesmeyer L. (2015): Lateral epicondylitis: this is still a main indication for extracorporeal shockwave therapy. Int J Surg. 2015 Dec;24(Pt B):165-70. doi: 10.1016/j.ijsu.2015.09.034. epub 2015 Oct 9. review.

Vulpiani MC, Nusca SM, Vetrano M, Serena Ovidi S, Baldini R, Piermattei C, Ferretti A, Saraceni VM (2015): Extracorporeal shock wave therapy vs cryoultrasound therapy in the treatment of chronic lateral epicondylitis. One year follow up study. Muscles, Ligaments and Tendons Journal 2015;5 (3):167-174.

Taheri P, Emadi M, Poorghasemian J. (2017): Comparison the Effect of Extra Corporeal Shockwave Therapy with Low Dosage Versus High Dosage in Treatment of Patients with Lateral Epicondylitis. Adv Biomed Res. 2017 May 29; 6:61. doi: 10.4103/2277-9175.207148. eCollection 2017.

Wong CW, Ng EY, Fung PW, Mok KM, Yung PS, Chan KM (2016): Comparison of treatment effects on lateral epicondylitis between acupuncture and extracorporeal shockwave therapy. Asia Pac J Sports Med Arthrosc Rehabil Technol. 2016 Nov 24; 7:21-26. doi: 10.1016/j.asmart.2016.10.001. eCollection 2017 Jan.

7. Dupuytren's disease

Prof. Dr. Karsten Knobloch (Hannover, Germany and Perchtoldsdorf, Austria)

Classification

M72.0 M. Dupuytren according to ICD-10
If applicable, M67.14 Contracture of the tendons of the hand according to ICD-10

Synonyms

Dupuytren's contracture, palmar fibromatosis

Etiology

Genetic component via altered single-nucleotide peptides (SNPs) with autosomal dominant inheritance with variable penetrance.

Symptoms

Palmary fibromatosis with initial nodules, possibly followed by strands, which can lead to flexion contracture without or when overcoming a finger joint, which then gives Dupuytren's contracture its name. The ring and little fingers in the palm and long finger planes are more commonly affected than average. These nodes/strands may also cause pain, presumably via ingrowth of skin pain fibers into the fibrotic nodes with corresponding strangulation. In addition to the clinical palpation findings, imaging, especially sonography, may also help to rule out benign or malignant tumors in differential diagnosis.

Apparative diagnostics

Sonographically, Dupuytren's nodes localized superficially subcutaneously often appear hypoechogenic, but sometimes isoechogenic to surrounding subcutaneous fat (Knobloch 2012). New ultrahigh-resolution power Doppler techniques suggest vascularization as a potential activity indicator (Knobloch, 2022). MRI T2 signal may potentially indicate Dupuytren's node activity as a biomarker and be prognostic for radiation success (Banks et al., 2018).

Therapy

Therapeutically, the nodular stage (tubiana N (nodular)) must be distinguished from the cord stage with finger joint contracture.

At the nodal stage, the following treatment options may be offered for symptomatic painful Dupuytren's nodes and suffering:

- Focused high-energy ESWT (typically three sessions 1-2 weeks apart, control after 6 months as a refresher, Knobloch et al. 2012; Knobloch et al. 2022).
- ESWT improves pain and patient satisfaction better than stretching or laser therapy at 1/2/3 months with no side effects (Notarnicola 2017).
- Radiotherapy to slow Dupuytren's progression (Banks 2018, Rödel 2017, Seegenschmiedt 2015).
- A case report of a 79-year-old noted radial pressure wave therapy (3bar, 12 Hz, 1400 pulses) four times with improvement in hand function for contracture (Brunelli et al., 2020)

In the largest randomized DupuyShock study to date (Knobloch et al. 2022), 52 patients with a mean age of 58±9 years with painful Dupuytren Nodes Tubiana N were included. The intervention group underwent three sessions of high energy electromagnetic ESWT (Storz Ultra, 2000 pulses, 3 Hz, up to 0.35mJ/mm^2, 49mJ/mm^2 /hand) compared to the placebo group.

Pain was significantly reduced by 54% in the intervention group at 3, 6 and 12 months. Similarly, the patient-oriented outcome scores DASH, Michigan Hand Questionnaire as well as the URAM Scale improved significantly in favor of the intervention group. No side effects were observed.

By analogy, the positive reports of pain reduction by focused ESWT in nodular form of Ledderhose's disease (Knobloch K, 2012; Hwang et al. 2020) of the sole of the foot and Peyronie's disease of the penis (Porst H, 2021, Krieger et al. 2019) can be read.

Radiation therapy in nodal stage Dupuytren's disease was evaluated in a cohort study of 135 patients with 208 symptomatic hands with orthovoltage irradiation of 30Gy. With a long follow-up period of 13 years, nodules remained stable in 59%, improved in 10%, and showed progression in 31% of cases.

In the strand stage with >20° joint contracture, the following therapeutic procedures are classically available for Dupuytren's disease:

- open surgery as selective fasciectomy
- Percutaneous Needle Fasciotomy (PNF)

Enzymatic fasciotomy with the collagenase Xiapex is no longer available outside the U.S. as of 2019.

Focused high-energy shock wave therapy can have additional positive effects in terms of wound healing, swelling reduction and, if necessary, recurrence prophylaxis as an adjunct before and immediately after the aforementioned procedures.

Shock wave therapy for Dupuytren's disease

Indication: indication by the expert physician

Contraindication:
malignant tumor in focus

Spatial requirements:
Certification criteria of a medical practice e.g., hygiene plan,
emergency management available according to DIN standard.

Preparation of the patient: differentiated and documented education and information

Physician and assistant personnel:
ESWT is a service to be performed personally by the physician qualified by specialty.

Implementation of the therapy:

Positioning in sitting or lying **position** according to the patient's wishes

Focused ESWT:

0.08-0.55mJ/mm^2 to VAS 5/10
2000 pulses per node, 3 sessions at weekly intervals,
after 6 months refresher ESWT if necessary

Documentation:
Designation of shock wave source and parameters used.

Literature:

Banks JS, Wolfson AH, Subhawong TK. T2 signal intensity as an imaging biomarker for patients with superficial fibromatoses of the hands (Dupuytren's disease) and feet (Ledderhose disease) undergoing defninitive electron beam irradiation. Skeletal Radiol 2018;47(2):243-51.

Brunelli S, Bonanni C, Traballesi M, Foti C. Radial ESWT: a novel approach for the treatment of Dupuytren's contractures: a case report. Medicine (Baltimore) 2020;99(24):e20587.

Hwang JT, Yoon KJ, Park CH, Choi JH, Park HJ, Park YS, Lee YT. Follow-up of clinical and sonographic features after ESWT in painful plantar fibromatosis. PLoS One 2020;15(8):e0237447.

Knobloch K, Kühn M, Vogt PM. Focused high-energy shock wave therapy improves quality of life in Dupuytren's disease-a randomized trial (DupuyShock). 43rd Annual Meeting of the German Society of Plastic, Reconstructive and Aesthetic Surgery (DGPRÄC), 2012, Bremen. doi: 10.3205/12dgpraec191

Knobloch K, Kühn M, Vogt PM. Focused high-energy shock wave therapy for palmar nodularity in Dupuytren's disease-a randomized trial (DupuyShock). 53rd Congress of the German Society for Hand Surgery 2012 Lübeck. doi: 10.3205/12dgh05

Knobloch K, Kühn M, Sorg H, Vogt PM. German version of the Unite rhumatologique des affections de la main (URAM) scale in Dupuytren's disease: the need for a uniform definition of recurrence. Arthritis Care Res (Hoboken) 2012:64(5):793.

Knobloch K, Vogt PM. High-energy focused ESWT reduces pain in plantar fibromatosis (Ledderhose's disease) BMC Res Notes 2012;5:542.

Knobloch K, Kuehn M, Papst S, Kraemer R, Vogt PM. German standardized translation of the michigan hand outcomes questionnaire for patient-related outcome measurement in Dupuytren disease. Plast Reconstr Surg. 2011 Jul; 128 (1): 39e-40e. doi: 10.1097/PRS.0b013e318218fd70.

Knobloch K, Kuehn M, Vogt PM. Focused extracorporeal shockwave therapy in Dupuytren's disease--a hypothesis. Med Hypotheses. 2011 May;76(5):635-7. doi: 10.1016/j.mehy.2011.01.018. Epub 2011 Feb 1.

Knobloch K. From nodules to chords in Dupuytren's contracture. MMW Fortsch Med 2012;154(19):36.

Knobloch K, Redeker J, Vogt PM. Antifibrotic medication using a combination of N-acetyl-L-cysteine (NAC) and ACE inhibitors can prevent the recurrence of Dupuytren's disease.

Med Hypotheses. 2009 Nov;73(5):659-61. doi: 10.1016/j.mehy.2009.08.011. epub 2009 Sep 1.

Knobloch K, Hellweg M, Sorg H, Nedelka T. Focused electromagnetic high-energetic ESWT reduces pain levels in the nodular state of Dupuytren's disease - a randomized controlled trial (DupuyShock). Laser Med Sci 2022;37(1):323-333.

Krieger JR, Rizk PJ, Kohn TP, Pastuszak A. Shockwave therapy in the treatment of Peyronie's disease. Sex Med Rev 2019;7(3):499-507.

Notarnicola A, Maccagnano G, Rifino F, Pesce V, Gallone MF, Covelli I, Moretti B. Short-term effect of shockwave therapy, temperature controlled high energy adjustable multi-mode emission laser or stretching in Dupuytren's disease: a prospective randomized clinical trial. J Biol Regul Homeost Agents 2017;31(3):775-84.

Porst H. Review of the current status of low intensity ESWT in erectile dysfunction (ED), Peyronie's disease (PD), and sexual rehabilitation after radical prostatectomy with special focus on technical aspects of the different marketed ESWT devices including personal experiences in 350 patients. Sex Med Rev 2021;9(1):93-122.

Rödel F, Fournier C, Wiedemann J, Merz F, Gaipl US, Frey B, Keilholz L, Seegenschmiedt MH, Rödel C, Hehlgans S. Basis of radiation biology when treating hyperproliferative benign diseases. Front Immunol 2017;8:519.

Seegenschmiedt MH, Micke O, Niewald M, Mücke R, Eich HT, Kriz J, Heyd R, German Cooperative Group on Radiotherapy of benign diseases. DEGRO guidelines for the radiotherapy of non-malignant disorders: part III: hyperproliferative disorders. Strahlenther Onkol 2015;191(7):541-8.

8. Trochanteric pain syndrome - Greater Throcanteric Pain Syndrome

PD Dr. Jörg Hausdorf (Munich, Germany)

ICD classification

M70.6

Synonyms GTPS (Greater Trochanteric Pain Syndrome)

Etiology

Bursitis trochanterica, gluteal tendon tendinosis, partial rupture, myofascial trigger points

Pelvic geometry, impaired offset after hip TEP, chronic friction loading with subsequential degeneration of the attachment of the gluteal muscles and irritation of the tract,

Symptoms

Functional pain (stance leg phase, stair climbing)

Night pain, lying on affected side is not possible.

Changing intensity

Clinical examination

Local pressure pain peri-trochanteric

Resisted External Rotation Test, Resisted Abduction Test, passive adduction pain, pos. Trendelenburg, FABER (Patrick's) Test (see Ganderton (2017)).

Apparatus diagnostics:

Ultrasound, X-ray, MRI

Differential diagnosis

Hip impingement (FAI), labral lesion, Coxarthrosis, femoral head necrosis, tumor, pathologic/fatigue fracture, piriformis syndrome. Sciatica, Fibromyalgia, Systemic diseases (spondylarthritides, gout), Periarticular ossifications

ConservativeTherapy

Acupuncture, Dry Needling

Manual medicine, physiotherapy, self-exercise

Weight reduction

Infiltration, NSAID

Phys. measures: Electrotherapy/ultrasound/thermotherapy.

SurgicalTherapy

Open/endoscopic bursectomy,

Arthroscopic/open gluteal tendon refixation

Tractus notching/extension, stitching of the tendon, trochanter reduction plasty.

Shockwave therapy

Indication: indication by the expert physician

Contraindication: malignant tumor in focus, local osteomyelitis in focus.

Before therapy:

Spatial requirements: Certification criteria of a medical practice e.g., hygiene plan, emergency management available according to DIN standard.

Preparation of the patient: differentiated (medical and economic) and documented education and information (onset of effect usually after approx. 4 weeks)

Physician and assistant personnel: ESWT is a service to be performed personally by the physician qualified by means of specialist knowledge.

Implementation of the therapy:

up to 5 treatments

Lateral position (with pillow support between the legs) or supine position

no local anesthesia, if necessary, conduction anesthesia, if necessary, cryotherapy

Coupling medium: ultrasound gel

Locating: Patient-oriented focusing/ultrasound

Shock Wave Source:

- Focused

  EFD:0.10-0.35mJ/mm² (pain-adapted dosing)

  Interval: 1-2 weeks

  Frequency: up to 5 Hz

  Pulses: 1500-2500/session

- Radial:

  Pressure strength: up to 4 bar (pain-adapted dosing)

  Interval: 1-2 weeks

  Frequency: up to 10 Hz

  Pulses: 2000-3000/session

After the therapy:

Documentation of device, treatment parameters**,** monitoring of circulatory function if necessary.

Complications/side effects:

Hematoma, pain intensification, nerve irritation

Aftercare:

individual sport adaptation, continuation of stretching exercises.

Clinical outcome assessment after 4 weeks and 8 weeks if necessary (see Ramon S (2020) and Carlisi (2019).

Literature:

Furia JP, Rompe JD, Maffulli N. Low-energy extracorporeal shock wave therapy as a treatment for greater trochanteric pain syndrome. Am J Sports Med. 2009; 37:1806-1813

Mani-Babu S, Barton C, Morrissey D. The effectiveness and.dose-response relationship of extracorporeal shock wave therapy in lower limb tendinopathy: a systematic review. J Sci Med Sport. 2012; 15:133-134.

Reid D. The management of greater trochanteric pain syndrome: A systematic literature review. J Orthop. 2016 Mar; 13(1): 15-28.

Rompe JD, Segal NA, Cacchio A, Furia JP, Morral A, Maffulli N. Home training, local corticosteroid injection, or radial shock wave therapy for greater trochanter pain syndrome. Am J Sports Med. 2009; 37:1981-1990.

Shi Li-Jun et al. Focused extracorporeal shock wave therapy with centrifugal exercise for the treatment of greater trochanteric pain syndrome. Zhongguo Gu Shang. 2021 Dec 25;34(12):1158-64.

Ramon S et al. Focused Shockwave Treatment for Greater Trochanteric Pain Syndrome: A Multicenter, Randomized, Controlled Clinical Trial.... J Bone Joint Surg Am. 2020 Aug 5;102(15):1305-1311.

Carlisi E et al. Focused extracorporeal shock wave therapy for greater trochanteric pain syndrome with gluteal tendinopathy: a randomized controlled trial. Clin Rehabil. 2019 Apr;33(4):670-680

Ganderton C et al. Demystifying the Clinical Diagnosis of Greater Trochanteric Pain Syndrome in Women. J Womens Health (Larchmt). 2017 Jun;26(6):633-643.

9. Plantar Fasciitis

PD Dr. Jörg Hausdorf (Munich, Germany)

Classification

M77.3ICD10

Synonyms:

Heel spur, fasciitis plantaris, plantar heel pain, medial Heel pain

Etiology:

Overweight, overload/misload,

Loss of the longitudinal arch

Training errors (increase in distance, duration, speed)

Standing professions

Bursitis/ irritation at the base of the plantar aponeurosis

Periosteal irritation

Symptoms:

Start-up pain, varying intensity, usually unilateral

20-30%both sides

Typical pain localization: Tub. med. calcanei

Occasional radiation laterally or distally

Apparatus diagnostics:

Ultrasound

X-ray

MRI

Differential diagnosis:

Tarsal tunnel syndrome, achillodynia, calcaneus fractures, compartment syndrome

Rupture of the plantar aponeurosis, plantar vein thrombosis

Systemic diseases (SLE, RA, Spondylarthritis, gout), osteomyelitis

Radicular symptoms, foot deformity

Conservative Therapy:

Physiotherapy/ self-exercises (eccentric exercises)

Myofascial trigger point therapy

Infiltration with PRP (platelet rich plasma) (see Johnson LG (2022)), dextrose.

Prolotherapy (see Lai et al. (20121)).

Insoles, relief

NSAIDS,

Phys. therapy: electrotherapy/ultrasound/thermotherapy

X-ray stimulation irradiation, laser therapy (see Naterstad I (2022)

Surgical therapy:

Radiofrequency Microtenotomy

Neurolysis (N. plant.med.)

Neurectomy of the N. plant. med./ Rr. Calcanei

Osteotomy of the spur (open/endoscopic)

Plantar fascia release (open/endoscopic)

Shockwave therapy

Indication:

Above symptoms, exclusion of differential diagnoses, indication by the expert physician.

Contraindication:

Malignant tumor in focus, local osteomyelitis in focus.

Before therapy:

Spatial requirements:

Certification criteria of a medical practice e.g. hygiene plan, emergency management available according to DIN standard.

Preparation of the patient:

Differentiated and documented education and information and information (bony spur persists, onset of action after weeks)

Physician and assistant personnel:

ESWT is a service to be performed personally by the physician qualified by means of specialist knowledge.

Implementation of the Therapy:

up to 5 treatments

no local anesthesia, cryotherapy if necessary

Coupling medium ultrasound gel

Locating: patient-oriented focusing, sonography if necessary.

Shock Wave Source:

- Focused:

EFD:0.08-0.35mJ/mm² (pain-adapted dosing)

Interval 1- 2 weeks

Frequency: up to 5Hz

Pulses: 1500-2500/session

- Radial:

Pressure strength: 2-4 bar (pain-adapted dosing)

Interval: 1 - 2 weeks

Frequency: up to max. 10 Hz

Pulses: 2000-3000/session

After therapy:

Documentation of treatment parameters, monitoring of circulatory function if necessary.

Complications/side effects:

Hematoma, pain intensification, nerve irritation

Aftercare:

Individual sport adjustment,

Continue stretching exercises.

Clinical success control after 4 and 8 weeks

Literature:

Aqil A, Siddiqui MR, Solan M, et al. Extracorporeal shock wave therapy is effective in treating chronic plantar fasciitis: a meta-analysis of RCTs. Clin Orthop Relat Res 2013; 471:3645-52

Chang KV et al. Comparative effectiveness of focused shock wave therapy of different intensity levels and radial shock wave therapy for treating plantar fasciitis: a systematic review and network meta-analysis. Arch Phys Med Rehabil. 2012 Jul;93(7):1259-68

Gerdesmeyer L, Frey C, Vester J, et al. Radial extracorporeal shock wave therapy is safe and effective in the treatment of chronic recalcitrant plantar fasciitis: results of a confirmatory randomized placebo-controlled multicenter study. Am J Sports Med 2008; 36:2100-9.

Gollwitzer H et al. Clinically relevant effectiveness of focused extracorporeal shock wave therapy in the treatment of chronic plantar fasciitis: a randomized, controlled multicenter study.J Bone Joint Surg Am. 2015 May 6;97(9):701-8.

Haake M, Buch M, Schoellner C, et al. Extracorporeal shock wave therapy for plantar fasciitis: randomized controlled multicenter trial. BMJ 2003; 327:75.

Ibrahim MI et al. Long-term results of radial extracorporeal shock wave treatment for chronic plantar fasciopathy: A prospective, randomized, placebo-controlled trial with two years follow-up. J Orthop Res. 2017 Jul;35(7):1532-1538.

Njawaya MM et al. Ultrasound Guidance Does Not Improve the Results of Shock Wave for Plantar Fasciitis or Calcific Achilles Tendinopathy: A Randomized Control Trial. Clin J Sport Med. 2018 Jan;28(1):21-27.

Roerdink RL et al. Complications of extracorporeal shockwave therapy in plantar fasciitis:

systematic review. Int J Surg. 2017 Oct; 46:133-145.

Rompe JD et al. Radial shock wave treatment alone is less efficient than radial shock wave treatment combined with tissue-specific plantar fascia-stretching in patients with chronic plantar heel pain. Int J Surg. 2015 Dec;24(Pt B):135-42.

Rompe JD, Meurer A, Nafe B, Hofmann A, Gerdesmeyer L. Repetitive low-energy shock wave application without local anesthesia is more efficient than repetitive low-energy shock wave application with local anesthesia in the treatment of chronic plantar fasciitis. J Orthop Res 2005; 23(4): 931-941

Saxena A et al. Treatment of Plantar Fasciitis with Radial Soundwave "Early" Is Better Than After 6 Months: A Pilot Study. J Foot Ankle Surg. 2017 Sep - Oct;56(5):950-953

Speed CA, Nichols D, Wies J, et al. Extracorporeal shock wave therapy for plantar fasciitis. A double blind randomized controlled trial. J Orthop Res 2003; 21:937-40

Sun J et al. Extracorporeal shock wave therapy is effective in treating chronic plantar fasciitis: A meta-analysis of RCTs. Medicine (Baltimore). 2017 Apr;96(15)

Johnson LG et al. Efficacy of Platelet-Rich Plasma in Soft Tissue Foot and Ankle Pathology. JBJS Rev 2022 Oct 3;10(10).

Naterstad IF et al. Efficacy of low-level laser therapy in patients with lower extremity tendinopathy or plantar fasciitis: systematic review and meta-analysis of randomized controlled trials. BMJ Open. 2022 Sep 28;12(9):e059479.

