

An explanation of shock waves

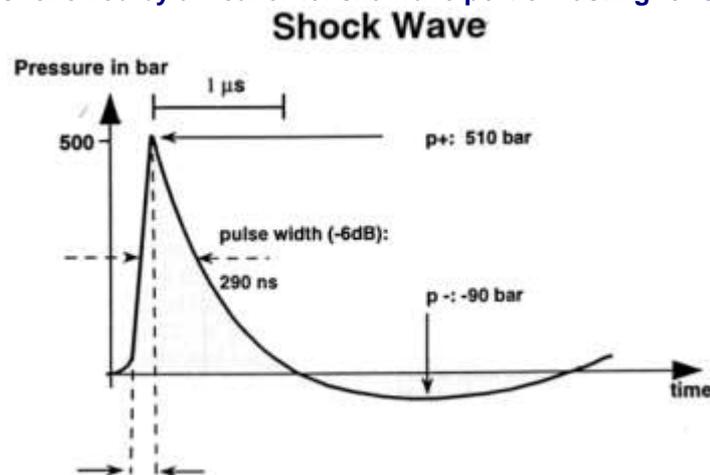
Introduction

In 1980 the first kidney-stone patient was treated successfully with a minimally invasive method called “extracorporeal shock-wave lithotripsy”. The first lithotripters generated shock waves using the “electrohydraulic” principle involving underwater spark discharge. This method was refined by a joint effort of scientists, engineers and medical specialists and is now used, in a more sophisticated form, in several types of shock- wave machines.

What are shock waves?

We find the following explanation in the Encyclopaedia Britannica: Shock waves are strong pressure waves generated in elastic media such as gases, liquids or solid substances by ultrasonic aircraft, explosions, lightning or other phenomena that create an extreme change in pressure. The high mechanical tension and pressure found at the shock front of a shock wave distinguishes shock waves from other kind of sound waves, such as ultrasonic waves. A characteristic feature of this kind of wave is that it travels at ultrasonic speed and increases in speed as the pressure rises.

The shock waves generated for medical purposes consist of a dominant pressure pulse which climbs steeply to hundreds of Mega- Pascals (MPa; 1 MPa = 10 bar) within several nanoseconds (nanosecond = 1/billionth of a second) and then falls again within several microseconds (microsecond = 1/millionth of a second); this wave is followed by a weaker tensile wave portion lasting for several microseconds.



The electrohydraulic generation principle – “a shock wave from the onset”

Shock waves are generated effectively and reproducibly in water by discharging a spark between two electrode tips.

The resulting thermal surge in water gives rise to a primary divergent shock front. Since the entire process takes place within a few nanoseconds, the plasma bubble expands at ultrasonic speed. The extremely rapid increase in pressure at this front leads to a high concentration of mechanical energy in the direction of wave propagation. (e.g., ESWT devices from HMT AG, TRT, MTS, Direx, CellSonic)

Focusing

To focus the primary expanding spherical shock front, an ellipsoid filled with water is used; the submerged spark is ignited at its first focal point. The shock front thus generated converges at the second focal point. When shock waves are used for medical purposes, the area to be treated (e.g. kidney stone, fracture gap or soft tissue/ tendon) is positioned via ultra-sound, x-ray techniques or even by skin-marking after palpation, at this focal point.

Non- linearity

High local overpressures generate a strong compression, and consequently a local increase in density, in the media. At the same time, the speed of sound is increased locally. As a result, sound portions which set out later catch up with the front during the propagation time of the wave culminating finally in the formation of an ideal steep shock front. The time required to build up a maximum front height depends on the pressure of the sound pulse, the focusing and the acoustic properties of the media.

Thermal effects

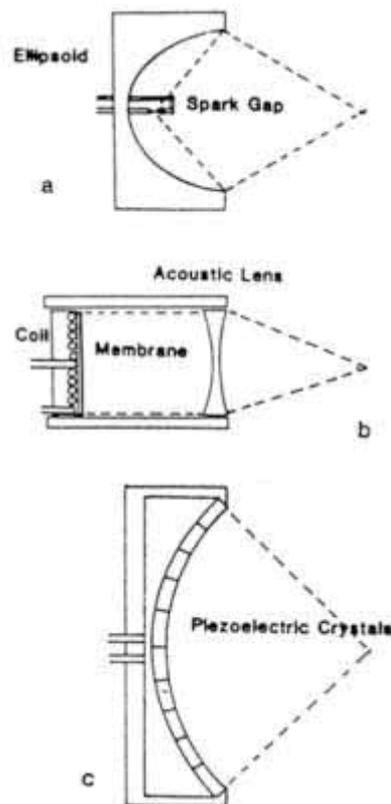
The duration of a shock- wave pulse is extremely short (3 – 5 nanoseconds). The amount of sound energy released at a pulse rate of 1 to 4 pulses per second is less than one Joule. This energy is not sufficient to bring about significant heating at the focus inside the body.

