RheinLaser

Shockwave Therapy Guidebook

Introduction

This is your comprehensive guide to shockwave therapy. Special thanks go to The International Society for Medical Shockwave Treatment who are at the forefront of Shockwave therapy research and development and much of this guidebook is produced using their data.

Currently in the UK there is a knowledge gap in Shockwave therapy in the scope of its applications and it's mechanisms of action. This gap includes organisations and major manufacturers of Shockwave devices that provide shockwave training courses.

This guidebook will give you enough knowledge to fill in the gaps on currently available information in Shockwave therapy and enable you to make an informed decision on whether it is right for your practice.

Shock waves

Shock waves are specific acoustic sound waves, which accompany our daily life without being noticed. Cracks of thunder, bangs of explosions or noise of clapping crowds are typical examples of shock waves. Earthquakes and collapses of cavitation bumbles generate shock waves. An airplane, which breaks the sound barrier, generates a very loud bang, which can lead to the jingle of glasses in a cupboard, the shock wave has transmitted energy from the airplane to the glasses.

The opportunity to transmit mechanical energy by shock waves led to different technical and medical applications. Here the physical basics and the merits of medical ESWT are described.

History

From the first investigation of the application of shock waves in medicine until today is a very short time. During the Second World War it was observed that the lungs of castaways were cracked because of the explosion of water bombs, although no outer symptoms of violence existed. This was the first time that the influence of shock waves, created by the explosions on tissue were observed.

In 1966 the interest in shock waves on humans was stimulated accidentally at Dornier company. During experiments with high velocity projectiles an employee touched the plate in the very moment where the projectile hit the plate. He felt something in his body like an electrical shock. Measurements show that no electricity was present. The generated shock wave traveled from the plate over the hand in the body. From 1968 until 1971 the interaction between shock waves and biological tissue in animals was investigated in Germany. Another field of interest was the transition of the shock wave into the body. It was observed that shock waves create low side effects on the way through muscles, fat- and connective tissue. Intact bone tissue remains unharmed under shock wave burden. The best transition media for the shock wave was water and gelatin because of the similarity in the acoustic impedance to the tissue.

These investigations and cooperation with physicians lead to the idea to disintegrate kidney stones with extracorporeal generated shock waves. In the beginning the technical and medical realisation of the idea was not very clear but the idea was born. 1971 Haeusler and Kiefer reported about the first in-vitro disintegration of a kidney stone with shock waves without direct contact to the stone. In 1974 the Department of Research and Science of Germany financed the research program "Application of the ESWL". Participants on this program were for example Eisenberger, Chaussy, Brendel, Forßmann and Hepp. 1980 the first patient with a kidney stone was treated in Munich with a prototype machine called Dornier Lithotripter HM1. In 1983 the first commercial lithotripter (HM3, Dornier) was installed in Stuttgart/Germany. In the next years in-vivo and in-vitro experiments with extracorporeal generated shock waves with the goal to disintegrate gallstones were carried out.

In 1985 the first clinical treatment of a gallbladder stone with ESWL was performed in Munich/Germany. One year later a prototype of a lithotripter without a bathtub was tested in Mainz. Today the treatment of kidney and ureteral stones with extracorporeal shock waves is the treatment of the first choice. Modern lithotripters work without a bathtub and without anaesthesia. For localisation of stones lithotripters are equipped with x-ray and/or ultrasound localisation systems. In the last 16 years more than 3 Million patients have been treated.

Physical principles of ESWT

A shock wave is defined by an abrupt, nearly discontinuous change in pressure and by having a velocity that is higher than the speed of sound in the medium it propagates. A typical pressure profile of a focused shockwave used for therapeutic purposes is shown in fig.1

Generally a shock wave can be described as a single pulse with a wide frequency range (from approx. 150 kHz up to 100 MHz), high pressure amplitude (up to 150 MPa), low tensile wave (up to -25 MPa), small pulse width and a short rise time of up to a few hundred nanoseconds.

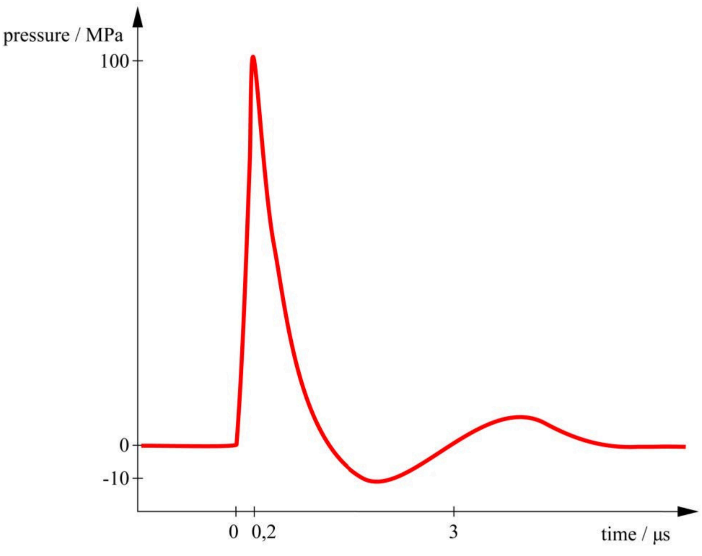

Fig. 1: Schematic pressure profile of a focused shockwave.