Lai Wei-Fu et al. The effectiveness of dextrose prolotherapy in plantar fasciitis: A systemic review and meta-analysis. Medicine (Baltimore) . 2021 Dec 23;100(51):e28216.

10. Achilles tendinopathy, insertional and non-insertional

Dr. Martin Ringeisen (Augsburg, Germany)

ICD classification

M77.3ICD10

Synonyms

Tendinosis, tendinitis, tendinopathy, mid-portion tendinopathy, insertional tendinopathy, enthesopathy, dorsal heel pain with/without posterior calcaneal spur,

Etiology

Overuse due to sports/ everyday life
Direct mechanical irritation of the Achilles tendon
Degeneration of the tendon tissue
Haglund exostosis
Foot deformities
Overweight
Reduced mobility OSG/USG and metatarsophalangeal joint of big toe

Symptoms

Local pressure pain, functional pain**.** Varying intensity, initially pain only on exertion, later persistent pain and pain at rest Swelling of the tendon, typically localized in the tendon course and/or at the attachment

Apparative diagnostics

Ultrasound
MRI
X-ray

Differential diagnoses

Inflammatory rheumatic diseases - primarily Bekhterev's disease, Reiter's disease,
Psoriatic arthritis,
Metabolic diseases - gout / hypercholesterolemia
Pharmaceutical-induced/slow ruptures,- especially due to gyrase inhibitors.
Pathologies of OSG/USG
Os-trigonum impingement/ flexor hallucis longus syndrome
Stress fractures
Bursitides
Spontaneous rupture

Conservative therapy

Loading adjustment and education
Best evidence exists for the combination of ESWT and eccentric loading.
Complementary physiotherapy, insoles, local measures,
Kinesio tape
Injections basically cortisone-free!

Surgical Therapy

Debridement of the tendon, stitching of the tendon, refixation(open).

Shockwave therapy

Indication:

Symptoms resistant to therapy, indication by a specialist physician.

Contraindication:

Malignant tumor in focus

Spatial requirements:

Certification criteria of a medical practice e.g. hygiene plan, emergency management available according to DIN standard.

Preparation of the patient:

Differentiated and documented education and
Information (onset of action after weeks)

Physician and assistant personnel:

ESWT is a service to be performed personally by the physician qualified by means of specialist knowledge.

Implementation of the therapy:

No local anesthesia, cryotherapy if necessary
Naming the SW source

- Focused
Coupling medium (ultrasound gel)
Once/several times (standard up to 3, max. 5 treatments)
EFD: 0.10 - 0.25 mJ/mm² depending on the device technology and the
Pain sensation of the patient
Frequency: up to max. 5 Hz
Pulses: 1500-2500/session
Interval: 1-2 weeks

- Radial
Coupling medium (ultrasound gel /cave air bubbles)
Several times (standard to 3, max. 5 treatments)
Pressure strength: 2-4 bar depending on the device technology and the
Pain sensation of the patient
Frequency: up to max. 10 Hz
Pulses: 2000-3000/session
Interval: 1-2 weeks

Localization: patient-oriented focusing with consideration of imaging, furthermore co-treatment of myofascial trigger points

Aftercare:

Adaptation of the load, sports modification
Continuation of stretching exercises/physiotherapy
Clinical success control after 8-12 weeks

Literature:

Ludger Gerdesmeyer, Rainer Mittermayr, Martin Fuerst, Munjed Al, Muderis, Richard Thiele, Amol Saxena, Hans Gollwitzer Current evidence of extracorporeal shockwave therapy in chronic Achilles tendinopathy, Review International Journal of Surgery 24 (2015) 154e159.

L. Gerdesmeyer, M. Maier, M. Haake, C. Schmitz, Physical-technical principles of extracorporeal shockwave therapy (ESWT), Orthopade 31 (2002) 610e617.

L. Gerdesmeyer, C. Frey, J. Vester, et al, Radial extracorporeal shockwave Therapy is safe and effective in the treatment of chronic recalcitrant plantar fasciitis: results of a confirmatory randomized placebo-controlled multicenter study, Am. J. Sports Med. 36 (2008) 2100e2109.

P. Diehl, H. Gollwitzer, J. Schauwecker, T. Tischer, L. Gerdesmeyer, Conservative treatment of chronic tendinopathies, Orthopade 43 (2014) 183e193. [4] M.A. Childress, A. Beutler, Management of chronic tendon injuries, Am. Fam. Physician 87 (2013) 486e490

J.A. Peters, J. Zwerver, R.L. Diercks, M.T. Elferink-Gemser, I. van dA-S, Preventive Interventions for tendinopathy: a systematic review, J. Sci. Med. Sport. (2015 Apr 1) 1440e2440.

R. Zwiers, J.I. Wiegerinck, C.N. van Dijk, Treatment of midportion Achilles tendinopathy: an evidence-based overview, Knee Surg. Sports Traumatol. Arthrosc. 22 (2014) 1433e7347.

B. Magnan, M. Bondi, S. Pierantoni, E. Samaila, The pathogenesis of Achilles tendinopathy: a systematic review, Foot Ankle Surg. 20 (2014) 154e159.

M.F. Joseph, K.R. Lillie, D.J. Bergeron, et al, Achilles tendon biomechanics in response to acute intense exercise, J. Strength Cond. Res. 28 (2014) 1181e1186.

J.I. Wiegerinck, G.M. Kerkhoffs, M.N. van Sterkenburg, I.N. Sierevelt, C.N. van Dijk, Treatment for insertional Achilles tendinopathy: a systematic review, KneeSurg. Sports Traumatol. Arthrosc. 21 (2013) 1345e1355.

V. Rowe, S. Hemmings, C. Barton, P. Malliaras, N. Maffulli, D. Morrissey, Conservative management of midportion Achilles tendinopathy: a mixed methods study, integrating systematic review and clinical reasoning, Sports Med. 42 (2012) 941e967.

K. Knobloch, The role of tendon microcirculation in Achilles and patellar tendinopathy, J. Orthop. Surg. Res. 3 (2008) 18.

P. Diehl, H. Gollwitzer, J. Schauwecker, T. Tischer, L. Gerdesmeyer, Conservative Treatment of chronic tendinopathies, Orthopäde 43 (2014) 183e193.

R. Kearney, M.L. Costa, Insertional Achilles tendinopathy management: a Systematic review, Foot Ankle Int. 31 (2010) 689e694.

J.P. Furia, Extracorporeal shockwave therapy in the treatment of chronic insertional Achilles tendinopathy, Orthopade 34 (2005) 571e578.

U. Balasubramaniam, R. Dissanayake, L. Annabell, Efficacy of platelet-rich plasma injections in pain associated with chronic tendinopathy: a systematic review, Phys. Sportsmed. (2015) 1e9.

R.S. Kearney, N. Parsons, D. Metcalfe, M.L. Costa, Injection therapies for Achilles tendinopathy, Cochrane Database Syst. Rev. 5 (2015). CD010960.

N. Maffulli, R. Papalia, S. D'Adamio, B.L. Diaz, V. Denaro, Pharmacological interventions for the treatment of Achilles tendinopathy: a systematic review of Randomized controlled trials, Br. Med. Bull. 113 (2015) 101e115.

J.P. Furia, High-energy extracorporeal shockwave therapy as a treatment for insertional Achilles tendinopathy, Am. J. Sports Med. 34 (2006) 733e740.

M.L. Costa, L. Shepstone, S.T. Donell, T.L. Thomas, Shockwave therapy for chronic Achilles tendon pain: a randomized placebo-controlled trial, Clin. Orthop. Relat. Res. 440 (2005) 199e204.

J.P. Furia, High-energy extracorporeal shockwave therapy as a treatment for Chronic non insertional Achilles tendinopathy, Am. J. Sports Med. 36 (2008)502e508.

S. Rasmussen, M. Christensen, I. Mathiesen, O. Simonson, Shockwave therapy for chronic Achilles tendinopathy: a double-blind, randomized clinical trial of efficacy, Acta Orthop. 79 (2008) 249 e256.

J.D. Rompe, B. Nafe, J.P. Furia, N. Maffulli, Eccentric loading, shock-wave treatment, or a wait-and-see policy for tendinopathy of the main body of tendo Achillis: a randomized controlled trial, Am. J. Sports Med. 35 (2007) 374e383.

J.D. Rompe, J. Furia, N. Maffulli, Eccentric loading compared with shockwave Treatment for chronic insertional Achilles tendinopathy. A randomized, Controlled trial, Am J Sports Med. 2009 Mar;37(3):463-70.

K.Feeney, The Effectiveness of Extracorporeal Shockwave Therapy for Midportion Achilles Tendinopathy: A Systematic Review, Cureus, 2022 Jul; 14(7): e26960.

I.Jarin , H.C. Baker , J.Turner Vosseller Functional Outcomes of Insertional Achilles Tendinopathy Treatment: A Systematic Review JBJS Rev 2021 Jun 14;9(6).

11. Patellar tendinopathy

Dr. Martin Ringeisen (Augsburg, Germany)

ICD classification

M77.3ICD10

Synonym

Tendinopathy/Tendinosis/Tendinitis of the Patellar Tendon, Jumpers Knee, Jumper's knee,

Definition

Functional overload of the patellar tendon origin due to repetitive stress of the knee extensors especially in sports such as volleyball, basketball, high jump, long jump, hill walking, kneeling occupational groups.

Etiology

Chronic overload/misuse
Training errors
Degenerative changes of the patellar tendon
Morphological structural change of the tendon due to mechanical stress
Anatomical variances of the femoropatellar joint

Symptoms

Pain initially after exertion, later with exertion and at rest Swelling and localized tenderness, pain on movement
Varying intensity
Typically localized at the patellar tip

Diagnosis:

Ultrasound
X-ray
MRI

Differential diagnoses

Femoropatellar arthritis/gonarthritis.
Metabolic Causes: Hyperlipidemia, gout, diabetes
Rheumatic underlying diseases
Hoffaitis/bursitis infrapatellaris
Pharmaceutical-induced tendopathies (e.g., gyrase inhibitors)
Sinding-Larsson-Johansson disease

Conservative therapy options

Load adjustment and education,
good evidence for ESWT and eccentric loading
Complementary measures: Physiotherapy,
Injections always without cortisone

Operative Therapy

Debridement of the tendon, denervation of the tendon / refixation (open/endoscopic)

Shockwave therapy

Indication:

Symptoms resistant to therapy, indication by a specialist physician.

Contraindication:

Malignant tumor in focus

Spatial requirements:

Certification criteria of a medical practice e.g., hygiene plan, emergency management available according to DIN standard.

Preparation of the patient:

Differentiated and documented education and Information (onset of action after weeks)

Physician and assistant personnel:

ESWT is a service to be performed personally by the physician qualified by means of specialist knowledge.

Implementation of the therapy:

No local anesthesia, cryotherapy if necessary
Naming the SW source

- Focused
  Coupling medium (ultrasound gel)
  Once/several times (standard up to 3, max. 5 treatments)
  EFD: 0.10 - 0.25 mJ/mm² depending on device technology and patient's pain perception.
  Frequency: up to max. 5 Hz
  Pulses: 1500-2500/session
  Interval: 1-2 weeks
- Radial
  Coupling medium (ultrasonic gel /cave air bubbles)
  Several times (standard to 3, max. 5 treatments)
  Pressure strength: Pressure strength: 2-4 bar depending on the device technology and the patient's pain sensation.
  Frequency: up to max. 10 Hz
  Pulses: 2000-3000/session
  Interval: 1-2 weeks

Localization: patient-oriented focusing with consideration of imaging, furthermore co-treatment of myofascial trigger points

After therapy:

Monitoring of circulatory function, if necessary,

Complications:

Hematoma, pain intensification, nerve irritation

Aftercare:

Adaptation of the load, sports modification
Clinical success control after 8 - 12 weeks

Literature:

Carlos Leal , Silvia Ramon, John Furia, Arnold Fernandez, Luis Romero ,

Leonor Hernandez-Sierra, Current concepts of shockwave therapy in chronic patellar tendinopathy, Review.

International Journal of Surgery 24 (2015) 160e164

M.E. Blazina, R.K. Kerlan, F.W. Jobe, V.S. Carter, G.J. Carlson, Jumper's knee, Orthop. Clin. North Am. 4 (1973) 665e678

A. Ferretti, Epidemiology of jumper's knee, Sports Med. 3 (1986) 289e295. O.B. Lian, L. Engebretsen, R. Bahr, Prevalence of jumper's knee among elite athletes from different sports: a cross-sectional study, Am. J. Sports Med. 33(2005) 561e567.

A. Ferretti, E. Ippolito, P. Mariani, G. Puddu, Jumper's knee, Am. J. Sports Med.11 (1983) 58e62

K.M. Khan, J.L. Cook, F. Bonar, P. Harcourt, M. Astrom, Histopathology of common tendinopathies. Update and implications for clinical management, Sports Med. 27 (1999) 393e408.

N. Maffulli, K.M. Khan, G. Puddu, Overuse tendon conditions: time to change a confusing terminology, Arthroscopy 14 (1998) 840e843.

P.J. Visentini, K.M. Khan, J.L. Cook, Z.S. Kiss, P.R. Harcourt, J.D. Wark, The VISA score: an index of severity of symptoms in patients with jumper's knee (patellar tendinosis). Victorian Institute of Sport Tendon Study Group, J. Sci. Med. Sport 1 (1998) 22e28.

M.C. Vulpiani, M. Vetrano, V. Savoia, E. Di Pangrazio, D. Trischitta, A. Ferretti, Jumper's knee treatment with extracorporeal shock wave therapy: a long term follow-up observational study, J. Sports Med. Phys. Fit. 47 (2007)323e328

M. Vetrano, A. Castorina, M.C. Vulpiani, R. Baldini, A. Pavan, A. Ferretti,

Platelet-rich plasma versus focused shock waves in the treatment of jumper's knee in athletes, Am. J. Sports Med. 41 (2013) 795e803

J.E. Gaida, J. Cook, Treatment options for patellar tendinopathy: critical review, Curr. Sports Med. Rep. 10 (2011) 255e270

C.J. Wang, J.Y. Ko, Y.S. Chan, L.H. Weng, S.L. Hsu, Extracorporeal shockwave for chronic patellar tendinopathy, Am. J. Sports Med. 35 (2007) 972e978

J. Zwerver, S.W. Bredeweg, I. Van den Akker-Scheek, Prevalence of jumper's knee among non-elite athletes from different sports: a cross-sectional survey, Am. J. Sports Med. 39 (2011) 1984e1988

H. Van der Worp, M. Van Ark, S. Roerink, G.J. Pepping, I. Van den Akker-Scheek, J. Zwerver, Risk factors for patellar tendinopathy: a systematic review.

of the literature, Br. J. Sports Med. 45 (2011) 446e452.

E. Witvrouw, J. Bellemans, R. Lysens, L. Danneels, D. Cambier, Intrinsic risk factors for the development of patellar tendinitis in an athletic population. A two-year prospective study, Am. J. Sports Med. 29 (2001) 190e195.

U.M. Kujala, K. Osterman, M. Kvist, T. Aalto, O. Friberg, Factors predisposing to patellar chondropathy and patellar apicitis in athletes, Int. Orthop. 10 (1986) 195e200.

J.D. Rees, N. Maffulli, J. Cook, Management of tendinopathy, Am. J. Sports Med.37 (2009) 1855e1867.

J.D. Rees, A.M. Wilson, R.L. Wolman, Current concepts in the management of tendon disorders, Rheumatol. Oxf. 45 (2006) 508e521.

K.M. Khan, N. Maffulli, B.D. Coleman, J.L. Cook, J.E. Taunton, Patellar tendinopathy: some aspbasic science and clinical management, Br. J. SportsMed. 32 (1998) 346e355.

M.E. Larsson, I. K€all, K. Nilsson-Helander, Treatment of patellar tendinopathy a systematic review of randomized controlled trials, Knee Surg. Sports Traumatol. Arthrosc. 20 (2012) 1632e1646.

E.C. Rodriguez-Merchan, The treatment of patellar tendinopathy, J. Orthop. Traumatol. 14 (2013) 77e81.

H. Visnes, R. Bahr, The evolution of eccentric training as treatment for patellar tendinopathy (jumper's knee): a critical review of exercise programmes, Br. J.Sports Med. 41 (2007) 217e223.

H. Van der Worp, I. Van den Akker-Scheek, H. Van Schie, J. Zwerver, ESWT for tendinopathy: technolog and clinical implications, Knee Surg. Sports Traumatol. Arthrosc. 21 (2013) 1451e1458

F. Ioppolo, J.D. Rompe, J.P. Furia, A. Cacchio, Clinical application of shock wave therapy (SWT) in musculoskeletal disorders, Eur. J. Phys. Rehabil. Med. 50(2014) 217e230.

C.J. Wang, Extracorporeal shockwave therapy in musculoskeletal disorders, J. Orthop. Surg. Res. 7 (2012) 11.

M.T. Van Leeuwen, J. Zwerver, I. Van den Akker-Scheek, Extracorporeal shockwave therapy for patellar tendinopathy: a review of the literature, Br. J. Sports Med. 43 (2009) 163e168.

F. Vara, N. Garzon, E. Ortega, G.J. Alarcon, E. Lopez, Treatment of the patellar tendinitis with local application of extracorporeal shock waves, Abstract41 from the 3rd Congress of the International Society for Medical Shockwave Treatment, 2000. Naples.

K.M. Taunton, J.E. Taunton, K.M. Khan, Treatment of patellar tendinopathy with extracorporeal shock wave therapy, B. C. Med. J. 45 (2003) 500e507.

K.H. Peers, Extracorporeal shock wave therapy in chronic patellar tendinopathy: a randomized double-blinded, placebo-controlled trial, Proefschr. KU Leuven 1 (2003) 3e11.

K.H. Peers, R.J. Lysens, P. Brys, J. Bellemans, Cross-sectional outcome analysis of athletes with chronic patellar tendinopathy treated surgically and by extracorporeal shock wave therapy, Clin. J. Sport Med. 13 (2003) 79e83.

J. Zwerver, F. Dekker, G.J. Pepping, Patient-guided piezo-electric extracorporeal shockwave therapy as treatment for chronic severe patellar tendinopathy: a pilot study, J. Back Musculoskelet. Rehabil. 23 (2010) 111e115.

H. Lohrer, J. Scholl, S. Arentz, Achilles tendinopathy and patellar tendinopathy. Results of radial shockwave therapy in patients with unsuccessfully treated tendinosis, Sportsverletz Sportschaden 16 (2002) 108e114.

J.P. Furia, J.D. Rompe, A. Cacchio, A. Del Buono, N. Maffulli, A single application of low-energy radial extracorporeal shock wave therapy is effective for the management of chronic patellar tendinopathy, Knee Surg. Sports Traumatol. Arthrosc. 21 (2013) 346e350.

A. Notarnicola, B. Moretti, The biological effects of extracorporeal shockwave therapy (ESWT) on tendon tissue, Muscles Ligaments Tendons 2 (2012) 33.

N. Maffulli, U.G. Longo, V. Denaro, Novel approaches for the management of tendinopathy, J. Bone Jt. Surg. Am. 92 (2010) 2604e2613.

A. Pascarella, M. Alam, F. Pascarella, C. Latte, M.G. Di Salvatore, N. Maffulli, Arthroscopic management of chronic patellar tendinopathy, Am. J. Sports Med. 39 (2011) 1975e1983.

K. Kulig, R. Landel, Y.-J. Chang, N. Hannanvash, S.F. Reischl, P. Song, G.R. Bashford, Patellar tendon morphology in volleyball athletes with and without patellar tendinopathy, Scand. J. Med. Sci. Sports 23 (2013) e81ee88.

J.A. Ogden, G.L. Cross, Atlanta, Georgia Electrohydraulic orthotripsy for chronic patellar tendinopathy, in Transactions of the 6th International Congress of the ISMST, Feb 11e13, 2003, 2003.

C. Leal, J.C. Lopez, J.M. Herrera, O.E. Reyes, M. Cortes, Shockwave biosurgery and autologous growth factors combined therapy in severe patellar tendinopathies, in: Transactions of the 9th International Congress of the ISMST, Apr. 23, 2006, 2006.

J. Crupnik, Eccentric loading plus radial shock wave therapy in the treatment of chronic patellar tendinopathy, in: Transactions of the 12th International Congress of the ISMST, Jun 2009.

E. Serrano, J.C. Criado, ESWT therapy in patellar tendinopathy comparison of 2protocols, in: Transactions of the 17th International Congress of the ISMST, Jun 2014, 2014.

C. Leal, O. Hernandez, M. Cardozo, M.C. Gallo, Shockwave therapy in patellar tendinopathies, in: Transactions of the 15th International Congress of the ISMST, Jun 2012, 2012.

C.J. Wang, J.Y. Ko, Y.S. Chan, L.H. Weng, S.L. Hsu, Extracorporeal shockwave for chronic patellar tendinopathy, in Transactions of the 10th International Congress of the ISMST, Jun 9th, 2007, 2007.

P.R. Rockett, M. Lui, Effectiveness of ESWT in patients with chronic patellar tendinopathy, in: Transactions of the 12th International Congress of the ISMST, Jun 2009, 2009.

J. Zwerver, M. Van Leeuwen, I. Van Den Akker-Scheek, ESWT for patellar tendinopathy, in: Transactions of the 12th International Congress of the ISMST, Jun 2009, 2009.

H. Van der Worp, H. Zwerver, I. Van Den Akker-Scheek, ESWT treatment protocols for jumper's knee: a worldwide survey, in: Transactions of the 13thInternational Congress of the ISMST, Jun 2010, 2010.