Differences between the various shock wave generation systems

“Shock wave from the onset” is typical for spark generated sound waves such as the CellSonic ESWT device.

This means that the sound front is extremely steep from the beginning.

None of the other generation systems known today, e.g. electromagnetic shock wave emitters (EMSE) or piezoelectric actually generate genuine shock waves; instead, they emit sinusoid or triangular rising signals. These systems make use of the non-linear effects described above to create a “real” physical steep shock wave via focusing devices. At low pressures, the typical wave path is not long enough to create a steeply rising signal.



How does a shock wave work?

The biophysical basis for the healing effects of shock wave treatments is not fully understood yet. The different densities exhibited by various human tissues play a decisive role in the release of energy by a shock wave.

At the boundary between two tissue structures with different densities (e.g. between tendon and bone), the energy of the shock wave is released as a result of acoustic impedance. The greater the difference in impedance, i.e. the more dramatic the “jump”, the more energy is released. In contrast to ultrasonic waves, shock waves release energy in the form of mechanical energy instead of thermal energy.

(cf. also “Thermal effects”). The use of a certain generating device, the parameters used and the physician’s experience all play an important role in getting a better result with ESWT.

Biological Mechanism of Musculoskeletal Shock Waves *

The biological mechanism of musculoskeletal shock waves (high-energy, focused ESWT) appeared to initially stimulate the expressions of angiogenic (the physiological process involving the growth of new blood vessels from pre-existing vessels) growth factors, and subsequently the ingrowth of neovascularization and the improvement in blood supply that leads to the repair of tendon and bone. Musculoskeletal shock waves produced consistent biological effects in tendon and bone and at the tendon-bone interface.

In contrast to lithotripsy where shock waves are used to disintegrate urolithiasis (e.g. kidney stone), shock waves in orthopedics (orthotripsy) are not used to disintegrate tissues but rather to microscopically cause interstitial (in between) and extracellular biological effects including tissue regeneration.

* from studies by the department of orthopaedic surgery and medical research Chang Gung memorial Hospital at Kaohsiung Taiwan.
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Focused and Radial Shock Waves - the differences

Extracorporeal Shock Wave Therapy (ESWT) employs medical high-energy focused shockwaves such as generated by the CellSonic Medical machine.

Radial Extracorporeal Shock Wave Therapy (RESWT) employs low- energy unfocused, radial pressure waves such as generated by the SynchroWave and Lithosplit machines from CellSonic Ltd.

The main technical differences between the two waves are set out in the following table. Focused shockwaves compared to Unfocused Radial Pressure Waves not only differ in their physical characteristics and the technique used for generating shocks but also in the order of magnitude of the parameters normally used.

	Focused Shock Waves	Radial or Unfocused Pressure Waves	Differences
Focused Propagation	yes	no	
Steepening	non-linear	linear	
Rise time	yes	no	
Compression pulse duration	typically 0.01 nanoseconds	typically 50 nanoseconds	1: 1000
Positive peak pressure	appr. 0.03 nanoseconds	appr. 200-2000 nanoseconds	1: 1000
Energy Flux Density	0 – 100 MPa	0 – 10 MPa	10: 1 / 100: 1
	0 – 3 mJ/mm ²	0 – 0.03 mJ/mm ²	10: 1

Extracorporeal Shock Wave Therapy ESWT



Wounds
Sports injuries
Non-invasive and sends shockwaves into the body

Intra-corporeal Shockwave Treatment



Physiotherapy
Non-invasive and works on the surface and shallow penetration

Non-invasive



Break and remove kidney stones
Probe goes into the kidney

invasive

The radial shock/ pressure waves are being produced by a system totally different to a focused shockwave.

The ESWT heads produce convergent shockwaves focused at a focal point 5mm, 20mm or 35mm from the surface of the shockhead. There is also an infinity head producing parallel shockwaves; the focus is infinity. By mistake such an infinity head is sometimes called unfocused.

The radial unfocused pressure waves have proven to be effective in Trigger Point Therapy (pain relief/reduction) and also for soft-tissue indications on and close to the surface such as tennis-elbow, achillodynia and similar in horses and pets. Radial shock waves are successful in physiotherapy.

The high-energy, focused shock wave ESWT systems, such as CellSonic Medical, treat musculoskeletal conditions below the surface, for example, heel spur, calcified shoulder, patellar tip syndrome and also non-union fractures and wounds. Similar indications in horses and other mammals are also treated. Results on deeper conditions will be quicker with fewer treatments than with the application of low-energy, unfocused radial pressure waves, Radial-ESWT.

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