There are three different focussed shockwave generator technologies.

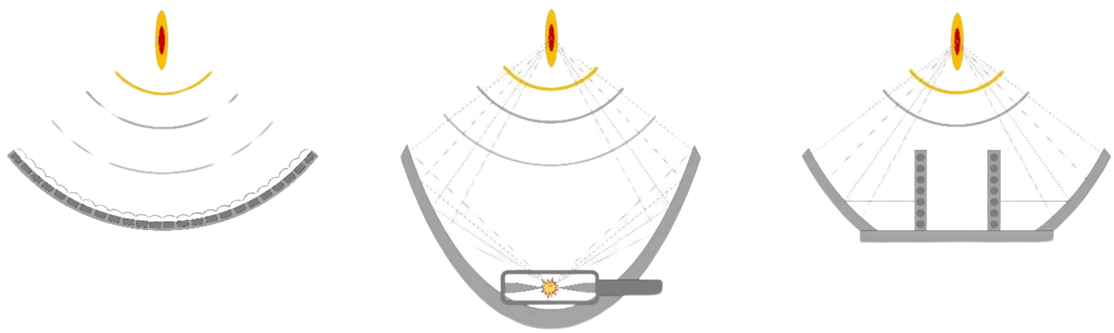

Fig. 2: Schematic illustrations of (left) piezoelectric, (centre) electrohydraulic, (right) electromagnetic shock wave generation principle. ©RWTH Aachen University, Germany

1) Piezoelectric

Piezoelectric generation principle is based on an inverse piezo-effect where a brief high voltage pulse causes an elongation of the piezo crystal. For shock waves high amplitudes are required. To achieve these high amplitudes, piezoelectric transducers, require large 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. Also a large single crystal can be used, alternatively, the piezo crystals can be stacked in double layers to achieve even higher summative amplitudes.

2) Electrohydraulic

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. 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 is achieved by using acoustic reflectors. It is only the electrohydraulic generation principle that maintains the true characteristic of a shockwave as it travels through water in the applicator head.

3) Electromagnetic

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, similar to a loudspeaker, but with higher energy. This membrane can be either flat or cylindrical to create planar or cylindrical pressure waves.

Radial Shockwaves (rSWT)

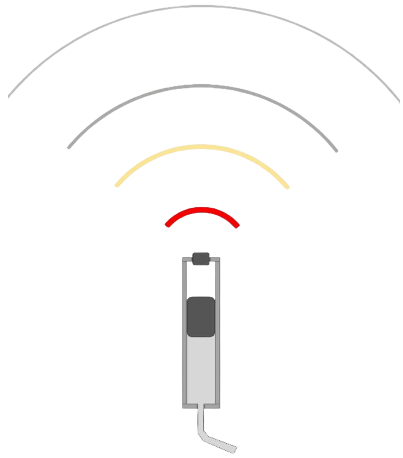

Fig. 3: ballistic (radial) generation principal

Radial shock wave ballistic devices generate a pressure wave by the collision of an accelerated projectile often called a bullet (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. The intensity decreases with the distance travelled by the shock wave. With rSWT. the sound waves have a different shapes and propagation and can be referred to more accurately as pressure waves. However, in medical terminology radial shock wave therapy has become established as the standard label for this technology.

Biological effects of shock waves

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 signalling pathways in treated cells through mechanotransduction (=the cellular translation of a mechanical stimulus into a biological response), which ultimately results in the regenerative effects of shock wave therapy.

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. The angiogenic and proliferative effect of SWT is dose-dependent up to 0.15 mJ/mm2 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

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 endothelialcells 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.

Mechanotransduction

In cellular biology, mechanotransduction (mechano + transduction) is any of various mechanisms by which cells convert mechanical stimulus into electrochemical activity. Important receptors for this are integrins. These are located on the cell surface, and 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.

Contraindications and adverse effects of ESWT

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

1 Malignant tumor in the shockwave field (not the tumor disease itself)

2 Fetus in the shockwave field (not the pregnancy itself)

3 Pacemaker/defibrillator in the shockwave field

Relative contraindication:

1 Brain tissue/CNS in the shockwave field (at high energy)

2 Vertebral bodies, skull bones and ribs

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

1 Lung tissue in the shockwave field

2 Malignant tumor in the shockwave field (not the tumor disease itself)

3 Significant coagulation disorder

4 Fetus in the shockwave field (not the pregnancy itself)

5 Pacemaker/defibrillator in the shockwave field

Reddening of the skin and bruising can occur as a side effect of radial shock wave application (ballistic pressure waves). In addition some pain can be experienced although this often dissipates quickly as the analgesic effect is activated. Lowering the bar pressure and increasing it to patient tolerance is the common method to avoid painful treatment.

Indications

For indications see the list on our website.

Whatever system you choose for your practice; radial, focussed or both, the indications are expanding through constant R&D. Investing in Shockwave equipment will expand your business offerings, improve patient/client outcomes and increase revenue.