R.W. Wu, C.J. Wang, J.Y.. Ko, Shockwave treatment for chronic patellar tendinopathy of the knee, in Transactions of the 13th International Congress ofthe ISMST, Jun 2010, 2010.

J.P. Furia, J.D. Rompe, A. Cacchio, N. Maffulli, Low energy extracorporeal shocktherapy as a treatment for chronic patellar tendinopathy, in: Transactions of the 14th International

Congress of the ISMST, Jun 2011, 2011.

C. Leal, D. Lemus, J. Juschten, Shockwave therapy for patellar tendinopathy inpatients with total knee arthroplasties, in: Transactions of the 17th International Congress of the ISMST, Jun 2014, 2014.

V. Korakakis , R.Whiteley , A.Tzavara , N.Malliaropoulos

The effectiveness of extracorporeal shockwave therapy in common lower limb conditions: a systematic review including quantification of patient-rated pain reduction, Br J Sports Med ,2018 Mar;52(6):387-407.

12. Tibial Stress Syndrome (TSS)

Dr. Martin Ringeisen (Augsburg, Germany)

ICD classification

M76.8ICD10

Synonyms

Shin splint
Periostitis/periostosis of the tibial edge
Bogus Leg Edge Syndrome
Medial tibial stress syndrome (MTSS)

Definition

Load-dependent pain at the medial edge of the tibia in the middle and lower third due to overloading of the tibialis posterior and flexor hallucis longus muscles with irritation of the tibial periosteum dorsomedially

Etiology

Chronic overload/misload.
Mostly due to athletic stress, often endurance sports or sprinters/jumpers.
High force effect due to hard floors/asphalt
After renewal of the footwear
When using spike shoes
Favored by increased pronation in buckling lowered feet.

Symptoms

Increasing pain at the medial tibial edge in the middle and distal thirds
Often bilateral occurrence
Local pressure pain, functional pain
Changing intensity

Apparatus diagnostics:

MRI
X-ray

Differential diagnoses

Bony pathologies of the middle/distal tibia, also bone marrow edema.
and stress fractures containing
Differentiation from the rare anterior compartment syndrome.

Conservative Therapy Possibilities

Load adjustment and education
ESWT
Physiotherapy, stretching,
Heel shock absorption

Shockwave therapy

Indication:

Symptoms resistant to therapy, indication by a specialist physician.

Spatial requirements:

Certification criteria of a medical practice e.g., hygiene plan, emergency management available according to DIN standard.

Preparation of the patient:

Differentiated and documented education and information (onset of action after weeks)

Physician and assistant personnel:

ESWT is a service to be performed personally by the physician qualified by means of specialist knowledge.

Implementation of the therapy:

no local anesthesia, cryotherapy if necessary
Naming the SW source

- Focused
  Coupling medium (ultrasound gel)
  Once/several times (standard up to 3, max. 5 treatments)
  EFD: 0.10 - 0.25 mJ/mm² depending on the device technology and the
  Pain sensation of the patient Frequency: up to max. 5 Hz
  Pulses: 1500-2500/session
  Interval: 1-2 weeks

- Radial
  Coupling medium (ultrasound gel /cave air bubbles)
  Several times (standard to 3, max. 5 treatments)
  Pressure strength: Pressure strength: 2-4 bar depending on the device technology and the
  Pain sensation of the patient
  Frequency: up to max. 10 Hz
  Pulses: 2000-3000/session
  Interval: 1-2 weeks
  Localization: patient-oriented focusing with consideration of imaging, furthermore co-treatment of myofascial trigger points

Aftercare:

Adaptation of the load, sports modification

Clinical success control after 8- 12 weeks

Literature

Korakakis V, Whiteley R, Tzavara A, Malliaropoulos N. The effectiveness of extracorporeal shockwave therapy in common lower limb conditions: a systematic review including quantification of patient-rated pain reduction. Br J Sports Med. 2017 Sep 27. pii: bjsports-2016-097347. doi: 10.1136/bjsports-2016-097347.

Gomez Garcia S, Ramon Rona S, Gomez Tinoco MC, Benet Rodriguez M, Chaustre Ruiz DM, Cardenas Letrado FP, Lopez-Illescas Ruiz Á, Alarcon Garcia JM. Shockwave treatment for medial tibial stress syndrome in military cadets: a single-blind randomized controlled trial. Int J Surg.2017 Oct; 46:102-109

Winters M1 , Eskes M, Weir A, Moen MH, Backx FJ, Bakker EW. Treatment of medial tibial stress syndrome: a systematic review. Sports Med. 2013 Dec;43(12):1315-33.

Moen MH1 , Rayer S, Schipper M, Schmikli S, Weir A, Tol JL, Backx FJ. Shockwave treatment for medial tibial stress syndrome in athletes; a prospective controlled study.Br J Sports Med. 2012 Mar;46(4):253-7.

Reshef N1 , Guelich DR. Medial tibial stress syndrome. Clin Sports Med. 2012 Apr;31(2):273-90.

H Steere, S DeLuca, J Borg-Stein, G Malanga, Adam S Tenforde, A Narrative Review Evaluating Extracorporeal Shockwave Therapy as a Potential Regenerative Treatment for Musculoskeletal Conditions in Military Personnel Military Medicine, Volume 186, Issue 7-8, July-August 2021, Pages 682-706,

13. Hamstring Tendinopathy

Dr. Martin Ringeisen (Augsburg, Germany)

ICD classification M76.9

Synonyms:

Origin tendinopathy at the tuber ischiadicum
Proximal hamstring tendinosis/ tendinopathy (PHT).

Definition

"Hamstrings": origin of 3 tendons at the tuber ischiadicum:
M.bicepsfemoris(caput longum)
M.semitendinosus
M.semimembranosus
Function: hip extension and knee flexion

Clinic

Pain in the area of the ischium,
Pain when sitting (driving a car)
Pain when climbing stairs and during inclination
"deep" glutealgia
often radiating dorsally to the back of the knee
Differentiation from ischialgia important.

Genesis:

Mainly due to sports trauma: football/skiing/sprinter/boxer/hurdler
Due to repetitive overload/stooping activities(gardening)
Degenerative structural change of the tendon.

Differential diagnoses

Affections of the n.ischiadicus: NPP/ neuroforaminal or recessal stenosis/ spinal stenosis
Ischial fractures/stress fractures/
Affections of the hip joint- centrocaudal arthroses
inflammations/tumors

Diagnosis

MRI
X-ray

Therapy

Load adjustment and education
ESWT, supplemented by stretching exercises and physiotherapy.
Operative: optional for complete rupture of the hamstring group in young competitive

athletes.

Shockwave therapy

Indication:

Symptoms resistant to therapy, indication by a specialist physician.

Contraindication:

Malignant tumor in focus, osteomyelitis.

Spatial requirements:

Certification criteria of a medical practice e.g., hygiene plan, emergency management available according to DIN standard.

Preparation of the patient:

Differentiated and documented education and Information (onset of action after weeks)

Physician and assistant personnel:

ESWT is a service to be performed personally by the physician qualified by means of specialist knowledge.

Implementation of the therapy:

No local anesthesia, cryotherapy if necessary
Naming the SW source

- FOCUSED
Coupling medium (ultrasound gel)
Once/several times (standard up to 3, max. 5 treatments)
EFD: 0.10 - 0.25 mJ/mm² depending on the device technology and the
Pain sensation of the patient Frequency: up to max. 5 Hz
Frequency: up to max. 5 Hz
Pulses: 1500-2500/session
Interval: 1-2 weeks

- RADIAL
Coupling medium (ultrasound gel /cave air bubbles)
Several times (standard to 3, max. 5 treatments)
Pressure strength: Pressure strength: 2-4 bar depending on the device technology and the
Pain sensation of the patient
Frequency: up to max. 10 Hz
Pulses: 2000-3000/session
Interval: 1-2 weeks
Localization: patient-oriented focusing with consideration of imaging, furthermore co-treatment of myofascial trigger points

Complications:

In rare cases hematoma, pain intensification, nerve irritation.

Aftercare:

Adaptation of the load, sports modification
Clinical success control after 8-12 weeks

Literature:

Korakakis V, Whiteley R, Tzavara A, Malliaropoulos N The effectiveness of extracorporeal shockwavetherapy in common lower limb conditions: a systematic review including quantification of patient-ratedpain reduction.Br J Sports Med. 2017 Sep 27. pii: bjsports-2016-097347. doi: 10.1136/bjsports-2016-097347.

Startzman AN, Fowler O, Carreira D. Proximal hamstring tendinosis and partial ruptures. Orthopedics. 2017 Jul 1;40(4):e574-e582. doi: 10.3928/01477447-20170208-05. epub 2017 Feb 14.

Cacchio A, Rompe JD, Furia JP, Susi P, Santilli V, De Paulis F. Shockwavetherapy for the treatment of chronic proximal hamstring tendinopathy in professional athletes. Am J Sports Med. 2011 Jan;39(1):146-53. doi: 10.1177/0363546510379324. epub 2010 Sep 20.

Mitchkash M, Robinson D, Tenforde AS. Efficacy of extracorporeal pulse-activated therapy in the management of lower-extremity running-related injuries: findings from a large case cohort. J Foot Ankle Surg. 2020; 59:795-800.

14. Ledderhose disease as plantar fibromatosis

Prof. Dr. Karsten Knobloch (Hannover, Germany, and Perchtoldsdorf, Austria)

Classification

M72.2 Plantar fibromatosis/M. Ledderhose

Etiology

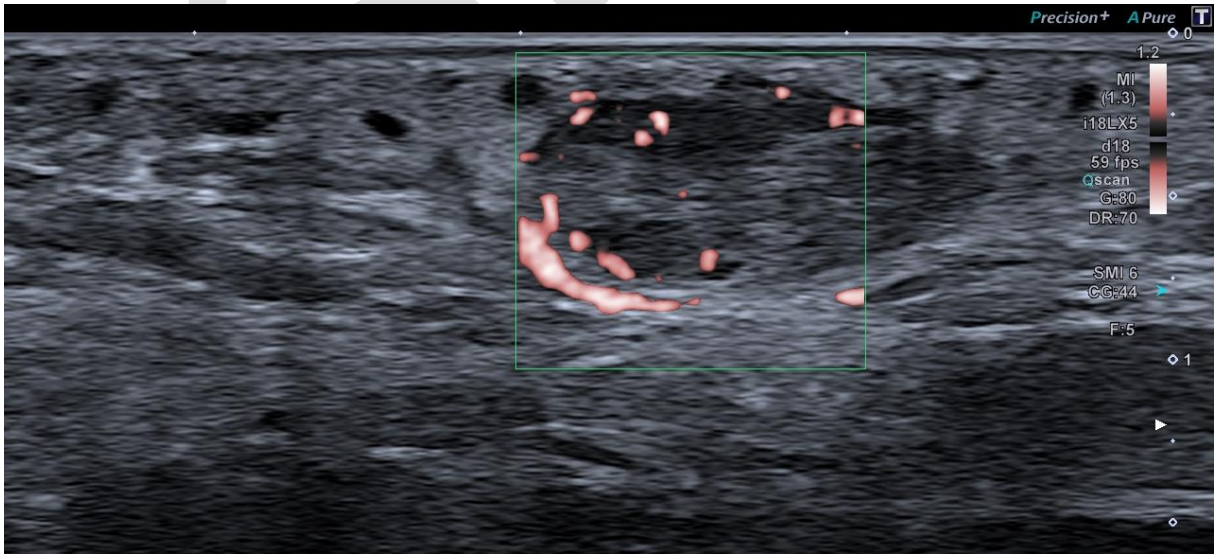
Genetic component via altered single-nucleotide peptides (SNPs) with autosomal-dominant inheritance with variable penetrance similar to Dupuytren's disease of the hand as palmar fibromatosis.

Symptoms

Plantar fibromatosis exclusively with nodule formation in the hollow of the foot, typically localized in a zone from the heel to the Lisfranc joint level and transversely in extension of the first to third metatarsal rays. In addition to the clinical palpation findings, imaging can and should help to rule out benign or malignant tumors (sarcoma, Toepfer et al., 2017) as a differential diagnosis.

Apparative diagnostics

Sonography
Sonographically, similar to Dupuytren's nodes of the hand, Ledderhose nodes appear superficially subcutaneously localized above the plantar fascia often hypoechogenic, but sometimes also isoechogenic to the surrounding subcutaneous fat. Localization below (deeper) to the plantar fascia suggests another process (e.g., sarcoma, Motolese 2013; Toepfer 2017). Modern ultra-high resolution Doppler techniques such as superb microvascular imaging (SMI) show different expressions depending on the degree of activity.



MRI The T2 signal from MRI can potentially be used as a biomarker to indicate the activity of a Ledderhose node and be prognostic for radiation success (Banks et al., 2018).

Therapy of Ledderhose's disease

The therapy of plantar Ledderhose's disease is similar to the nodular stage of Dupuytren's disease of the hand as palmar fibromatosis and Peyronie's disease of the penis.
At the nodal stage, the following treatment options may be offered for symptomatic painful Ledderhose nodes and suffering:

- Focused ESWT
  high-energy ESWT (typically three sessions 1-2 weeks apart, control after 6 months as a refresher, Knobloch 2012). A South Korean study group has used a mean of 8 (5-12) focused ESWT situations (Hwang et al., 2020)
- Plantar radiotherapy for progression inhibition (Heyd 2010, Seegenschmiedt 2013 & 2015, Rödel 2017).
- Surgical excision is associated with a recurrence rate >50%.

Shock wave therapy for M. Ledderhose (plantar fibromatosis)

Indication:

Indication by an expert physician

Contraindication:

Malignant tumor in focus

Spatial requirements:

Certification criteria of a medical practice e.g., hygiene plan, emergency management available according to DIN standard.

Preparation of the patient:

Differentiated and documented education and information

Physician and assistant personnel:

ESWT is a service to be performed personally by the physician qualified by means of specialist knowledge.

Implementation of the therapy:

Positioning in sitting or lying **position** according to the patient's wishes.
Focused ESWT:

- 0.08-0.55mJ/mm^2 (in individual cases up to 1.24mJ/mm^2 electromagnetic), 2000 pulses, 3 sessions at weekly intervals, after 6 months refresher ESWT if necessary depending on disease activity.
- High-energy focused electromagnetic ESWT (2000 pulses, up to 1.24mJ/mm^2, 3 sessions) reduces pain on a visual analog scale VAS by 50% after six weeks and up to 75% after three months (Knobloch et al. 2012).

Literature

Banks JS, Wolfson AH, Subhawong TK. T2 signal intensity as an imaging biomarker for patients with superficial fibromatoses of the hands (Dupuytren's disease) and feet (Ledderhose disease) undergoing definitive electron beam irradiation. Skeletal Radiol

2018;47(2):243-51.

Carroll P, Henshaw RM, Garwood C, Raspovic K, Kumar D. Plantar fibromatosis: pathophysiology, surgical and nonsurgical therapies: an evidence-based review. Foot Ankle Spec 2018 Jan 1.

Heyd R, Forn AP, Herkströter, Rödel C, Müller-Schimpfle M, Fraunholz I. Radiation therapy for early stages of Ledderhose disease. Strahlenther Onkol 2010;186(1):24-.

Hwang JT, Yoon KJ, Park CH, Choi JH, Park HJ, Park YS, Lee YT. Follow-up of clinical and sonographic features after ESWT in painful plantar fibromatosis. PLoS One 2020;15(8): e0237447.

Knobloch K. Ledderhose's disease - an update on therapeutic options. MMW Fortschr Med 2012;154(19):43-4.

Knobloch K, Vogt PM. High-energy focused ESWT reduces pain in plantar fibromatosis (Ledderhose's disease). BMC Res Notes 2012; 5:542.

Motolese A, Mola F, Cherubino M, Giaccone M, Pellegatta I, Valdatta L. Squamous cell carcinoma and ledderhose disease: a case report. Int J Low Extrem Wounds 2013;12(4):297-300.

Rödel F, Fournier C, Wiedemann J, Merz F, Gaipl US, Frey B, Keilholz L, Seegenschmiedt MH, Rödel C, Hehlgans S. Basis of radiation biology when treating hyperproliferative benign diseases. Front Immunol 2017; 8:519.

Seegenschmiedt MH, Micke O, Niewald M, Mücke R, Eich HT, Kriz J, Heyd R, German Cooperative Group on Radiotherapy of benign diseases. DEGRO guidelines for the radiotherapy of non-malignant disorders: part III: hyperproliferative disorders. Strahlenther Onkol 2015;191(7):541-8.

Seegenschmiedt MH, Attassi M. Radiation therapy for Ledderhose disease-indication and clinical results. Radiation Oncol 2013;179(12):847-53.

Toepfer A, Harrasser N, Dreyer F, Mogler C, Walther M, von Eisenhart-Rothe R. Epithelioid sarcoma of the plantar fascia mimicking Morbus Ledderhose - a severe pitfall for clinical and histopathological misinterpretation. Foot Ankle Surg 2017;23(4): e25-30.

15. Osteoarthritis / Gonarthrosis – Knee Osteoarthitis

Sergej Thiele (Berlin, Germany)

Classification

M15-M19 n. ICD-10

Synonym

Osteoarthrosis, in English Osteoarthritis

Definition

Degenerative joint disease associated with wear, tear, and age and involving the musculoskeletal system. Characterized by degenerative destruction of cartilage and damage to adjacent structures, such as bone, muscle, capsule, and ligaments.

Etiology

Damage to the articular cartilage with preserved mobility, "wear and tear", with a mismatch of load and load-bearing capacity

Pathogenesis

Overuse with subsequent matrix degradation (initially reversible, then irreversible in the course) Accompanying synovitis, incipient joint incongruence and loss of cartilage substance

Classification

Kellgren and Lawrence
OARSI
Classification according to Altmann - differentiation of primary and secondary arthroses

Medical history

Gradual onset
Pain and loss of function
Pain on exertion

Diagnostics:

X-ray
MRI
Laboratory diagnostics

Differential diagnoses:

Arthritides of the rheumatic system
Infectious arthritis

Therapy

Physiotherapy and physical applications
NSAIDS
Infiltrations

Surgical therapies:

Arthroplasty
Arthroplasty

Shock wave therapy

Hypothesis and treatment strategy

The aim of the treatment is to reduce pain and improve function for individual relief and, if necessary, to delay endoprosthetic treatment.
Lee and Han report improvement in function and reduction in pain
Wang et al. describe the prevention and treatment of osteoarthritis in an animal model using the rat knee.
Chen et al, in a comparative study of ESWT and ultrasound in patients with knee joint osteoarthritis, achieved pain reduction in the ESWT group and improvement in ROM and Lequesne score.
Lee et al. Show a positive effect in ESWT treatment on pain and function.
Symptoms and range of motion can be positively influenced by reduction of NO, increased expression of growth factors such as vWF, VEGF, BMP-2 and osteocalcin, and suppression of metalloproteinases (MMP-1 and MMP-3).

Implementation of the therapy:

- Focused

Impulses:

2000 - 4000 pulses, with 0.25 - 0.6 mJ/mm², at femoral condyle and tibial plateau

Localization and location:

Palpatory

Aftercare:

Free movement, avoidance of overloading
ESWT is a service to be performed personally by the qualified, expert physician
At the present time, ESWT for osteoarthritis cannot be included in the treatment recommendations because sufficient data are not yet available. Nevertheless, a recommendation to perform ESWT in early stages of osteoarthritis can be identified, especially for rhizarthrosis and gonarthrosis. Treatment depending on the complaints at the bone/cartilage or at the synovium and capsule and the accompanying structures.

Literature:

Thiele, R., Marx, S. Case presentation of arthroscopically controlled therapy of osteochondrosis dissecans using ESWT. Arthroscopy 16 (7 2003), 266-271.

Dahlberg J1, Fitch G, Evans RB, McClure SR, Conzemius M.; The evaluation of extracorporeal shockwave therapy in naturally occurring osteoarthritis of the stifle joint in dogs.Vet Comp Orthop Traumatol. 2005;18(3):147-52.

Ochiai N1, Ohtori S, Sasho T, Nakagawa K, Takahashi K, Takahashi N, Murata R,

Takahashi K, Moriya H, Wada Y, Saisu T.; Extracorporeal shock wave therapy improves motor dysfunction and pain originating from knee osteoarthritis in rats. Osteoarthritis Cartilage. 2007 Sep;15(9):1093-6. epub 2007 Apr 26.

Mayer-Wagner S1, Ernst J, Maier M, Chiquet M, Joos H, Müller PE, Jansson V, Sievers B, Hausdorf J.The effect of high-energy extracorporeal shock waves on hyaline cartilage of adult rats in vivo. J Orthop Res. 2010 Aug;28(8):1050-6. doi: 10.1002/jor.21074.

Kawcak CE1, Frisbie DD, McIlwraith CW. Effects of extracorporeal shock wave therapy and polysulfated glycosaminoglycan treatment on subchondral bone, serum biomarkers, and synovial fluid biomarkers in horses with induced osteoarthritis.Am J Vet Res. 2011 Jun;72(6):772-9. doi: 10.2460/ajvr.72.6.772.

Wang CJ, Sun YC, Wong T, et al: Extracorporeal shockwave therapy shows time-dependent chondroprotective e ects in osteoarthritis of the knee in rats. J Surg Res, 2012, 178: 196-205.

Zhao Z1, Ji H, Jing R, Liu C, Wang M, Zhai L, Bai X, Xing G. Extracorporeal shock-wave therapy reduces progression of knee osteoarthritis in rabbits by reducing nitric oxide level and chondrocyte apoptosis. Arch Orthop Trauma Surg. 2012 Nov;132(11):1547-53. doi: 10.1007/s00402-012-1586-4.Epub 2012 Jul 24.

