shockwave therapy

Physics of the shock waves

High Medical Technologies

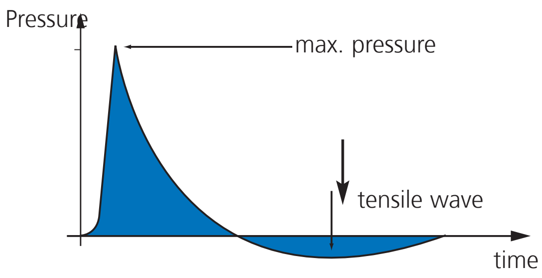
Shock Waves: History and Underlying Principle

Introduction

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

What are shock waves?

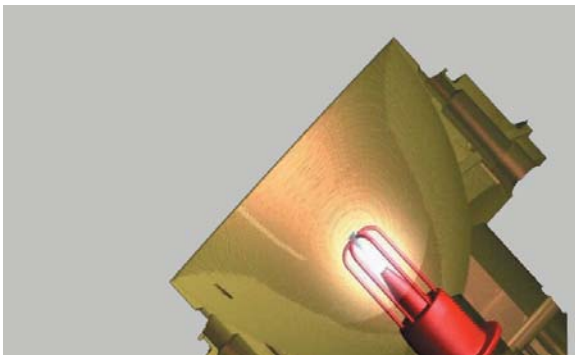
We find the following explanation in the Encyclopaedia Britannica: shock waves are strong pressure waves generated in elastic media such as gases, liquids or solid substances by ultrasonic aircraft, explosions, lightning or other phenomena that create an extreme change in pressure. The high mechanical tension and pressure found at the shock front of a shock wave distinguishes shock waves from other kinds 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"

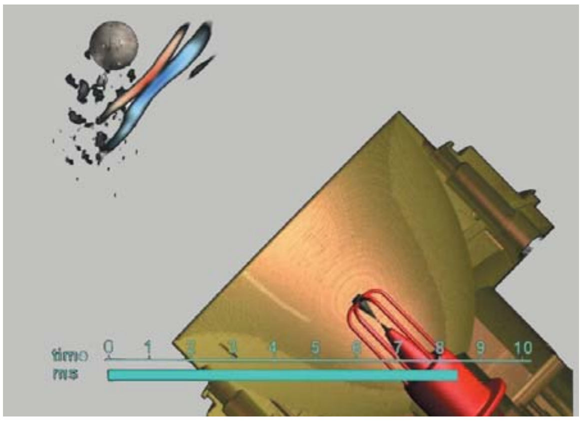
Such waves can be generated effectively and reproducibly in water by discharging a spark between two electrode tips. The resulting thermal surge in the water gives rise to a primary divergent shock front. Since the entire process takes place within a few nanoseconds, the plasma bubble expands at ultrasonic speed. The extremely rapid increase in pressure at this front leads to a high concentration of mechanical energy in the direction of wave propagation.



Electrode in the ellipsoid, ignition

Focusing

To focus the primary expanding spherical shock front, an open rotation ellipsoid filled with water is used; the underwater 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 or fracture gap) is positioned, via ultrasound or x-ray techniques, at this focal point.



What happens when a shock wave hits a urinary calculus

Mechanism of action and effects of shock waves

Non-linearity

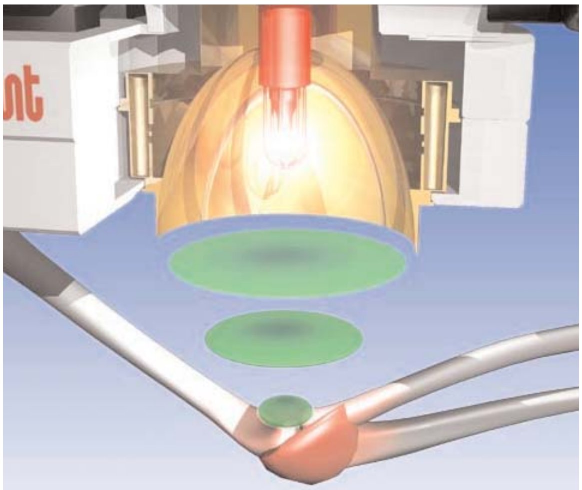
High local overpressures generate a strong compression, and consequently a local increase in density, in the media. At the same time, the speed of sound is increased locally. As a result, sound portions which set out later are enabled to catch up with the front during propagation time of the wave, culminating 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 µs). If we calculate the amount of sound energy released at a pulse rate of 1 to 4 pulses per second, we obtain distinctly less than one Joule. This energy is not sufficient to bring about significant heating at the focus.

Differences between the various shock wave generation systems

“Shock wave from the onset” is typical for spark generated sound waves. This means that the sound front is extremly steep from the beginning. None of the other generation systems known today, e.g. electromagnetic shock wave emitters (EMSE) or piezoelectric generators, actually generate 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 focussing devices. At low pressures, the typical wave path is not long enough to create a steeply rising signal.



How does the shock wave work?

The biophysical basis for the healing effects of shock wave treatments is not yet fully understood. 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").