Lee YH, Han EY: A comparison of the effects of PNF, ESWT, and TPI on pain and function of patients with myofascial pain syndrome. J Phys TherSci, 2013, 25: 341-344.

Wang CJ1, Hsu SL, Weng LH, Sun YC, Wang FS. Extracorporeal shockwave therapy shows a number of treatment-related chondroprotective effect in osteoarthritis of the knee in rats. BMC Musculoskelet Disord. 2013 Jan 28; 14:44. doi: 10.1186/1471-2474-14-44.

Zhao Z1, Jing R, Shi Z, Zhao B, Ai Q, Xing G.

Efficacy of extracorporeal shockwave therapy for knee osteoarthritis: a randomized controlled trial. J Surg Res. 2013 Dec;185(2):661-6. doi: 10.1016/j.jss.2013.07.004. epub 2013 Jul 30.

Chen TW1, Lin CW1, Lee CL2, Chen CH2, Chen YJ1, Lin TY1, Huang MH3.The efficacy of shock wave therapy in patients with knee osteoarthritis and popliteal cyamella. Kaohsiung J Med Sci. 2014 Jul;30(7):362-70. doi: 10.1016/j.kjms.2014.03.006. Epub 2014 Apr 18.

Wang P, Liu C, Yang XT, Wei XF, Zhou YJ, Yang L, He CQ.

[Effect of extracorporeal shock wave therapy on cartilage and subchondral bone remodeling in rabbits with ACLT-induced osteoarthritis]. [Sichuan

Da Xue Xue Bao Yi Xue Ban. 2014 Jan;45(1):120-5.

16. Osteochondrosis dissecans – Osteochondritis dissecans

Sergej Thiele (Berlin, Germany)

M93.2- n. ICD 10

Synonyms

Osteochondrosis dissecans, OD, OCD, subchondral osteonecrosis, articular mouse

Definition

Osteochondrosis dissecans is a localized disease of joints that usually develops during growth and belongs to the group of aseptic bone necrosis. The segmental involvement of subchondral bone and overlying cartilage can lead to the formation of free joint bodies. Mostly convex joint partner, femoral condyles and talus shoulder are particularly frequently affected.

Etiology

Unknown, trauma sequelae and perfusion disorders of unknown genesis are discussed. Constitutionally favoring factors, such as axial malalignments and ligament instabilities, must be taken into account.

Pathogenesis

Subchondral necrosis: Initial stage possibly with induction of reparative processes from surrounding tissue.
Sclerosis or demarcation: Continued loading or other disturbance of remodeling leads to bone compaction in the border region.
Dissekat formation: Demarcation of a chondral - osteochondral fragment with initially still fibrous fixation (dissekat in situ), possibly later release from the mouse bed (free joint body).
The pathogenetic process can come to a halt at any stage.
Classifications:

- Combined classification according to Bruns with arthroscopic, MRI diagnostic and radiological assessment.
- Radiological classification according to Berndt and Harty
- Criteria for questionment stability or resolution on MRI:
  Greater than 1 cm
  Hyperintensity of the surrounding margin greater than 3 mm
  Hypertensive fluid signal on fast scan or T2 between lesion and overlying femur

Medical history

Pain, swelling, blockage, limitation of movement, Givingway
Special history: athletic physical exertion, previous joint injury, hematologic disease, steroid medication.

Diagnostics

Clinical diagnostics, often still unspecific
Apparative diagnostics: X-ray, CT, MRI with KM (Gd)

Differential diagnoses

Osteonecrosis: Perthes disease, Köhler I and II, femoral head necrosis
Secondary osteonecrosis after trauma, cortisone injection, meniscus lesion
Osteochondral fractures
Osteoarthritis

Therapy

Relief, sports leave
Gait training,
Movement exercises, especially abduction and internal rotation,
Analgesics,
NSAIDS,
Physiotherapy,
Orthotic fitting for relief,
HBO therapy

Destination

Revitalization of the osteochondral district
Avoidance of progression (dissection)
Prevention of osteoarthritis

Surgical Therapies

Boring, (anterograde, retrograde)
subchondral spongioplasty
Dissecat fixation (e.g. by means of fibrin glue, resorbable pins, osteosynthesis with metallic implants, possibly spongiosaplasty)
Dissect removal
Cartilage/bone grafting

Shock wave therapy

Indication:

Indication by an expert physician
Therapy should be given at the earliest possible stage, but definitely before the dissect is resolved.

Spatial requirements:

Certification criteria of a medical practice e.g. hygiene plan, emergency management available according to DIN standard.

Preparation of the patient:

Differentiated and documented education and information

Physician and assistant personnel:

ESWT is a service to be provided personally by the physician qualified by means of specialist knowledge

Implementation of the therapy:

Documentation:

Designation of the shock wave source and the parameters used
High energy, focused
2500 - 3500 pulses, with 0.35 - 0.6mJ/mm², if possible, at the necrosis edge

Localization and location:

Either arthroscopically or after MRI with anatomical orientation using X-ray image converter

Anesthesia:

Conduction or general anesthesia

Aftercare:

Relief for 2 - 6 weeks, orthograde loading in orthosis possible if necessary.
Follow-up: MRI control recommended after 6 and 12 months

Literature:

Lauber S, Ludwig J, Lauber H-J, Hötzinger H, Dreisilker U, Rädel R, Platzek P (2000) MRI after Shockwave Treatment for Osteonecrosis of the Femoral Head In: Coombs R, Schaden W, Zhou S (2000) Musculoskeletal Shockwave Therapy. Greenwich Medical Media Ltd.

Lauber S, Ludwig J, Lauber J, Hötzinger J (2001) The ESWT treatment of femoral head necrosis and osteochondrosis dissecans. In: Extracorporeal shock wave therapy in orthopedics (Siebert W, Buch M [eds.]). ecomed.

Thiele, R., Marx, S. Case presentation of arthroscopically controlledtherapy of osteochondrosis dissecans mittels ESWT. Arthroscopy 16 (7 2003), 266-271.

Thiele, R., Marx, S. The treatment of osteochondral lesions by ESWT. Orthopaedic Practice 42, 4 (4 2006), 55-59.

Moretti, B., Notarnicola, A., Moretti, L., Giordano, P., and Patella, V. A volleyball player with bilateral knee osteochondritis dissecans treated with extracorporeal shock wave therapy. Musculoskelet Surg 93, 1 (May 2009), 37-41.

C.J. Wang, Y.C. Sun, T. Wong, S.L. Hsu, W.Y. Chou, H.W. Chang, Extracorporeal shockwave therapy shows time-dependent chondroprotective effects in osteoarthritis of the knee in rats, J. Surg. Res. 178 (1) (2012 Nov) 196e205.

Lyon R, Liu XC, Kubin M, Schwab J. Does Extracorporeal Shock Wave Therapy Enhance Healing of Osteochondritis Dissecans of the Rabbit Knee, Clin. Orthop Relat Pres (2013) 471:1159-1165.

Thiele S., Thiele R, Gerdesmeyer L; Adult osteochondrotitis dissecans and focussed ESWT: A successful treatment option, International Journal of Surgery 24 (2015); 191-194.

17. Bone Marrow Edema

Dr. Martin Ringeisen (Augsburg, Germany)

ICD classification

M85 ICD10

Synonyms

Bone marrow edema syndrome, Transient osteoporosis, Bone bruise, Migrating bone marrow edema syndrome, Mechanical bone marrow edema, Reactive bone marrow edema, Degenerative/metabolic bone marrow edema, Postoperative bone marrow edema, Transient osteoporosis, Osteoporosis migrans/saltans, Local osteoporosis.

Etiology/Classification

First description and conceptualization by AJ Wilson, Radiology, 1988:
Bone marrow edema (BMO) describes increased water accumulation, which is represented by signal enhancement of water-sensitive sequences on MRI and is due to edema/hematoma formation. BME = MR graphic feature
CAVE: an edema-equivalent image signal does not explain its genesis: delineation of tumor/ inflammation/ trauma/ degeneration required!

Distinguish:

1. primary/idiopathic CMO
   - CMEA according to Thiryayi et al. 2008 Eur.J.Radiol.: clinical radiographic entity without signs of avascular necrosis, trauma or infection, primarily at the hip and knee with acute or chronic pain.
2. Secondary SME
   - Mechanical/traumatic: edema due to repetitive overload/stress response/stress fracture/bone bruise.
   - Tumorigenic in metastases or malignant hemopathies
   - Ischemic (avascular necrosis)
   - Trophic/vasomotor/ CRPS
   - Degenerative/metabolic
   - Postoperative

Symptoms/progression

Pain at rest, pain on exertion, bone knock pain
Functional limitation
Primary CMO usually self-limiting: 6 to 18 months but can also take on a life of its own and lead to intolerable constant pain with massive restriction of movement up to immobility and destruction of the bone.

Apparative diagnostics

MRI as gold standard

Differential diagnosis

Especially in the case of secondary CMED, the underlying pathologies have to be evaluated. Any CMO that does not have a clearly identifiable background is suspicious for the presence of a malignant hemopathy, especially from the group of gammopathies (e.g., plasmocytoma/Morbus Waldenström). In these cases, the relevant laboratory parameters should be determined serologically.

Conservative therapy

Load adjustment, unloading, physiotherapy, analgesia, focused shock wave therapy, electromagnetic transduction therapy (EMTT).

By analogy with the literature (1), only when the above measures fail:

off-label drug therapy: bisphosphonates iv. or orally, iloprost

Surgical Therapy:

Core decompression

Shockwave therapy

Indication:
Symptoms resistant to therapy, indication by a specialist physician.

Contraindication:

Malignant tumor in focus

Spatial requirements:

Certification criteria of a medical practice e.g., hygiene plan, emergency management available according to DIN standard.

Preparation of the patient:

Differentiated and documented education and

Information (onset of action after weeks)

Physician and assistant personnel:

ESWT is a service to be performed personally by the physician qualified by means of specialist knowledge.

Implementation of the therapy:

ESWT in CMO corresponds to the algorythm of other indications in pathologies of the bone such as pseudarthrosis or stress fracture:
If required, line anesthesia/sedation/general anesthesia.

- Electrohydraulic:
  Single treatment, after 3 to 6 months second or third treatment possible
  Frequency:1- 4 Hz
  3000 (2000 - 4000) pulses
  EFD: up to 0.4 mJ/mm²
- Electromagnetic:
  1 to 4 treatments, 1/week
  Frequency:1- 4 Hz

4000 pulses
EFD: up to 0.5 mJ/mm²

- Piezoelectric:
  No reference literature available (according to preamble Physical Principles).
  Radial:
  No reference literature available (according to preamble Physical Principles).

Locating: patient-centered focusing with imaging in mind

After therapy:

Monitoring of circulatory function if necessary

Complications:

Hematoma, pain intensification, nerve irritation

Aftercare:

Adaptation of the load, sports modification
Clinical success control after 8-12 weeks
Should controlling imaging be performed, it is imperative to note that clinical cure is not necessarily associated with complete remission of the CMO, and regression of the CMO on MRI often occurs with a significant time delay.

Literature:

Stumpf, U., Kraus, M., Baumbach, S. F., Koliogiannis, V., Bechtold-Dalla Pozza, S., Feist-Pagenstert, I., Fürmetz,J., Baur-Melnyk,A., Saller, M., Straube, A., Leipe,J., Schmidmaier, R. (2021). Bone marrow edema syndrome: interdisciplinary diagnostic strategy and therapeutic options. Osteology, 30(01), 26-32.

Cao J, Zhang C, Huang H, Yang L, Duan X. Bone Marrow Edema Syndrome of the Foot Treated with Extracorporeal Shock Wave Therapy: A Retrospective Case Series. J Foot Ankle Surg. 2021 May-Jun;60(3):523-528. doi: 10.1053/j.jfas.2020.10.007. epub 2020 Oct 7. PMID: 33573900.

Häußer J, Wieber J, Catalá-Lehnen P. The use of extracorporeal shock wave therapy for the treatment of bone marrow oedema - a systematic review and meta-analysis. J Orthop Surg Res. 2021 Jun 9;16(1):369. doi: 10.1186/s13018-021-02484-5. PMID: 34107978; PMCID: PMC8188716.

Vitali M, Naim Rodriguez N, Pedretti A, Drossinos A, Pironti P, Di Carlo G, Fraschini G. Bone Marrow Edema Syndrome of the Medial Femoral Condyle Treated With Extracorporeal Shock Wave Therapy: A Clinical and MRI Retrospective Comparative Study. Arch Phys Med Rehabil. 2018 May;99(5):873-879. doi: 10.1016/j.apmr.2017.10.025. epub 2017 Dec 7. PMID: 29223709.

Kang S, Gao F, Han J, Mao T, Sun W, Wang B, Guo W, Cheng L, Li Z. Extracorporeal shock wave treatment can normalize painful bone marrow edema in knee osteoarthritis: a comparative historical cohort study. Medicine (Baltimore). 2018 Feb;97(5):e9796. doi: 10.1097/MD.00000000009796. PMID: 29384878; PMCID: PMC5805450.

Gao F, Sun W, Li Z, Guo W, Kush N, Ozaki K. Intractable bone marrow edema syndrome of the hip. Orthopedics. 2015 Apr;38(4):e263-70. doi: 10.3928/01477447-20150402-53.

PMID: 25901618.

GAO, Fuqiang, et al. Extracorporeal shock wave therapy in the treatment of primary bone marrow edema syndrome of the knee: a prospective randomised controlled study. BMC Musculoskeletal Disorders, 2015, Jn 16, pp. 1-8.

Notarnicola A, Moretti L, Tafuri S, Panella A, Filipponi M, Casalino A, Panella M, Moretti B.; Clinic of the Orthopedics Department of Bari University Hospital (Italy).

Shockwave therapy in the management of complex regional pain syndrome of medial femoral condyle of the knee. Ultrasound Med Biol. 2010 Jun;36(6):874-9. doi: 10.1016/j.ultrasmedbio.2010.03.012. Epub 2010 May 5.

18. Pseudarthrosis and Delayed Healing Bone Fractures

Prof. Dr. Wolfgang Schaden (Ludwig Boltzmann Institute for Traumatology in cooperation with AUVA, Austria)

ICD-10 (2011 version): M-84.1, M-84.2

Classification
Pseudarthrosis: Failure of bone healing > 6 to 9 months
Delayed fracture healing: No bone healing 3-6 months after fracture/operation

Synonyms Wrong joint Non-union Delayed union

Etiology
Interposition of soft tissues in the fracture gap
Dislocation or distraction (insufficient contact of fragments), inadequate inmobilization or mobilization too early, insufficient blood supply, infection, systemic diseases (diabetes mellitus, arterial occlusive disease, cortisone, smoking, etc.)

Symptoms
Bending and spraining pain, strain and relief pain, swelling, redness, hyperthermia, (abnormal mobility)

Apparative diagnostics: (combination of imaging methods) X-ray, CT, (MRI)

Differential diagnosis Osteomyelitis, Pathological fracture, Congenital anomalies, Stress fracture

Shockwave therapy

Indication:
Non-through fracture without significant dislocation according to the above definition without progression in the course of X-ray controls, persistent fracture gap. In long tubular bones, the success rate decreases with fracture gap > 5mm.

Indication by an expert physician.

Contraindication:
Epiphyseal joint in focus
Brain tissue or spinal cord in focus,
Tumor tissue in focus,
Lung tissue in focus
Significant coagulopathy (check coagulation status).

Spatial requirements:
Ability to provide regional or general anesthesia X-ray localization.

Certification criteria of a medical practice e.g., hygiene plan, emergency management available according to DIN standard

Preparation of the patient: differentiated and documented education and information

Documentation:
Designation of the shock wave source and the parameters used.

Physician and assistant staff: ESWT is a service to be provided personally by the qualified physician.

Implementation of therapy: conduction anesthesia/general anesthesia, stable positioning of the patient/extremity.

Coupling medium: Ultrasound gel, if necessary, Vaseline/castor oil

Locating: Radiological, (ultrasound)

Avoidance of large vessels/nerves in focus

Electrohydraulic:
One-time treatment, after 3 to 6 months second or third treatment possible
Frequency:1- 4 Hz
3000 (2000 - 4000) pulses
EFD: 0.3 - 0.4 mJ/mm²

Electromagnetic:
3to 4 treatments; in 3 to 7 days interval.
Frequency:1- 4 Hz
4000 pulses
EFD: 0.4 - 0.7 mJ/mm² (long tubular bones); 0.1 mJ/mm² (navicular bone)

Piezoelectric:
No reference literature available (according to preamble).

Radial:
No reference literature available (according to preamble).

Complications:
Temporary hematoma discoloration, pain intensification, nerve irritation, failure of osseous healing.

After therapy:
After ESWT, the pseudarthrosis should be immobilized exactly between 3 and 5 weeks, depending on the localization, in order not to endanger the newly sprouting capillaries (this may result in relief for this period, especially in the lower extremity).

If the osteosynthesis material is in place and there are no clinical and/or radiological signs of loosening, no further measures are required other than rest.

In the case of a loosened implant and conservatively pretreated fractures, fixation should be applied according to the guidelines for conservative fracture treatment. In the case of particularly mobile pseudarthroses, especially in the lower leg region, an external fixator must also be applied in individual cases. In the case of fractures not at risk of dislocation, X-ray checks at four-week intervals are sufficient (otherwise at

correspondingly shorter intervals).

Literature:

Publications with evidence level from Ib to IIb (Pubmed27.04.2018):

Cacchio, A., Giordano, L., Colafarina, O., Rompe, J. D., Tavernese, E., Ioppolo, F., Flamini, S., Spacca, G., and Santilli, V. Extracorporeal shock-wave therapy compared with surgery for hypertrophic long-bone nonunions. J Bone Joint Surg Am 91, 11 (Nov 2009), 2589-97.

Furia, J. P., Juliano, P. J., Wade, A. M., Schaden, W., and Mittermayr, R. Shock wave ther- apy compared with intramedullary screw fixation for nonunion of proximal fifth metatarsal metaphyseal-diaphyseal fractures. J Bone Joint Surg Am 92, 4 (Apr 2010), 846-54.

Stojadinovic, A., Kyle Potter, B., Eberhardt, J., Shawen, S. B., Andersen, R. C., Fors- berg, J. A., Shwery, C., Ester, E. A., and Schaden, W. Development of a prognostic naive bayesian classifier for successful treatment of nonunions. J Bone Joint Surg Am 93, 2 (Jan 2011), 187- 94.

Notarnicola, A., Moretti, L., Tafuri, S., Gigliotti, S., Russo, S., Musci, L., and Moretti, B. Extracorporeal shockwaves versus surgery in the treatment of pseudoarthrosis of the carpal scaphoid. Ultrasound Med Biol 36, 8 (Aug 2010), 1306-13.

Other publications:

Haupt, G., et al: Enhancement of fracture healing with extracorporeal shock waves. AUA Annual Meeting, New Orleans 1990.

Valchanov, V. D. and Michailov, P.: High energy shock waves in the treatment of delayed and non-union of fractures. Int Orthop 15, 3 (1991), 181-184.

Beutler S, Regel G, Pape HC, Machtens S, Weinberg AM, Kremeike I, Jonas U, Tscherne H.: Extracorporeal shock wave therapy for delayed union of long bone fractures - preliminary results of a prospective cohort study. Trauma Surgeon. 1999 Nov;102(11):839-47

Ikeda K, Tomita K, Takayama K.: Application of extracorporeal shock wave on bone: preliminary report. J Trauma. 1999 Nov;47(5):946-50.

Rompe JD, Rosendahl T, Schöllner C, Theis C. High-energy extracorporeal shock wave treatment of non-unions. ClinOrthopRelat Res. 2001 Jun;(387):102-11.

Wang CJ, Chen HS, Chen CE, Yang KD: Treatment of non-unions of long bone fractures with shock waves. Clin Orthop Relat Res. 2001 Jun;(387):95-101.

Schaden W, Fischer A, Sailler A.: Extracorporeal shock wave therapy of non-union or delayed osseous union. Clin Orthop Relat Res. 2001 Jun;(387):90-4.

Wang FS, Yang KD, Wang CJ, Huang HC, Chio CC, Hsu TY, et al. Shockwave stimulates oxygen radical-mediated osteogenesis of the mesenchymal cells from human umbilical cord blood. J Bone Miner Res 2004 Jun;19(6):973-82.

Chen YJ, Kuo YR, Yang KD, Wang CJ, Sheen Chen SM, Huang HC, et al. Activation of extracellular signal-regulated kinase (ERK) and p38 kinase in shock wave-promoted bone formation of segmental defect in rats. Bone 2004 Mar;34(3):466-77.

Wang CJ, Liu HC, Fu TH.: The effects of extracorporeal shockwave on acute high-energy long bone fractures of the lower extremity. Arch Orthop Trauma Surg. 2007 Feb;127(2):137-42.

Bara T, Synder M.: Nine-years' experience with the use of shock waves for treatment of bone union disturbances. Ortop Traumatol Rehabil. 2007 May-Jun;9(3):254-8.

Wang CJ, Wang FS, Yang KD: Biological effects of extracorporeal shockwave in bone healing: a study in rabbits. Archives of orthopaedic and trauma surgery 2008, 128:879-884.

Xu ZH, Jiang Q, Chen DY, Xiong J, Shi DQ, Yuan T, et al. Extracorporeal shock wave treatment in nonunions of long bone fractures. Int Orthop 2009 Jun;33(3):789-93.

Xu ZH, Jiang Q, Chen DY, Xiong J, Shi DQ, Yuan T, Zhu XL.: Extracorporeal shock wave treatment in non-unions of long bone fractures. Int Orthop. 2009 Jun;33(3):789-93.

Wang CJ, Yang KD, Ko JY, Huang CC, Huang HY, Wang FS.: The effects of shockwave on bone healing and systemic concentrations of nitric oxide (NO),TGF-beta1, VEGF and BMP-2 in long bone non-unions. Nitric Oxide. 2009 Jun;20(4):298-303.

Elster EA, Stojadinovic A, Forsberg J, Shawen S, Andersen RC, Schaden W.: Extracorporeal shock wave therapy for non-union of the tibia. J Orthop Trauma. 2010 Mar;24(3):133-41.

Zelle B A, Gollwitzer H, Zlowodzki M, Buhren V: Extracorporeal shock wave therapy: current evidence.J Orthop Trauma 2010;24:S66-S70.

Furia, J. P., Rompe, J. D., Cacchio, A., and Maffulli, N. Shock wave therapy as a treatment of non-unions, avascular necrosis, and delayed healing of stress fractures. Foot Ankle Clin 15, 4 (Dec 2010), 651-62.

Cacchio A, Giordano L, Colafarina O, Rompe JD, Tavernese E, Ioppolo F, Flamini S, Spacca G, Santilli V. Extracorporeal shock-wave therapy compared with surgery for hypertrophic long-bone non-unions. J Bone Joint Surg Am. 2010 May;92(5).

Ayeni OR, Busse JW, Bhandari M.: Using extracorporeal shock-wave therapy for healing long-bone non-unions. Clin J Sport Med. 2011 Jan;21(1):74-5.

Stojadinovic A, Kyle Potter B, Eberhardt J, Shawen SB, Andersen RC, Forsberg JA, Shwery C, Ester EA, Schaden W.: Development of a prognostic naive Bayesian classifier for successful treatment of non-unions. J Bone Joint Surg Am. 2011 Jan;93(2):187-94.

Xu JK, Chen HJ, Li XD, Huang ZL, Xu H, Yang HL, et al. Optimal intensity shock wave promotes the adhesion and migration of rat osteoblasts via integrin beta1-mediated expression of phosphorylated focal adhesion kinase. J BiolChem 2012 Jul 27;287(31):26200-12.

Sun D, Junger WG, Yuan C, Zhang W, Bao Y, Qin D, et al. Shockwaves induce osteogenic differentiation of human mesenchymal stem cells through ATP release and activation of P2X7 receptors. Stem Cells 2013 Jun;31(6):1170-80.

Schaden W, Mittermayr R, Haffner N, Smolen D, Gerdesmeyer L, Wang C-J, Extracorporeal shockwave therapy (ESWT) e First choice treatment of fracture non-unions? International Journal of Surgery 24 (2015) 179 - 183

Alkhawashki H M I, Shock wave therapy of fracture nonunion. (2015). Injury, 46(11):2248-52.

Kertzman P, Lenza M, Pedrinelli A, Ejnisman B, Shockwave treatment for musculoskeletal diseases and bone consolidation: qualitative analysis of the literature. (2015). Rev Bras Ortop, 50(1):3-8.

Kuo S-J, Su I-C, Wang C-J, Ko J-Y, Extracorporeal shockwave therapy (eswt) in the treatment of atrophic non-unions of femoral shaft fractures. (2015). Int J Surg, 24(Pt B):131-134.

Everding J, Freistühler M, Stolberg-Stolberg J, Raschke M J, Garcia P, Extracorporeal shock wave therapy for the treatment of pseudarthrosis: New experiences with an old technology. The Trauma Surgeon. (2016).

Zhai L, Ma X-L, Jiang C, Zhang B, Liu S.-T, Xing G-Y, Human autologous mesenchymal stem cells with extracorporeal shock wave therapy for nonunion of long bones. Indian J Orthop, 2016 50(5):543-550.

Haffner N, Antonic V, Smolen D, Slezak P, Schaden W, Mittermayr R, Stojadinovic A, Extracorporeal shockwave therapy (eswt) ameliorates healing of tibial fracture non-union unresponsive to conventional therapy. (2016) Injury, 47(7):1506-13.

19. Stress fractures

Prof. Dr. Wolfgang Schaden (Ludwig Boltzmann Institute for Traumatology in cooperation with AUVA, Austria)

ICD-10: M-84.3

Synonyms

Fatigue fractures, march fractures,

Etiology

Local overuse of bony structures due to unaccustomed external stressors.

Symptoms

Local pressure pain, redness, swelling, bending and strain pain.

Apparative diagnostics: (combination of imaging methods)
X-ray
CT
MRI

Differential diagnosis

Osteomyelitis,
Pathological fracture
Congenital anomalies
Bone marrow edema

Conservative therapy

Immobilization
Relief
Pulsating ultrasound
Magnetically induced electrotherapy

Operative therapy

Debridement of the fracture (bone grafting)
Osteosynthesis

Shockwave therapy

Indication:

Indication by a physician

Contraindication:

Epiphyseal joint in focus
Tumor tissue in focus
Significant coagulopathy (check coagulation status)

Spatial requirements:

Possibility of regional or general anesthesia, X-ray localization.
Certification criteria of a medical practice e.g., hygiene plan, emergency management available according to DIN standard.

Preparation of the patient:

Differentiated and documented education and information

Implementation of the therapy:

ESWT is a service to be provided by the qualified physician Line anesthesia/general anesthesia.
Stable positioning of the patient/limb
Naming the SW source
Coupling medium Ultrasound gel (Vaseline/castor oil)
Localization: Radiological / ultrasound

- Electrohydraulic:
  One-time treatment, after 3 to 6 months second or third treatment possible
  Frequency:1- 4 Hz
  3000 (2000 - 4000) pulses
  EFD: 0.3 - 0.4 mJ/mm²
- Electromagnetic:
  2 to 4 treatments; in 3 to 7 days interval.
  Frequency:1- 4 Hz
  4000 pulses
  EFD: 0.4 - 0.7 mJ/mm²
- Piezoelectric:
  No reference literature available (according to preamble).
- Radial:
  No reference literature available (according to preamble).

Complications:

Temporary hematoma discoloration, temporary pain intensification, nerve irritation, failure of osseous breakdown.
Pseudarthrosis

After therapy:

After ESWT, the stress fracture should be relieved between 4 and 6 weeks, depending on the localization. Active movement exercises without load can be started immediately.
In patients with questionable compliance, fixation in a plaster or plastic bandage is indicated. Since patients with stress fractures are often top athletes who immediately resume their full training program when their symptoms subside, which often occurs immediately after ESWT, particular attention must be paid to compliance.
The course of healing is assessed primarily by clinical development but can be detected somewhat delayed in appropriate imaging techniques.

Literature

Saunier J, Chapurlat R, Stress fracture in athletes. 2017 May 13. pii: S 1297-319 Joint Bone Spine.

Leal C, D'Agostino C, Garcia S G, Fernandez A, Current concepts of shockwave therapy in stress fractures, International Journal of Surgery 24 (2015) 1 - 6.

Audain R, Alvarez Y, Perez N, Barrios G, Focused shockwaves in. the treatment and prevention of tibial stress fractures in athletes, in: Transactions of the ISMST 15th International ISMST Congress, Cartagena, 2012.

Abello S, Leal C, ESWT in foot navicular stress fracture of a high performance athlete, in: Transactions of the ISMST 14th International ISMST Congress Kiel, 2011.

Furia, J. P., Rompe, J. D., Cacchio, A., and Maffulli, N. Shock wave therapy as a treatment of non-unions, avascular necrosis, and delayed healing of stress fractures. Foot Ankle Clin 15, 4 (Dec 2010), 651-62.

Moretti B, Notarnicola A, Garofalo R, Shock waves in the treatment of stress fractures, Ultrasound Med. Biol. 35 (2009) 1042 - 1049.

Moretti B, Notarnicola A, Marlinghaus E, Garofalo R, Moretti L, Patella S, Patella V, ESWT in stress fractures, in: Transactions of the 12th International ISMST Congress, June 2009.

Knobloch K, Schreibmueller L, Jagodzinski M, Zeichen J, Krettek C, Rapid. rehabilitation program following sacral stress fracture in a long-distance running female athlete, Arch. Orthop. Trauma Surg. 127 (9) (2007) 809 - 813.

Taki M, Iwata O, Shiono M, Extracorporeal shock wave therapy for resistant stress fractures in athletes, Am. J. Sports Med. 35 (2007) 1188 - 1192.

Leal C, Shockwave biosurgery for stress fractures, in: Transactions of the ISMST 9th International ISMST Congress, Rio de Janeiro, 2006.

Herrera J M, Leal C, Murillo M, Duran R, Lopez J C, Reyes O E, Treatment. of tibial stress fractures in high performance athletes with extracorporeal shockwave lithotripsy, Rev. la Soc. Colomb. Cirugia Ortop. Traumatol. SCCOT 19 (1) (2005) (in Spanish).

Leal C, Herrera J M, Murillo M, Duran R, Reyes O E, Lopez J C, Extracorporeal shockwave therapy in tibial stress fractures, in: Abstracts of the International Society of Arthroscopy Knee Surgery and Orthopedic Sports Medicine Medicine ISAKOS Biennial Congress, Hollywood USA, Apr 2005.

Audain R, Maggiore G, Herrera J, Almao M, A clinical case of treating stress fractures with ESWT, in: Transactions of the ISMST 6th International ISMST Congress, Orlando, 2003.

Gordon R, Lynagh L, ESWT treatment of stress fractures, in: Transactions of the ISMST 5th International ISMST Congress, Winterthur, 2002.

Leal C, Herrera J M, Murillo M, Duran R, Reyes O E, Lopez J C, ESWT in high performance athletes with tibial stress fractures, in: Transactions of the ISMST 5th International ISMST Congress, Winterthur, 2002.

Hotzinger A, Radelberger L, Lauber U S, Lauber H, Platzekc P, Ludwig J, MRI guided SWT of multiple stress fractures of the tibia, in: Transactions of the ISMST 2nd International ISMST Congress, London, 1999.

Audain Roberto, Maggiore Giovanni, Herrera Jesus, Almao Miguel, Clinical Case of Treating Stress Fractures with ESWT, Presentation 6th Congress of the ISMST, Orlando, USA,

20. Aseptic femoral head necrosis

Prof. Dr. Wolfgang Schaden (Ludwig Boltzmann Institute for Traumatology in cooperation with AUVA, Austria)

ICD-10: M97.0

Etiology, pathogenesis, pathophysiology

The etiology is not yet clear, discussed are a vascular risk due to a subcritical vascular supply in the predilection age, constitutional influences, possible multiple bone infarcts.
The disease occurs particularly in humans and in domestic dogs. The exact causes are not fully understood; femoral head necrosis occurs more frequently in diabetes mellitus and in alcoholism. Prolonged treatment with anticoagulants can also result in femoral head necrosis.
Femoral head necrosis can occur after injury to the femoral head. This is then referred to as post-traumatic femoral head necrosis. Typically, femoral head necrosis occurs after shearing of the femoral head in traumatic dislocation of the hip.
Without any apparent cause, such as an accident, a hip suddenly begins to hurt. The mobility of the joint is restricted, mostly the internal rotation and extension is inhibited. The normal X-ray can often show no pathological changes in the first stage, only the examination with MRI (also with contrast medium) shows the change of the metabolic state in the diseased bone in the early stage.
Medical Classification Staging
according to ARCO

- Stage A0:
  Pain in the hip without verifiable signs on x-ray, CT scan, scintigram, or MRI
- Stage A1:
  X-ray and CT are normal, MRI shows change in medial femoral head less than 15% of surface area.
- Stage A2:
  no sickle sign, on X-ray sclerosis, osteolysis and focal porosis, area 15 - 30%.
- Stage A3:
  Sickle sign on X-ray, more than 30% surface area affected on MRI and CT.
- Stage A4:
  Osteoarthritis, signs of osteoarthritis on radiograph, narrowing of joint space, change in acetabula, joint destruction.

Medical history

Specific history: knee pain, limping, laziness to walk, fatigability, pain intervals, alcohol consumption, metabolic pathologies, medication history, sickle cell anemia.
General history: familial occurrence, hip dysplasia, infection.

Diagnostics

Apparative diagnostics: see above.
Differential diagnosis: bacterial coxitis, tumor diseases, coxarthrosis

Therapy

Objectives: Preservation of the femoral head, freedom from pain and mobility.
Conservative therapy:
Iloprost infusion therapy, analgesics, NSAIDs, physical therapy, gait training, range of motion exercises, especially abduction and internal rotation, stress reduction, orthotic fitting for relief, HBO therapy, electromagnetic transduction therapy (EMTT).
Surgical therapy:
In stage I and II, tapping for decompression; in stage III and IV, joint replacement, hip arthroplasty,

Shockwave therapy

Indication:

Indication by the expert physician
Before therapy:
Spatial requirements:
Certification criteria of a medical practice e.g.
Hygiene plan, emergency management available according to DIN standard.
Preparation of the patient:
Differentiated and documented education and information
Physician and assistant personnel:
ESWT is a service to be performed personally by the physician qualified by means of specialist knowledge.

Implementation of the therapy:

Treatment under general anesthesia or conduction anesthesia
Positioning of the patient with exposure of the findings (external rotation and extension)
Visualization of the area previously localized in MRI with gadolinium by X-ray image converter.
Localization of the vascular nerve bundles.
Shock Wave Source:
High energy, focused.
Positioning of the high-energy transducer,
4000 - 6000 pulses, high energy 0.35 - 0.6 mJ/mm² energy flux density,
1-3 treatment with 12 weeks interval

Postoperative follow-up:

Relief for 6 weeks on crutches, physiotherapeutic mobilization and movement exercises, then increasing load up to competitive sports when symptom-free. MRI control immediately in case of deterioration, otherwise after 6 to 12 months at the earliest, since the MRI remains positive for a long time even if the patient is free of symptoms.

Documentation:

Documentation of the shock wave source and treatment parameters: physician responsible for ESWT
For treatments under general or conduction anesthesia: OP report

Literature

D.S. Hungerford, [Role of core decompression as treatment method for ischemic femur head necrosis], Orthopade 19 (1990) 219 - 223. J. Ludwig, S. Lauber, H.J. Lauber, U. Dreisilker, R. Raedel, H. Hotzinger, Highenergy shock wave treatment of femoral head necrosis in adults, Clin. Orthop. Relat. Res. (2001) 119 - 126.

C.J. Wang, F.S. Wang, C.C. Huang, K.D. Yang, L.H. Weng, H.Y. Huang, Treatment for osteonecrosis of the femoral head: comparison of extracorporeal shockwaves with core decompression and bone-grafting, J. Bone Jt. Surg. Am. 87 (2005) 2380 - 2387.

M.C. Vulpiani, M. Vetrano, D. Trischitta, L. Scarcello, F. Chizzi, G. Argento, V.M. Saraceni, N. Maffulli, A. Ferretti, Extracorporeal shock wave therapy in early osteonecrosis of the femoral head: prospective clinical study with longterm follow-up, Archives Orthop. Trauma. Surg. 132 (2012) 499 - 508.

C.J. Wang, F.S. Wang, J.Y. Ko, H.Y. Huang, C.J. Chen, Y.C. Sun, Y.J. Yang, Extracorporeal shockwave therapy shows regeneration in hip necrosis, Rheumatology, 47 (2008) 542 - 546.

J.M. Chen, S.L. Hsu, T. Wong, W.Y. Chou, C.J. Wang, F.S. Wang, Functional outcomes of bilateral hip necrosis: total hip arthroplasty versus extracorporeal shockwave, Archives Orthop. Trauma. Surg. 129 (2009) 837 - 841.

D. Kusz, A. Franek, R. Wilk, P. Dolibog, E. Blaszczak, P. Wojciechowski, P. Krol, B. Kusz, The effects of treatment the avascular necrosis of the femoral head with extracorporeal focused shockwave therapy, Ortop. Traumatol. Rehabil. 14 (2012) 435 - 442.

C.J. Wang, C.C. Huang, J.W. Wang, T. Wong, Y.J. Yang, Long-term results of extracorporeal shockwave therapy and core decompression in osteonecrosis of the femoral head with eight- to nine-year follow-up, Biomed. J. 35 (2012) 481 - 485.

C.J. Wang, F.S. Wang, K.D. Yang, C.C. Huang, M.S. Lee, Y.S. Chan, J.W. Wang, J.Y. Ko, Treatment of osteonecrosis of the hip: comparison of extracorporeal shockwave with shockwave and alendronate, Archives Orthop. Trauma. Surg. 128 (2008) 901 - 908.

P.C. Lin, C.J. Wang, K.D. Yang, F.S. Wang, J.Y. Ko, C.C. Huang, Extracorporeal shockwave treatment of osteonecrosis of the femoral head in systemic lupus erythematosis, J. Arthroplasty 21 (2006) 911 - 915.

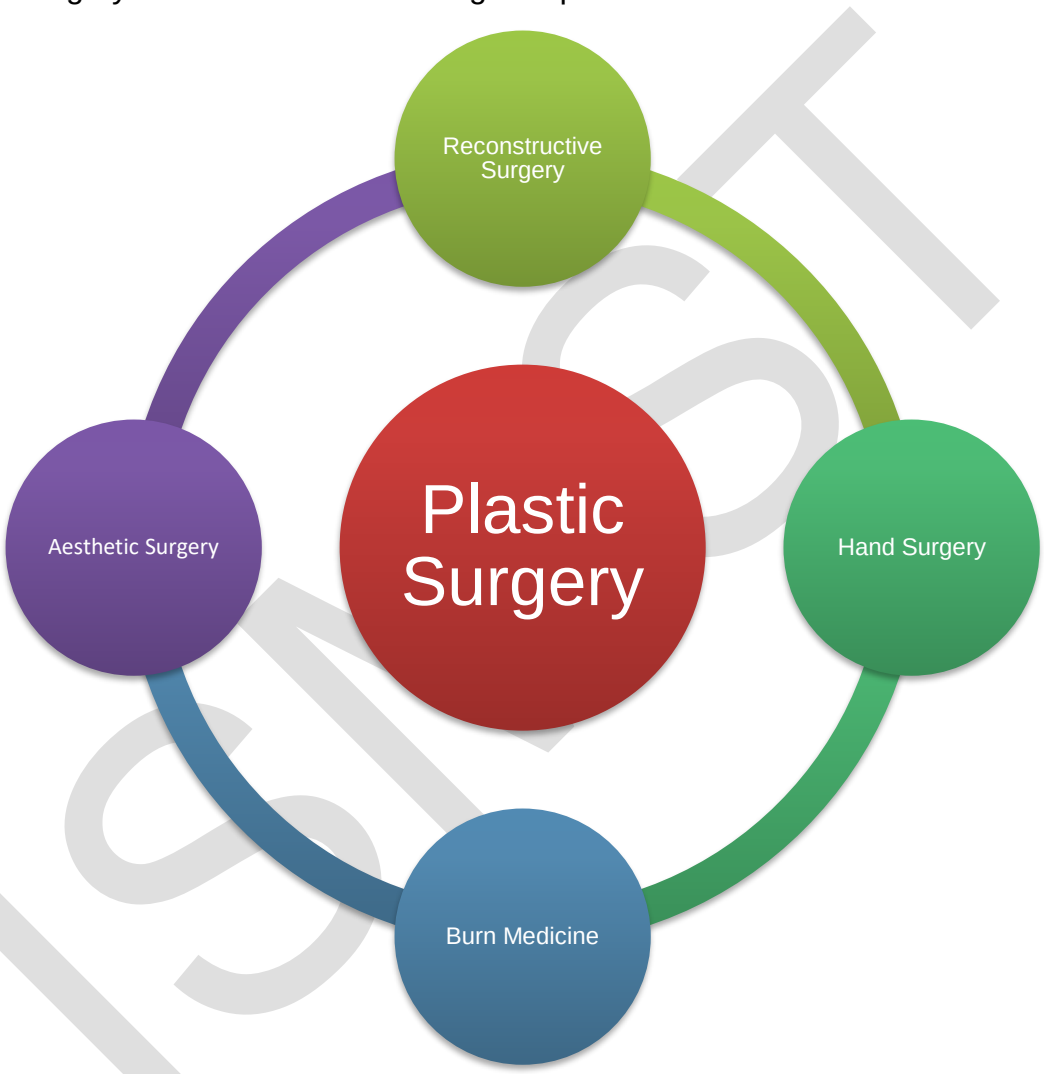
C.-J. Wang, J-H Cheng, C.-C. Huang, H.-K. Yip, S. Russo, Extracorporeal shockwave therapy for avascular necrosis of femoral head, International Journal of Surgery 24 (2015) 113 - 119.

21. ESWT on the skin

Prof. Dr. Karsten Knobloch (Hannover, Germany, and Perchtoldsdorf, Austria)

Introduction

The application of ESWT to the skin has been published both clinically and experimentally for various indications. The skin is also an excellent model to study the multiple effects of ESWT.
Plastic surgery is based on the following four pillars:



Both experimental and clinical data are now available for all four of the afore mentioned pillars of plastic surgery, some in randomized-controlled trial form.
Close analysis of these reports immensely expands the understanding of the potential effects of ESWT. For example, burn medicine is a focus in this context, where healing of the skin after a burn injury is significantly faster under ESWT if the burn is a dermal 2a° burn. The healing of a defined surgical wound is also positively influenced by ESWT, which was excellently worked out by the randomized-controlled study of Ottomann in split skin removal sites.

ESWT for burn injuries & scars

The German Association for Burn Medicine DAV has published an AWMF guideline on burn medicine, parts of which are reproduced here.

Definition burn injury of the skin

Thermal or chemical effects cause damage to the skin at varying depths, leading to partial or complete death of the skin.

Burning depths of the skin

Division	Clinical image	Combustion depth
first degree	Redness	superficial epithelial damage without cell death
Second degree a	Blistering red background strongly painful	Damage to the epidermis and superficial parts of the dermis with sequestration.
Second degree b	Blistering light background painful	extensive damage to the dermis with preservation of hair follicles and glandular appendages
third degree	Epidermis shred tissue after cleaning white no pain	complete destruction of epidermis and dermis
fourth degree	Charring Lysis (in case of chem. damage)	Destruction of extensive layers with subcutaneous fat tissue, possibly muscles, tendons, bones and joints

Assessment of the combustion depth
The severity of a burn injury is measured by the extent and depth of the burned surface. Accompanying injuries additionally intensify the trauma.

a) Calculation of the burned surface according to the rule of nine and/or the palm rule.
b) Depth of the injury
c) Other internal burns/burns/toxic damage (e.g., inhalation trauma (common), acid/leach ingestion).
d) Concomitant injuries (fractures)

Transfer to burn centers

- All patients with burns to the face/neck, hands, feet, ano-genital region, axillae, areas over large joints, or other complicated localization
- Patients with more than 15% second-degree burns on body surface area
- Patients with more than 10% third-degree burns on body surface area
- Patients with concomitant mechanical injuries
- All patients with inhalation damage
- Patients with preexisting conditions or age less than 8 years or greater than 60 years.
- All patients with electrical injuries

Wound treatment

- First-degree and 2a-degree burns are treated conservatively.
- 2b-grade and deeper burns should be treated surgically as early as possible depending on the overall condition of the injured person (necrosis removal, rapid skin grafting)

For ESWT, the following experimental as well as clinical data are available, particularly on split-thickness skin healing and 2a° burn and burn scars.

Experimental data ESWT for burns

- Second degree burns re-epithelialize significantly faster in rat animal model after single focused ESWT (0.11mJ/mm2, 500 pulses, 4Hz, Djedovic et al., 2014).
- TGFß1, alpha-smooth muscle actin, collagen-I, fibronection and twist-1 are significantly increased after foc. ESWT (0.03-0.3mJ/mm21000 pulses) in dermal fibrocytes reduced in hypertrophic scar tissue (Cui et al, 2018).
- The early proinflammatory immune response 1 h after severe cutaneous burn is reduced by ESWT (Davis et al., 2009)
- (de)focused ESWT improves tissue necrosis of skin flaps by enhancing angiogenesis (Mittermayr et al., 2011).
- Cutaneous tissue oxygen saturation is significantly increased after high-energy focused ESWT in a rat animal model (Kraemer et al., 2016)
- Cutaneous skin perfusion is significantly increased after high-energy focused ESWT in rat animal model (Kraemer et al., 2016)
- Contralateral tissue oxygen saturation is significantly increased after unilateral high-energy focused ESWT to the opposite leg (remote) in a rat animal model (Kisch et al., 2015)
- Contralateral cutaneous skin perfusion is significantly increased after unilateral high-energy focused ESWT to the opposite leg (remote) in a rat animal model (Kisch et al., 2015)
- Repeated ESWT sessions improve angiogenesis in full-thickness skin burns more than a single ESWT session (Goertz et al., 2012, Goertz et al., 2014).

Clinical data ESWT for burns

ESWT has been in clinical published studies to date on the following:

Figure. Primary outcome parameters of clinical trials of ESWT for burn injuries.

Burn Scar Healing

- (De)focused ESWT can significantly accelerate wound healing in 2a° burns (superficial dermal) (LoE 1b, Ottomann et al., 2012.).
- ESWT improves wound healing in 2° burns with improved perfusion measured with Laser Doppler (LoE 3, Arno et al. 2010).
- Split skin sites heal significantly faster after single preventive (de)focused ESWT before surgery (LoE 1b, Ottomann et al, 2010).
- Burn scarring can be improved by (de)focused ESWT.
- Scar keloid height as well as scar function can be significantly improved by three times shock wave therapy (Wang et al. 2018)

Burn Scar Pain

- Burn scar pain can be significantly reduced from 7.8±1.5 to 3.8±2.4 by three sessions of focused ESWT (electromagnetic 0.05-0.15mJ/mm2, 2000 pulses, three sessions, 4Hz) (RCT, n=40, Cho et al., 2016)

Burns Scar Itch

- Burn scar itch can be significantly reduced (6.3±1.3 to 3.6±2, p<0.001, Yoo et al, 2017; Aguilera-Saez J et al 2022) by focused ESWT (0.05-0.2mJ/mm2, 2000 pulses, electromagnetic) three times.

Burn Scar Hand Function

- Hand function with retracting burn scars is improved by (de)focused ESWT (Vancouver Scar Scale, Saggini et al. 2016).

Literature

Experimental:

Cui HS, Hong AR et al. ESWT alters the expression of fibrosis-related molecules in fibroblast derived from human hypertrophic scar. Int J Mol Sci 2018 Jan 2;19(1):e124.

Davis TA, Stojadinovic A, Anam K, Amare K, Amare M, Naik S, Peoples GE, Tadaki D, Elster EA. Extracorporeal shock wave therapy suppresses the early proinflammatory immune response to a severe cutaneous burn injury. Int Wound J 2009;66(1):11-21.

Djedovic G, Kamelger FS, Jeschke J, Piza-Katzer H. Effect of ESWT on deep partial-thickness burn injury in rats: a pilot study. Plast Surg Int 2014; 2014:495967.

Goertz O, Lauer H, Hirsch T, Ring A, Lehnhardt M, Langer S, Steinau HU, Hauser J. Extracorporeal shock waves improve angiogenesis after full thickness burn. Burns 2012;38(7):1010-8.

Goertz O, von der Lohe L, Lauer H, Khosrawipour T, Ring A, Daigeler A, Lehnhardt M, Kolbenschlag J. Repetitive extracorporeal shockwave applications are superior in inducing angiogenesis after full thickness burn compared to single application. Burns 2014;40(7):1365-74.

Kraemer R, Sorg H, Forstmeier V, Knobloch K, et al. Immediate-dose-response effect of high-energy versus low-energy ESWT on cutaneous microcirculation. Ultrasound Med Biol 2016;42(12):2975-82.

Kisch E, Sorg H, Forstmeir V, Knobloch K et al. Remote effects of ESWT on cutaneous microcirculation. J Tissue Viability 2015 ;24(4) :140-5.

Mittermayr R, Hartinger J, Antonic V, Meinl A, Pfeifer S, Stojadinovic A, Schaden W, Redl H. Extracorporeal shock wave therapy (ESWT) minimizes ischemic tissue necrosis irrespective of application time and promotes tissue revascularization by stimulating angiogenesis. Ann Surg 2011;253(5):1024-32.

Clinical:

AWMF-S1 guideline for thermal-chemical injuries.

Aguilera-Saez J, Munoz P, Serracanta J, Monte A, Barret JP. ESWT role in the treatment of burn patients: a systematic literature review. Burns 2020;46(7):1525-32.

Aguilera-Saez J, Dos Santos BP, Serracanta J, Monte-Soldado A, Bosacoma P, Rivas-Nicolls D, Barret JP. The effect of ESWT in the treatment of burn scars: a prospective, randomized controlled trial. Burns 2022;48(3):577-84.

Arno A, Garcia O, Hernan I, Sancho J, Acosta A, Barret JP. Extracorporeal shock wave, a new non-surgical method to treat severe burns. Burns 2010;37(6):844-9.

Cho YS, Joo SY, Cui H et al. Effect of ESWT on scar pain in burn patients: a prospective, randomized, single-blind, placebo-controlled study. Medicine (Baltimore) 2016;95(32).e4575.

Fioramonti P et al, ESWT for the management of burn scars. Dermatol Surg 2012;38:778-82.

Joo SY, Cho YS, Seo CH. The clinical utility of ESWT for burn pruritus: a prospective, randomized, single-blind study. Burns 2017 Oct 10.

Lee SY, Joo SY, Cho YS, Hur GY, Seo CH. Effect of ESWT for burn scar regeneration: a prospective, randomized, double-blinded study. Burns 2021;47(4):821-7.

Ottomann C, Hartmann B, Tyler J, Maier H, Thiele R, Schaden W, Stojadinovic A. Prospective randomized trial of accelerated re-epithelization of skin graft: donor sites using extracorporeal shock wave therapy. J Am Coll Surg 2010;211(3):361-7.

Ottomann C, Stojadinovic A, Lavin PT, Gannon FH, Heggeness MH, Thiele R, Schaden W, Hartmann B. Prospective randomized phase II trial of accelerated reepithelization of superficial second-degree burn wounds using extracorporeal shock wave therapy. Ann Surg 2012;255(1):23-9.

Saggini R, Saggini A, Spagnoli AM et al. ESWT: an emerging treatment modality for retracting scars of the hands. Ultrasound Med Biol 2016;42(1):185-95.

Wang CJ, Ko JY, Chou WY, Cheng JK, Kuo YR. Extracorporeal shockwave therapy for treatment of keloid scars. Wound Repair Regen 2018;Jan 13.

22. ESWT for Cellulite

Prof. Dr. Karsten Knobloch (Hannover, Germany, and Perchtoldsdorf, Austria)

Synonyms

Orange Peel, Peau d'orange

Etiology

Female gender with differentiated subcutaneous fat with subcutaneously fibrosed connective tissue tracts
Potentially accompanying lymphedema

Symptoms

Dimpling of the skin mainly gluteal and dorsal in the upper third of the back thighs. The dimpling is caused by fibrotic subcutaneously located fibrous gaps that pull the dermis inward. It is not uncommon for the dimpling to be combined with lymphedema. The quality of life can be affected in a lasting way, independent of the clinical-objective findings. This psychological dimension can be assessed with validated questionnaires, e.g., according to Doris Hexsel.

Investigation

- Digital standardized photographs in standing position from dorsal and in 90° lateral view with relaxed gluteal muscles are recommended.
- The dents can be additionally marked with kohl pencil while standing.
- Circumferential measurements in lateral comparison at defined localizations
- Body weight
- Quality of life with QoL score according to Hexsel, translated by Knobloch

Imaging

- Digital standardized photographs in standing position from dorsal and in 90° lateral view with relaxed gluteal muscles are recommended.
- The dents can be additionally marked with kohl pencil while standing.
- Perimeter measurements
- If necessary, 3D photography with e.g., Vectra system (Canfield)

Therapy options

Individual:

- Strengthening the gluteal muscles
- Fat-burning endurance sports (especially hill walking or stepper through the gluteal fascia course, Troia et al., 2021).
- Weight reduction
- textile compression therapy for concomitant lymphedema

Biophysical:

- radial and or focused ESWT
- Low level laser therapy (especially in the 500nm wave range)
- LPG Massage

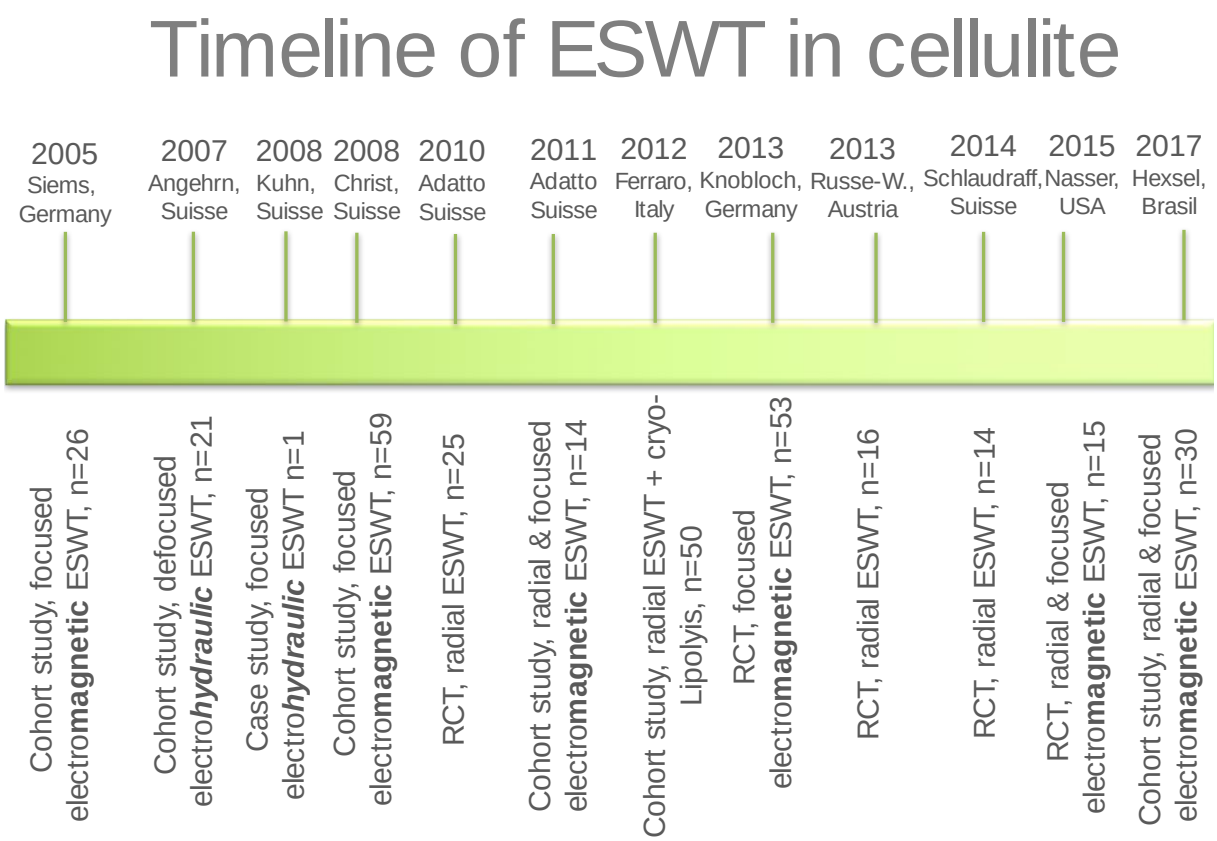
Medication:

- Collagenase (Xiapex) Injection

Operational:

- subcutaneous incision

Shock wave therapy for cellulite



Indication:

Indication by the expert physician

Contraindication:

Malignant tumor in focus, pregnancy

Spatial requirements:

Certification criteria of a medical practice e.g. hygiene plan, emergency management available according to DIN standard.

Preparation of the patient:

Differentiated and documented education and information

Physician and assistant personnel:

ESWT is a service to be performed personally by the physician qualified by means of specialist knowledge.

Implementation of the therapy:

Marking in standing position, positioning for ESWT in prone position

- RADIAL ESWT:
  1.5-4 bar, 3000 pulses, 5-10Hz, 6-8 sessions
- FOCUSED ESWT:
  0.08-0.35mJ/mm^2, 2000 pulses, 6-8 sessions.

If necessary, supplementary vibration therapy with 35-50Hz

Since the first published report by Siems in 2005, more than a dozen clinical studies have been published on the use of ESWT. Both radial and focused ESWT are effective in the treatment of cellulite in the available clinical studies with a follow-up period of 3 to 12 months, although neither procedure shows superiority due to lack of comparative studies to date. What all studies have in common is the absence of side effects.

- Radial ESWT:
  - 7 published studies with 4 RCTs & 3 cohort studies.
- Focused ESWT:
  - 5 published studies with 1 RCT & 4 cohort studies.
- Combination radial and focused ESWT:
  - 3 published study with 1 RCT & 2 cohort studies.
- Generator type of focused ESWT:
  - Focused electromagnetic ESWT
    - In 5 studies (2 RCT, 3 cohort studies).
  - Focused electrohydraulic ESWT
    - In 2 studies (1 cohort study, 1 case report).
  - No piezoelectric ESWT clinical studies on cellulite to date.

Typically, one to one session per week and between six to eight total sessions of ESWT were performed for cellulite in the clinical trials. Both the skin appearance and the subjective perception of the patients on the basis of validated quality of life scores with the Cellulite Quality of Life scale could be improved.

Literature

Allam NM, Elshorbagy RT, Eid MM, Abdelbasset WK, Elkholi SM, Eladl HM. Comparison of ESWT vs. manual lymphatic drainage on cellulite after liposuction: a randomized clinical trial. Evid Based Complement Alternat Med 2021;9956879.

Christ C, Brenke G, Sattler G, et al. Enhancement of skin elasticity and revitalization of the dermis in cellulite and connective tissue weakness by extracorporeal acoustic wave therapy (AWT). Aesthetic Dermatology 2008; 1:2-10.

Sattler G, Pohl U, Raegener K. Pilot study acoustic wave therapy (AWT) for cellulite. Aesthetic Dermatology 2008; 2:16-25.

Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomized and non-randomized studies of health care interventions. J Epidemiol Community Health. 1998;52(6):377-84.

Adatto M, Adatto-Neilson R, Servant JJ, Vester J, Novak P, Krotz A. Controlled, randomized study evaluating the effects of treating cellulite with AWT®/EPAT®. J Cosmet Laser Ther 2010; 12:176-182.

Knobloch K, Joest B, Krämer R, Vogt PM. Cellulite and focused extracorporeal shockwave therapy for non-invasive body contouring: a randomized trial. Dermatol Ther (Heidelb) 2013;3(2):143-55.

Russe-Wilflingseder K, Russe E, Vester JC, Haller G, Novak P, Krotz A. Placebo controlled, prospectively randomized, double-blinded study for the investigation of the effectiveness and safety of the acoustic wave therapy (AWT) for cellulite treatment. J Cosmet Laser Ther 2013;15(3):155-62.

Schlaudraff KU, Kiessling MC, Csaszar NB, Schmitz C. Predictability of the individual clinical outcome of extracorporeal shock wave therapy for cellulite. Clin Cosmet Investig Dermatol 2014; 7:171-83.

Nasser AH, Dorizas AS, Shafai A, Sadick NS. A randomized, controlled clinical study to investigate the safety and efficacy of acoustic wave therapy in body contouring. Dermatol Surg 2015;41(3):366-70.

Siems W, Grune T, Voss P, Brenke R. Anti-fibrosclerotic effects of shock wave therapy in lipedema and cellulite. Biofactors 2005;24(1-4):275-82.

Angehrn F, Kuhn C, Voss A. Can cellulite be treated with low-energy extracorporeal shock wave therapy? Clin Interv Aging 2007;2(4):623-30.

Christ C, Brenke R, Sattler G, Siems W, Novak P, Daser A. Improvement in skin elasticity in the treatment of cellulite and connective tissue weakness by means of extracorporeal pulse activation therapy. Asthet Surg J 2008;28(5):538-44.

Adatto MA, Adatto-Neilson R, Novak P, Krotz A, Haller G. Body shaping with acoustic wave therapy AWT/EPAT: randomized, controlled study on s14 subjects. J Cosmet Laser Ther 2011;13(6):291-6.

Ferraro GA, De Francesco F, Cataldo C, Rossano F, Nicoletti G, D'Andrea F. Synergistic effects of cryolipolysis and shock waves for noninvasive contouring. Aesthet Plast Surg 2012;36(3):666-79.

Hexsel D, Camozzato FO, Silva AF, Siega C. Acoustic wave therapy for cellulite, body shaping and fat reduction. J Cosmet Laser Ther 2017;19(3):165-73.

Kuhn C, Angehrn F, Sonnabend O, Voss A. Impact of extracorporeal shock waves on the human skin with cellulite: a case study of a unique instance. Clin Interv Aging 2008;3(1):201-10.

Troia S, Moreira AM, Pisco D, Noites A, Vale AL, Carvalho P, Vilarinho R. Effect of shock wave therapy associated with aerobic exercise on cellulite: a randomized controlled trial. J Cosmet Dermatol 2021;20(6):1732-42.

23. Myofascial syndrome, trigger point diseases and disfunctions of muscles and fasciae

Dr. med. Hannes Müller-Ehrenberg (Münster, Germany)

Introduction:

Muscles and fasciae are well innervated and often the cause of acute and chronic pain. Accordingly, myofascial tissue should also be specifically examined in musculoskeletal complaints and taken into account in the classification (according to ICD -10). A myofascial trigger point (MTrP) is a circumscribed structure in muscle or connective tissue that triggers pain and is involved in a musculo-skeletal pain process.
Thanks to their precise application even in deeper tissue layers, focused shock waves are used both in diagnostics and in the therapy of myofascial complaints and trigger points.
Muscles and fascia represent an anatomical and functional unit, which is also treated together.
ESWT is also indicated for connective tissue disorders.

Classification

ICD 10: M79.1 for myofascial pain syndrome and additional local or regional pain e.g., lumboischialgia M54.4

Synonyms

Myofascial Pain Syndrome, Myogelosis, Muscle Hard Tension, MuscularTrigger Points, Myofascial Trigger Points, Fascial Shortening, Fascial Dysfunction.

Etiology

Acute and chronic injury of skeletal muscles
acute and chronic overload, overstretching, direct trauma, non-physiological stresses on the musculoskeletal system
in combination with enthesiopathy, incorrect loading (e.g., false statics, muscular imbalances) radiculopathies, arthrogenic dysfunctions and irritations, diseases of internal organs, endocrine diseases, psychosomatic reactive changes

Symptoms

Local pain with localization at the musculo-skeletal system, increased tenderness (local), transfer pain (pseudo radicular spread common), dysesthesias, tension and stretch pain, joint pain, tendon pain, regional pain (e.g., headache), muscle shortening, muscle hardening, strength reduction, coordination disorder, vegetative symptoms.

Diagnostics:

Basic diagnostics: clinical neurological-orthopedic examination.
Clinical examination (mobility, sensorimotor function, specific stretch testing). Palpation is the gold standard of clinical examination of muscles and fascia including trigger point diagnosis.

Diagnostic ESWT: with feedback (= feedback) and according to diagnostic criteria (e.g., "recognition", "transfer pain")

Apparative diagnostics:

If necessary, orienting ultrasound examination at the treatment site for local diagnosis. Elastographic ultrasound diagnostics possible (in clinical use so far without relevance), high-resolution MRI (in scientific studies, so far without relevance in clinical use).

Differential diagnoses:

Differential diagnosis of myalgias and diseases of the musculo-skeletal system. Muscle and soft tissue tumors, primary and secondary myopathies, neurological Systemic diseases, neurogenic dysfunctions, rheumatic diseases, hormonal disorders (e.g., hyperparathyroidism, hypothyroidism), drug side effects (e.g., lipid-lowering agents).

Conservative therapies

Dry needling, ischemic compression, acupuncture, stretching, electrotherapy, fascia release techniques, fascia therapies, infiltrations, muscle relaxation techniques, physiotherapy according to IMTT standard, thermotherapy ("Stretch and Spray")

Shockwave therapy

Indication:

Indication by the expert physician

Before therapy:

Spatial requirements: Certification criteria of a medical practice e.g. hygiene plan, emergency management available according to DIN.
Preparation of the patient: Positioning in pain-free position, structures to be treated easily accessible.
Clarification: therapy pain also after treatment (approx. 20-30%, mostly similar to a "sore muscle"), if necessary NSAID medication, vegetative reaction (e.g., sweating, circulatory reaction) possible
Physician and assistant personnel: ESWT is a service to be provided personally by the physician qualified by means of specialist knowledge.

Contraindication:

Malignant tumor in focus

Implementation of the therapy:

Principle: exact myofascial trigger point treatment on the pain point with pain-adapted intensity (energy).
Usually, a recognition of the pain and a "referred pain" is triggered.

- Focused shock wave
  Location: after previous palpation, application patient-oriented focus (biofeedback).

Energy: EFD: up to 0.30 mJ/mm2 EFD
Interval: 1-2 x week
Frequency: FSW 3-5 Hz,
2000 - 4000 pulses per session, 200 - 400 pulses per MTrP
3-8 treatments
Coupling medium: ultrasound gel
no local anesthesia

- Radial pressure wave:
  Location: after previous palpation, patient-oriented application (biofeedback).
  Energy: up to 2,5 bar
  Interval: 1-2 x week
  Frequency: up to10 Hz,
  2000 - 4000 pulses per session,
  3-8 treatments
  coupling medium ultrasound gel
  no local anesthesia

Documentation:

See preamble.
Designation of the exact ESW application with anatomical localization (e.g., treated muscle or anatomical structure).
Naming of the diagnostic criteria triggered during shock wave therapy: local pain, "recognition", "transfer pain" (feedback) and, if applicable, a muscular twitch reaction
Designation of the shock wave source, the number of SW pulses and the intensity (EFD).

Aftercare:

Individual load adjustment, continuation of conservative therapies, independent stretching exercises and fascia treatment, physiotherapy

Literature:

Amelio E, Manganotti P: Effect of shockwave stimulation on hypertonic plantar flexor muscles in patients with cerebral palsy: a placebo-controlled study. J RehabilMed, 2010

Hausdorf J, Lemmens MA, Heck KD, et al. Selective loss of unmyelinated nerve fibers after extracorporeal shockwave application to the musculoskeletal system. Neuroscience. 2008Jul 31; 155(1):138-144.

Hong JO1, Park JS1, Jeon DG1, Yoon WH1, Park JH1. Extracorporeal Shock Wave Therapy Versus Trigger Point Injection in the Treatment of Myofascial Pain Syndrome in the Quadratus Lumborum. Ann Rehabil Med. 2017 Aug;41(4):582-588. doi: 10.5535/arm.2017.41.4.582. Epub 2017 Aug 31.

Jeon JH1, Jung YJ, Lee JY, Choi JS, Mun JH, Park WY, Seo CH, Jang KU. The effect of extracorporeal shockwave therapy on myofascial pain syndrome. Ann Rehabil Med. 2012 Oct;36(5):665-74. doi: 10.5535/arm.2012.36.5.665. epub 2012 Oct 31.

Ji HM, Kim HJ, Han SJ. Extracorporeal shockwave therapy in myofascial pain syndrome of upper trapezius. Ann Rehabil Med. 2012; 36:675-80.

M. Gleitz, K. Hornig, Trigger Points - Diagnosis and Treatment Concepts with Special Consideration of Extracorporeal Shock Waves Orthopade 41 (2012).

Kraus M, Reinhart E, Krause H, Reuther J. [Low energy extracorporeal shockwave therapy (ESWT) for treatment of myogelosis of the masseter muscle]. Mund Kiefer Gesichtschir.
1999; 3(1):20-3.

Lee JY, Kim SN, Lee IS, Jung H, Lee KS, Koh SE.
Effects of Extracorporeal Shock Wave Therapy on Spasticity in Patients after Brain Injury: A Meta-analysis J Phys Ther Sci. 2014 Oct;26(10):1641-7.

Lohse-Busch H, Kraemer M, Reime U.
[A pilot investigation into the effects of extracorporeal shockwaves on muscular dysfunction in children with spastic movement disorders].Pain. 1997 Apr 18;11(2):108-12.

Maier M, Averbeck B, Spleen S, Refior HJ, Schmitz C. Substance P and prostaglandin E2 release after shockwave application to the rabbit femur. Clin Orthop Relat Res. 2003 Jan 2003(406):237-245.

Manganotti P, Amelio E: Long-term effect of shockwave therapy on upper limb hypertonia in patients affected by stroke. Stroke, 2005

Mariotto S, Cavalieri E, Amelio E, et al: Extracorporeal shockwaves: from lithotripsy to anti-inflammatory action by NO production. Nitric Oxide, 2005

Mense S, Simons DG. Muscle pain: understanding its nature, diagnosis, and treatment.
Philadelphia: Lippincott Williams & Wilkins; 2001.

Moghtaderi A., Khosrawi S., Dehghan F. Extracorporeal shockwave therapy of gastroc-soleus trigger points in patients with plantar fasciitis: A randomized, placebo-controlled trial. Adv Biomed Res. 2014; 3: 99

Müller-Ehrenberg, H., Fleckenstein, J. Benefits of extracorporeal shock wave in back pain. *Pain Med* **39**, 43-45 (2023).

Müller-Ehrenberg H, Licht G. Diagnosis and therapy of myofascial pain syndrome with focused shock waves (ESWT), Medizinisch Orthopädische Technik. 2005; 5:1-6.

Müller-Ehrenberg H, Thorwesten L, Pottebaum M, Epping H, Gries L, Völker K: Change in static and dynamic strength abilities after treatment of myofascial trigger points using focused ESWT for shoulder pain in sports, Sportärztekongress 2012 Frankfurt.

Schenk I, Vesper M, Nam VC. [Initial results using extracorporeal low energy shockwave therapy ESWT in muscle reflex-induced lock jaw]. Oral and Maxillofacial Surgery. 2002 Sep 2002; 6(5):351-355.

Ramon S, Gleitz M, Hernandez L, Romero LD Update on the efficacy of extracorporeal shockwave treatment for myofascial pain syndrome and fibromyalgia. International Journal of Surgery 24 (2015).

Shah JP, Danoff JV, Desai MJ, et al. Biochemicals associated with pain and inflammation are elevated in sites near to and remote from active myofascial trigger

points. Arch Phys Med Rehabil. 2008 Jan; 89(1):16-23.

Travell J, D.G. S. Manual of muscle trigger points. Upper extremities, head, and thorax. 1 ed. Stuttgart: Gustav Fischer Verlag; 1998.

Travell J, D.G. S. Manual of muscle trigger points. Lower extremities and pelvis. 1ed. Munich: Urban & Fischer Verlag; 2000.

Wall PD, Cronly-Dillon JR. Pain, itch, and vibration. Arch Neurol. 1960 Apr 1960.

24. Shock wave therapy for urological diseases (excluding lithotripsy)

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Extracorporeal shock wave therapy (ESWT) has also been used for urological indications since the mid-1990s. Here, the focus was initially on induratio penis plastica. The classic shock wave lithotriptors were used for the treatment. This was usually done using higher energy densities (0.5- 0.9 mJ/mm^2) and the use of local anesthesia. Success rates between 60 and 70% have been reported.
With the development of the smaller hand-held shock wave applicators, low-intensity ESWT has been used for other urologic indications and its efficacy has been demonstrated by randomized trials.
Today, the following indication areas are established:

- -Induratio penis plastica
- -Erectile Dysfunction
- -Chronic pelvic pain
- -Micturition symptoms in benign prostatic obstruction.
- -promotion of wound healing after Fournier`s gangrene

Induratio penis plastica, Peyronie's disease (IPP)

Introduction

Induratio penis plastica (IPP) is also called Peyronie`s disease. It is characterized by fibrotic thickening to calcification of the tunica albuginea in the area of the penile shaft. This usually results in penile curvature and may be associated with pain at rest and during erection. The prevalence is between 0.5 and 2%, and the peak age of patients is between 50 and 60 years of age.

The cause of induratio penis plastica is currently unclear. Recurrent microtrauma (e.g., during sexual intercourse) is discussed, whereby the resulting microvascular damage, genetically triggered via TGF-β, can lead to a prolonged inflammatory reaction with atypical wound healing and scarring. In approximately 10%, IPP is associated with Dupytren's disease. Fibrinogen deposits with collagen-rich fibers and little elastin are found in the plaques.

Classification: ICD 10: N48.6

Symptoms

Induratio penis plastica typically progresses in two disease phases.

Inflammatory phase

In the acute inflammatory phase, there is usually localized pain in the unerect or erect penis. In addition, there is formation of a palpable, initially relative soft nodule or plaque

in the area of the tunica albuginea with successive dorsal or lateral curvature of the penis. The plaques are usually located on the concave side of the deviation and therefore also lead to problems during sexual intercourse.

Post inflammatory phase

After this initially progressive and undulating phase, a stable post-inflammatory (fibrotic) phase is reached after about one year - even without therapy - in which the pain is usually regressive. The plaques harden and may calcify. Spontaneous remission occurs in 3 to 13% of patients. More commonly, however, penile shortening or cohabitation problems develop due to penile curvature, as does erectile dysfunction.

Diagnostics

Medical history

Anamnestic questions are asked about cohabitation trauma, pain during erection, localization of induration, duration of the disease and penile deviation. Since 2013, a validated questionnaire (PDQ- Peyronie`s disease Questionaire + IIEF) exists, but it can only be used in case of cohabitation activity in the last four weeks. Psychological distress and assessment of quality of life should also be evaluated.

Physical examination

The palpable findings of IPP are characteristic. With septal localization or formation of small nodules, the lesions are sometimes difficult to detect. Penile deviation toward the plaque is initially visible only during an erection, so the patient should be asked to undergo *autophotography.* Ultimately, the extent of the plaque is independent of the extent of deviation.

Imaging

Penile ultrasound can provide a rough orientation of the extent of the plaques. These show up as circumscribed, anechoic thickenings of the tunica albuginea. If calcifications are present in the plaque area, recognizable by the dorsal acoustic shadow, the patients probably respond poorly to conservative therapy. This may also be a factor in the choice of shock wave energy density.

Intracavernosal injection of prostaglandin E1 and performance of color-coded duplex sonography can demonstrate rigidity, deviation angle, penile deformity, hourglass phenomena, and distal flakiness (flaccidity) and concomitant erectile dysfunction.

Therapy

Causal drug therapy is currently not possible. Conservative approaches are used empirically in the inflammatory phase. In particular, they are intended to reduce pain and halt disease progression. The post-inflammatory stage already represents the endpoint of the disease, therefore conservative therapy in this phase probably comes too late. Only in the post-inflammatory stage of the disease can the penile deviation be surgically corrected.

Oral therapy

Since the cause of induratio penis plastica is currently (2019) unknown and most forms of drug treatment represent an off-label use, the efficacy of individual treatment options must be critically considered and further evaluated in placebo-controlled studies. The previous study data on conservative therapy are mostly contradictory, so that they are only recommended with restraint by the 2022 guidelines of the European Association of Urology (EAU). In principle, therefore, the efficacy of
Potassium para-aminobenzoate (Potaba®): unclear mechanism of action, possibly indirect antifibrotic effect via influencing the serotonin metabolism, but also vitamin E, colchicine, tamoxifen are doubted. Only the use of the phosphodiesterase-5-inhibitor (Tadalafil) has been shown to reduce pain.

Intralesional therapy

Intralesional drug injection is another therapeutic option that results in high drug concentrations in the plaque area. To be used:

- Collagenase clostridium histolyticum (Xiaflex®): Available since 2013, this is the only FDA and EMA approved drug to date for the treatment of palpable plaque in penile deviation of at least 30°. With controversial efficacy, marketing in Germany has been discontinued, so it can only be obtained through international pharmacies. In addition, side effects (e.g. penile hematoma and ecchymosis, pain and swelling in the injection area) up to rupture of the corpus cavernosum are relatively frequent.
- Verapamil: conflicting data, few side effects (e.g., nausea, drowsiness, ecchymosis).

Extracorporeal shock wave therapy

While radiotherapy is not effective, the efficacy of ESWT has been demonstrated in randomized prospective studies. However, the exact mechanism of action is still unclear; direct destruction and remodeling of the penile plaque or plaque lysis due to activation of macrophages and induction of neovascularization are discussed.
The significant reduction in pain can also be reliably demonstrated in long-term studies. Therefore, ESWT is also recommended for this purpose in the EAU guidelines.
For the treatment of penile deviation, the data are considered insufficient so far.

Implementation of ESW therapy:

So far, there is only experience with the application of focused shock waves.
Locating:
When lithotripters were used, ultrasound or x-ray localization was used. This may also be necessary today for the treatment of extensive plaques. When using low-intensity applicators, palpatory localization of the plaques is sufficient, if necessary, with simultaneous plaque modeling.
Energy: EFD: 0.30- 0.55 mJ/mm² depending on the device technology and the patient's perception of pain.
Interval: 1x / week
Frequency: 2-4 Hz
3000 pulses per session,

6-10 treatments
Coupling medium ultrasound gel
If necessary, line anesthesia (penile block) when lithotriptors are used or the patient is highly sensitive to pain.
Documentation: see preamble
Accompanying ESWT: if necessary, continuation of medication (e.g., PDE-5 inhibitors)
Complications: none known with LI-ESWT; with HESWT: penile hematoma 2%.

Aftercare:
Initially 6 treatments followed by a 3-month break to wait for success. Response to ESWT followed by another 4 sessions.

In case of failure of ESWT, surgical correction of penile deviation by means of plicature, plaque excision, incision with Tachosil-patch is still possible.

Erectile dysfunction

Introduction:

Erectile dysfunction (ED) refers to the lack of limb rigidity during intercourse to perform successful coitus. ED is a worldwide condition affecting approximately 50% of all men between 40 and 70 years of age with varying degrees of severity. Organic factors are the main cause (60-80%) of ED, and here circulatory disorders of the erectile tissue on the basis of an often generalized vascular disease are in the foreground.
In the interdisciplinary treatment concept of the ED, low-dose focused ESWT has played a significant role since 2010.
Previous clinical trials have demonstrated efficacy of ESWT even in the setting of PDE 5 inhibitor inefficacy and intolerance, particularly in vascular ED, although it is unclear whether maintenance therapy is necessary.
Since 2015, the European Association of Urology has listed Li-ESWT alongside PDE-5 inhibitors as the method of first choice for the treatment of vascular erectile dysfunction.

Classification
ICD 10: N48.4 erectile dysfunction of organic origin

Etiology
70% organic factors especially arterial circulatory disorders, damage to the corpus cavernosum (e.g., "venous leak", veno-occlusive dysfunction) nerve dysfunction (e.g. post prostatectomy surgery) also multifactorial with psychological factors ICD-10 F52.2 (e.g. fear of failure). Risk factors are hypertension, diabetes mellitus, hyperlipidemia and nicotine abuse.

Symptoms
Lack of erectile function or stiffness of the member for the duration of sexual intercourse.

Diagnostics

Andrological-urological examinations (ultrasound, duplex sonography of the penis with artificial erection (intracavernous prostaglandin E1 injection) with measurement of arterial flow velocity.
Graduation of erection (E1-E5)
Clarification of psychological causes of erectile dysfunction
Standard questionnaire IIEF (before and after therapy)

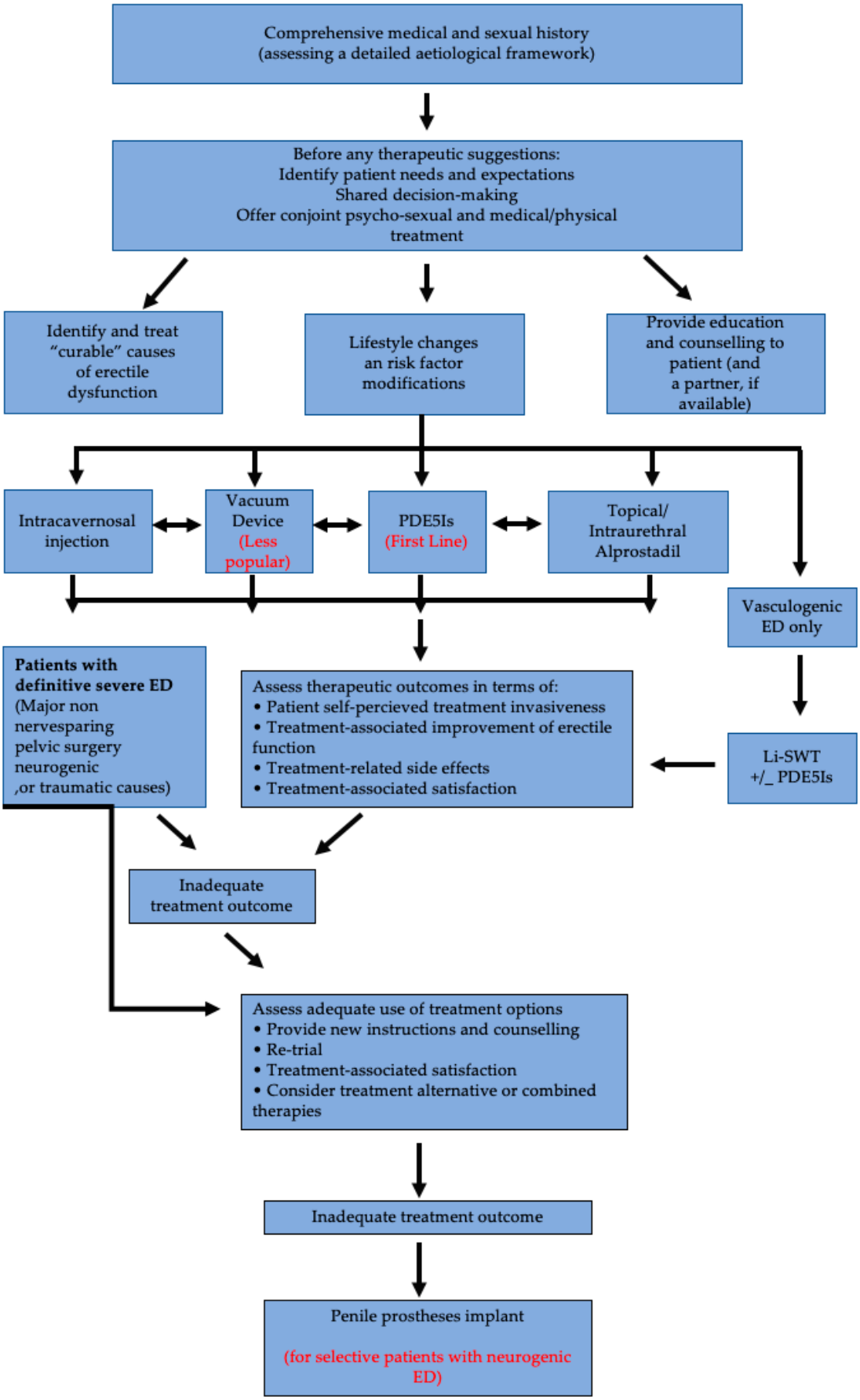

Figure 1Flow chart for erectile dysfunction therapy according to EAU guideline 2023

Therapy

Medicinal with PDE 5 inhibitors
Intraurethral: Prostaglandin E1-pellet (MUSE)
Intracavernous: prostaglandin E1 (e.g., Caverject)
mechanical: vacuum pumps etc., less significant since the introduction of PDE 5 inhibitors
surgical: after exhaustion of all conservative therapies e.g., vascular surgery, penile prostheses (penile implants)

Shockwave therapy

Indication:

Vascular erectile dysfunction caused by endothelial dysfunction, cavernous erectile dysfunction (cavernous insufficiency = "venous leakage"), increased blood flow in the corpus cavernosum caused by dysfunction or damage to the smooth muscles of the erectile tissue (insufficiency erection), neurogenic dysfunction due to a defect in the periprostatic nerve pathways.

Contraindication: malignant tumor in focus (penile carcinoma).

Before therapy:

Spatial requirements: Certification criteria of a medical practice e.g. hygiene plan, emergency management available according to DIN.

Preparation of the patient:

Differentiated (medical and economic) and documented education and information.

Storage: structures to be treated easily accessible, if necessary, support holder

Physician and assistant personnel: ESWT is a service to be provided personally by the physician qualified by means of specialist knowledge.

Principle: While most ESWT indications focus on local focused therapy, in the treatment of ED, the planar application along the entire corpus cavernosum is important. Therefore, linear focused shock wave application (with piezo-electric source) is also sometimes used. However, spot-focused shock wave applicators have been mostly used.
Application: In the meantime, a standardized procedure has been agreed upon.
500 pulses each are applied to
the penile shaft (base, distal) and to the crura (from caudal) on both sides.
Locating: No locating modality required
Energy density: EFD: 0.10 - 0.25 mJ/mm² depending on the device technology and the patient's perception of pain.
Frequency: 2-6 Hz, piezo-electric also up to 8Hz
Interval: 1-2x /week
3000 (= 6x 500) pulses per session,
4-12 treatments (depending on the success of the therapy)
Coupling medium ultrasound gel
No anesthesia

Documentation: s Preamble
After ESW therapy: no further immediate action, if necessary, continue medication (e.g., PDE-5 inhibitor).

Complications: none known

Follow-up:

Continuation of conservative therapies, control of endothelial dysfunction (e.g., arteriosclerosis) useful. It is important to document the success of therapy by IIEF-score and duplex sonography. Recently, visible changes in the structure of the corpora on ultrasound (7.5 MHz transducer) have also been reported.
The importance of maintenance therapy (e.g., after 3 months) is still unclear.

ESWT in ED after radical prostatectomy.

In recent years, the first positive studies of Li-ESWT postoperatively after radical prostatectomy have been reported, with earlier and higher potency rates. However, multicenter randomized trials are lacking.
Here, the shock wave is primarily applied from the perineum, as it is most likely to be a neurogenic ED.

Chronic pelvic pain

Introduction:

Chronic pelvic pain is a very complex clinical picture or symptom complex. Chronic pelvic pain is understood to be permanent or recurring pain in men or women that is felt in the pelvic region. It is often associated with negative effects, for example on the psyche, as well as with other symptoms such as discomfort during urination or disturbances in sexual function.
If a classic disease is found as the cause (e.g., infection, cancer), it is referred to as disease-specific pelvic pain. In this case, treatment of the underlying disease is the first priority (see, for example, chronic bacterial prostatitis, prostate carcinoma, endometriosis, etc.). If, on the other hand, no pathological changes are detectable, the term chronic pelvic pain syndrome (CPPS) is used. On examination, no bacteria are found as a trigger, but in men sometimes inflammatory cells are found in the prostate secretion or in the semen (see below for examination).
In men, two clinical pictures (with numerous designations) used to be distinguished here: Chronic abacterial prostatitis (congestive prostatitis; inflammatory cells present) and prostatodynia (prostatopathy, non-inflammatory pelvic pain syndrome, prostatic congestion, prostatosis, pelvic floor myalgia, vegetative urogenital syndrome = VUG; no inflammatory cells present). Since examination and treatment do not differ, the two can be combined to form PSS.

A not insignificant part of pelvic pain is due to functional and structural changes of myofascial structures. Between 22 and 93% of chronic pelvic pain is thought to be of myofascial origin (Ross, V.; 2021).
Myofascial pain can occur alone or along with conditions such as dysmenorrhea, prostatodynia, vaginismus, or endometriosis and is a common reason for pain during intercourse.

Classification

ICD 10: R 10.2 Pelvic and perineal pain

Diagnosis

There is no specific test for PSS. Therefore, the examinations serve on the one hand, to detect or exclude pathological changes that can cause chronic pelvic pain and, on the other hand, to collect findings that characterize the PSS in the specific case:
Thus, a physical examination should be performed first; this usually includes digital rectal examination (DRU) with palpation of the pelvic floor structures (if accessible) and, in men, palpation of the prostate. Palpation should also include myofascial trigger points in the pelvic floor and abdomen. Measurement of residual urine by ultrasound (sonography) can exclude incomplete bladder emptying (in men also an indication of prostate enlargement, see BPH). Determination of the PSA value and transrectal ultrasound (TRUS) can help to rule out prostate cancer.
Urine tests are important: In the classic four-glass specimen or in urine specimens obtained before and after prostatic massage, no pathogens are found in appreciable quantities in the prostatic secretions or in the specimens obtained after prostatic massage, and there are usually no signs of inflammation. The latter also applies to the semen. In the case of complaints in the lower urinary tract (especially urination, see LUTS), urine flow measurement (uroflowmetry) should be considered.
It is also important to objectify the complaints by means of an appropriate questionnaire (e.g., IPPS score).

Therapy

The initial focus is on drug therapy to relax the pelvic floor and bladder outlet (e.g., alpha blocker tamsulosin). Success has also been reported with pentosan polysulfate. However, this is usually not sufficient.
In this situation, Li-ESWT with perineal application has been successfully used.

Extracorporeal shock wave therapy

Application: A focused shock wave source is used, which reaches the deeper urogenital structures from perineal and also the myofascial trigger points (MTrPs) in the pelvic floor (penetration depth between 2-5cm). Likewise, MTrPs typically located in the lower abdomen, lower lumbar spine and adductors should be visited and directly treated by ESWT.
Locating: No imaging locating modality required, orientation to patient feedback.
Energy density: EFD: 0.1- 0.35 mJ/mm² depending on the device technology and the patient's perception of pain.

Frequency: 3-6 Hz
Interval: 1-2x /week
2000 - 4000 pulses per session,
6 -10 treatments
Coupling medium: ultrasound gel
No anesthesia
Documentation: s Preamble
After ESW therapy: no further immediate action, continue medication if necessary (e.g., tamsulosin).

Complications: none known

Micturition difficulties in benign prostatic obstruction.

Introduction

Micturition symptoms associated with enlarged prostate are also summarized as Lower Urinary Tract Syndrome (LUTS). They are characterized by frequent urination (pollakiuria), weakened urinary stream and even urinary retention. Relatively effective drug alternatives, such as alpha-blockers or 5-alpha-reductase inhibitors, have existed for a long time, but they are also characterized by certain side effects (hypotension, loss of libido).
Here, it has been shown experimentally in animals that Li-ESWT lead to stimulation of nitric oxide synthetase, resulting in relaxation of the bladder neck.
This fact was the basis for clinical trials of Li-ESWT in LUTS. Certainly, LI-ESWT cannot replace surgical therapy (e.g., TUR prostate or laser enucleation), but a recent meta-analysis of the data suggests that Li-ESWT may be equivalent to drug therapy.
Recent clinical and anatomical studies suggest that, similar to chronic pelvic syndrome, there is functional dysfunction of the urogenital system due to myofascial structures (fascial adhesions, trigger points, etc.).

Diagnosis

Diagnosis includes physical examination including digito-rectal palpation as well as examination for myofascial trigger points (MTrPs), transrectal ultrasound, uroflow, and residual urine determination. It is also important here to objectify the micturition symptoms by means of a standardized questionnaire (IPSS score).
(Furthermore, an examination for myofascial trigger points (MTrPs) should also be performed in the extended pelvic region (lumbar spine, lower extremity)).
Focused ESWT is particularly suitable for this type of diagnosis, as deeper MTrPs can also be reached without difficulty, and the patient's feedback makes it possible to accurately classify the myofascial component in the symptoms.

Therapy

Drug: alpha blockers, 5-alpha reductase inhibitors, taldalafil
ESWT: The application of shock waves is similar to chronic pelvic pain. No side effects were observed.

Surgical therapy: TUR prostate, laser enucleation, as established procedures.

Promotion of wound healing after Fournier`s gangrene

In the early 1990s, Gerald Haupt was already able to show that low-energy shock waves promote wound healing. In the meantime, there are numerous reports on the positive effect of shock wave application in wounds that are difficult to heal (e.g., diabetic ulcer). This has prompted the first author of this chapter to use ESWT for wound healing after Fournier`s gangrene with and without plastic coverage by swing flaps.

Fournier`s gangrene represents a necrotizing fasciitis in the area of the external genitalia and the perineum. It requires immediate radical excision of the affected skin and subcutaneous areas and intensive therapeutic treatment of the patient. After successful primary treatment, different techniques are used to cover the skin defects (split skin, swing flaps). These are associated with the risk of secondary healing. Based on the good experience with low-intensity extracorporeal shock wave therapy (Li-ESWT) in the treatment of chronic skin ulcers, adjuvant treatment was recently reported in three cases with secondary healing after swing flap surgery. Subsequently, complete closure of the defect with shock wave-induced growth of localized tissue was achieved.

LI-ESWT

Shock wave source: Focal
Application: Distributed over the wound edges
Energy density: EFD: 0.10- 0.25 mJ/mm² depending on the device technology and the patient's perception of pain.
Frequency: 3-5 Hz
2000-4000 pulses
2-3x/ week
Treatment duration: 6-12 weeks
Complications: none

References ED and ESWT

Abe Y, Ito K, Hao K, Shindo T, Ogata T, et al. (2014) Extracorporeal low-energy shock-wave therapy exerts anti-inflammatory effects in a rat model of acute myocardial infarction. Circ J 78(12): 2915-2925.

Abu-Ghanem Y, Kitrey ND, Gruenwald I, Appel B, Vardi Y (2014) Penile low-intensity shock wave therapy: a promising novel modality for erectile dysfunction. Korean J Urol.55(5): 295-299.

Sexual dysfunction in men with chronic prostatitis/chronic pelvic pain syndrome: improvement after trigger point release and paradoxical relaxation training, Anderson RU, Wise D, Sawyer T, Chan CA, J Urol. 2006

Bechara A, Casabé A, De Bonis W, Nazar J (2015) Effectiveness of low-intensity extracorporeal shock wave therapy on patients with erectile dysfunction (ED) who have failed to respond to PDE5i therapy. A pilot study. Arch EspUrol 68(2): 152-160.

Becker M, Goetzenich A, Roehl AB, Huebel C, de la Fuente M, et al. (2014) Myocardial

effects of local shock wave therapy in a Langendorff model. Ultrasonics 54(1): 131-136.

Bonder, J. H., Chi, M., & Rispoli, L. (2017). Myofascial pelvic pain and related disorders. *Physical medicine and rehabilitation clinics of North America*, *28*(3), 501-515

Chitale S, Morsey M, Swift L, Sethia K (2010) Limited shock wave therapy vs sham treatment in men with Peyronie's disease: results of a prospective randomized controlled double-blind trial. BJU Int 106(9): 1352-1356.

Chung E, Cartmill R (2015) Evaluation of clinical efficacy, safety and patient satisfaction rate after low-intensity extracorporeal shockwave therapy for the treatment of male erectile dysfunction: an Australian first open-label single-arm prospective clinical trial. BJU Int 115(Suppl 5): 46-49.

Dal Farra, F., Aquino, A., Tarantino, A. G., & Origo, D. (2022). Effectiveness of Myofascial Manual Therapies in Chronic Pelvic Pain Syndrome: A Systematic Review and Meta-Analysis. *International urogynecology journal*, *33*(11), 2963-2976.

Doggweiler-Wiygul R., Urologic myofascial pain syndromes (2004), Curr Pain Headache Rep. 2004.

EAU Guidelines. Edn. presented at the EAU Annual Congress Milan 2023. ISBN 978-94-92671-19-6.

Frederice, C. P., Brito, L., Pereira, G., Lunardi, A., & Juliato, C. (2021). Interventional treatment for myofascial pelvic floor pain in women: systematic review with meta-analysis. *International urogynecology journal*, *32*(5), 1087-1096

Fojecki GL, Tiessen S, Osther PJS. Effect of Linear Low-Intensity Extracorporeal Shockwave Therapy for Erectile Dysfunction-12-Month Follow-Up of a Randomized, Double-Blinded, Sham-Controlled Study. Sex Med. 2018 Mar;6(1):1-7

Frey A, Sønksen J, Fode M (2016) Low-intensity extracorporeal shockwave therapy in the treatment of postprostatectomy erectile dysfunction: a pilot study. Scand J Urol 50(2): 123-127.

Ghahhari J , De Nunzio C , Lombardo R**,** Ferrari R**,** Lorenzo Gatti**,** Ghidini N**,** Calarco Piazza R , Faieta A , Cindolo L.: Shockwave Therapy for Erectile Dysfunction: Which Gives the Best Results? A Retrospective National, Multi-Institutional Comparative Study of Different Shockwave Technologies. Surg Technol Int. 2022 May 19; 40: 213

Goertz O, Lauer H, Hirsch T, Ring A, Lehnhardt M, et al. (2012) Extracorporeal shock waves improve angiogenesis after full thickness burn. Burns 38(7): 1010-1018.

IlanGruenwalda, OferShenfeldb, JuzaChenc, Gil Ravivd, Santiago Richtere, et al. (2006) Positive effect of counseling and dose adjustment in patients with erectile dysfunction who failed treatment with sildenafil. EurUrol 50(1): 134-140.

Hatzichristou D, d'Anzeo G, Porst H, Buvat J, Henneges C, et al. (2015) Tadalafil 5 mg once daily for the treatment of erectile dysfunction during a 6-month observational study (EDATE): impact of patient characteristics and comorbidities. BMC Urol 15: 111.

Haupt G, Haupt A, Ekkernkamp A, Gerety B, Chvapil M. Influence of shock wave healing. Urology 1992; 39: 529-532

Hausner T, Nógrádi A. The use of shock waves in peripheral nerve regeneration: new perspectives? Int Rev Neurobiol. 2013; 109:85-98.

Hayashi D, Kawakami K, Ito K, Ishii K, Tanno H, et al. (2012) Low-energy extracorporeal shock wave therapy enhances skin wound healing in diabetic mice: a critical role of endothelial nitric oxide synthase. Wound Repair Regen 20(6): 887-895.

Hazan-Molina H, Reznick AZ, Kaufman H, Aizenbud D (2015) Periodontal cytokines profile under orthodontic force and extracorporeal shock wave stimuli in a rat model. J Periodontal Res 50(3): 389-396.

Ioppolo F, Rompe JD, Furia JP, Cacchio A (2014) Clinical application of shock wave therapy (SWT) in musculoskeletal disorders. Eur J Phys Rehabil Med 50(2): 217-230.

Kim JH, Kim JY, Choi CM, Lee JK, Kee HS, et al. (2015) The dose-related effects of extracorporeal shock wave therapy for knee osteoarthritis. Ann Rehabil Med 39(4): 616-623.

Li H, Matheu MP, Sun F, Wang L, Sanford MT, et al. (2016) Low-energy shock wave therapy ameliorates erectile dysfunction in a pelvic neurovascular injuries rat model. J Sex Med 13(1): 22-32.

Lin G, Van Kuiken M, Wang G, Banie L, Tan Y, Zhou F, Wang Z, Chen Y, Zhang Y, Lue TF. Microenergy acoustic pulse therapy restores function and structure of pelvic floor muscles after simulated birth injury. Transl Androl Urol. 2022 May;11(5):595-606.

Liu J, Zhou F, Li GY, Wang L, Li HX, et al. (2013) Evaluation of the effect of different doses of low energy shock wave therapy on the erectile function of streptozotocin (STZ)-induced diabetic rats. Int J MolSci 14(5): 10661-10673.

Lu Z., et al. Low-intensity Extracorporeal Shock Wave Treatment Improves Erectile Function: A Systematic Review and Meta-analysis. Eur Urol (2016)

Mense S, Hoheisel U (2013) Shock wave treatment improves nerve regeneration in the rat. Muscle Nerve 47(5): 702-710.

Oginski N, Apel H, Richterstetter M, Lieb V, Fiebig C, Goebell PJ, Wullich B, Sikic D. Analysis of the Impact of Clinical Factors on Low-Intensity Extracorporeal Shockwave Therapy for Erectile Dysfunction. Urol Int. 2022;106(10):1041-1049.

Olsen AB, Persiani M, Boie S, Hanna M, Lund L (2015) Can low-intensity extracorporeal shockwave therapy improve erectile dysfunction? A prospective, randomized, double-blind, placebo-controlled study. Scand J Urol 49(4): 329-333.

Palmieri A, Imbimbo C, Creta M, Verze P, Fusco F, et al. (2012) Tadalafil once daily and extracorporeal shock wave therapy in the management of patients with Peyronie's disease and erectile dysfunction: results from a prospective randomized trial. Int J Androl 35(2): 190-195.

Pelayo-Nieto M, Linden-Castro E, Alias-Melgar A, Espinosa-Pérez Grovas D, Carreño-de la Rosa F, et al. (2015) Linear shock wave therapy in the treatment of erectile dysfunction. ActasUrolEsp 39(7): 456-459.

Poulakis V, Skriapas K, de Vries R, Dillenburg W, Ferakis N, et al. (2006) Extracorporeal shockwave therapy for Peyronie's disease: an alternative treatment? Asian J Androl 8(3): 361-366.

Qiu X, Lin G, Xin Z, Ferretti L, Zhang H, et al. (2013) Effects of low-energy shockwave therapy on the erectile function and tissue of a diabetic rat model. J Sex Med 10(3): 738-746.

Rassweiler JJ, Knoll T, Köhrmann KU, McAteer JA, Lingeman JE, et al. (2011) Shock

wave technology and application: an update. Eur Urol 59(5): 784-796.Rosen RC, Allen KR, Ni X, Araujo AB (2011) Minimal clinically important differences in the erectile function domain of the International Index of Erectile Function scale. Eur Urol 60(5): 1010-1016.

Rassweiler J: Re: Extracorporeal shock wave therapy (ESWT) in urology: A systematic review of outcome in Peyronie`s disease, erectile dysfunction, and chronic pain. (Words of Wisdom) Eur Urol 2018; 74: 115-117

Rassweiler JJ, Scheitlin W, Goezen AS, Rassweiler-Seyfried MC. Low-energy shock wave therapy in the management of wound healing following Fournier`s gangrene. Eur Urol Open Sci. 2022 Sep 13; 45:8-11.

Ross, V., Detterman, C., & Hallisey, A. (2021). Myofascial Pelvic Pain: An Overlooked and Treatable Cause of Chronic Pelvic Pain. *Journal of midwifery & women's health*, *66*(2), 148-160.

Sandoval Salinas C, González Rangel AL, Cataño Cataño JG, Fuentes Pachón JC, Castillo Londoño JS. Efficacy of robotic-assisted prostatectomy in localized prostate cancer: a systematic review of clinical trial. Adv Urol. 2013:105651. doi: 10.1155/2013/105651. epub 2013 Nov 10.

Schaden W, Thiele R, Kölpl C, Pusch M, Nissan A, Attinger CE, Maniscalco-Theberge ME, Peoples GE, Elster EA, Stojadinovic A. Shock wave therapy for acute and chronic soft tissue wounds: a feasibility study. J Surg Res. 2007;143(1):1-12.

Skolarikos A, Alargof E, Rigas A, Deliveliotis Ch, Konstantinidis E (2005) Shockwave therapy as first-line treatment for Peyronie's disease: a prospective study. J Endourol 19(1): 11-14.

Sokolakis I, Pyrgidis N, Neisius A, Gierth M, Knoll T, Rassweiler J, Hatzichristodoulou G, on behalf of the German Society for Shock Wave Lithotripsy. The effect of low-intensity shock wave therapy on non-neurogenic lower urinary tract symptoms. A systematic review and meta-analysis of pre-clinical and clinical studies. Eur Urol Focus 2021; May 10: S 2405-4569(21)00127-9.

Srini VS, Reddy RK, Shultz T, Denes B (2015) Low intensity extracorporeal shockwave therapy for erectile dysfunction: a study in an Indian population. Can J Urol 22(1): 7614-7622.

Taheri P, Shahbandari M, Parvaresh M, Vahdatpour B. Extracorporeal Shockwave Therapy for Chronic Venous Ulcers: A Randomized Controlled Trial. Galen Med J. 2021 Apr 25;10:e1931. doi: 10.31661/gmj. v10i0.1931. eCollection 2021.

Tara S, Miyamoto M, Takagi G, Kirinoki-Ichikawa S, Tezuka A, et al. (2014) Low-energy extracorporeal shock wave therapy improves microcirculation blood flow of ischemic limbs in patients with peripheral arterial disease: pilot study. J Nippon Med Sch 81(1): 19-27.

Tian WJ, Jeon SH, Cho HJ, Ha US, Hong SH, Lee JY, Piao JJ, Xin ZC, Chen YG, Feng HY, Kim SW, Bae WJ, Rajasekaran MR. Effect of Li-ESWT on testicular tissue and function in androgen-deficient rat model. Oxid Med Cell Longev. 2022 Mar 14; 2022:5213573. doi: 10.1155/2022/5213573. eCollection 2022.PMID: 35320975.

Vardi Y, Appel B, Kilchevsky A, Gruenwald I (2012) Does low intensity extracorporeal shock wave therapy have a physiological effect on erectile function? Short-term results of a randomized, double-blind, sham controlled study. J Urol 187: 1769-1775.

Yao H, Wang X, Liu H, Sun F, Tang G, Bao X, Wu J, Zhou Z, Ma J. Systematic Review and Meta-Analysis of 16 Randomized Controlled Trials of Clinical Outcomes of Low-Intensity Extracorporeal Shock Wave Therapy in Treating Erectile Dysfunction, Am J Mens Health. 2022 Mar-Apr;16(2):15579883221087532

Yee CH, Chan ES, Hou SS, Ng CF (2014) Extracorporeal shockwave therapy in the treatment of erectile dysfunction: a prospective, randomized, double-blinded, placebo-controlled study. Int J Urol 21(10): 1041-1045.

Zimmermann R, Cumpanas A, Miclea F, Janetschek G (2009) Extracorporeal shock wave therapy for the treatment of chronic pelvic pain syndrome in males: a randomised, double-blind, placebo-controlled study. Eur Urol 56(3): 418-424.