Extracorporeal shock wave lithotripsy

Extracorporeal shock wave lithotripsy (ESWL) is a non-invasive method used primarily in the treatment of kidney stones and gallstones. The principle of the method consists in supplying pressure energy sufficient to disturb the stones in the patient's body so that the tissues are not damaged. This is due to the special course of the "pressure wave" carrying energy, as well as its spatial focus.

Alternatively, the terms *lithotripsy* and *lithotriptor* are used. Their use is not a grammatical error if the unity of style is observed throughout the document.

The method was first introduced to the market in the early 1980s by Dornier Medizintechnik GmbH. The application of shock waves is also used in other indications.

Shock wave

The shock wave is a non-periodic type of disturbance (excitement) propagating through the environment. In general, a shock wave is a surface of discontinuity of thermodynamic quantities describing the state of the environment. In the case of the shock wave used in lithotripsy, the propagating disorder is a sharp change in pressure. This shock wave is in principle similar to, for example, a shock wave propagating from the site of an explosion.

Because it is a propagating change in pressure, the shock wave has the character of an acoustic phenomenon. Even its behavior, at least in terms of refraction and reflection, corresponds to that of sound waves. For this reason, the term acoustic impedance makes sense and it is possible to study the behavior of the shock wave at the interface of two environments with different acoustic impedance, thanks to which the beam optics is also a useful tool[pozn 1]

The focused shock wave

To be able to deliver sufficient energy to be able to fragment it without damaging the soft tissues, it is possible to shape the shock wave by reflection or refraction so that it reaches the maximum pressure values at the point of application inside the patient's body. Such shock waves are called "focused shock waves".

Interaction of shock waves with stone

Because the acoustic impedance of the stone is significantly different from the acoustic impedance of the soft tissues, there is a significant difference in pressure at the interface and inside the stone when the shock wave strikes this interface, resulting in stress in the concrete. Due to the fact that the peak pressure of the shock wave reaches tens of megapascals, the forces acting on the stone reach such values, that the strength limit of the stone is exceeded (of the order of 10^8 Pa) and its fragmentation occurs.

The cooperating mechanism of stone fragmentation is cavitation, which arises due to tensile forces in the fluid near the stone surface.

One shock wave is usually not enough to fragment a stone. Their number, which is necessary for the complete destruction of the stone, is 50-4000, on average 1000, depending on the amplitude of the shock wave pressure, the size and composition of the stone, and the type of shock wave generator.

Lithotryptor

A lithotripter, that is, an apparatus that performs lithotripsy, typically consists of the following parts:

- shock wave source
- focusing device
- binding environment
- stone aiming equipment

The shock wave generator

The sources of shock waves can be divided according to two aspects. The first aspect is the geometric arrangement of the active site in which the shock waves arise. In point generators, shock waves are generated in a relatively small place, which can be seen as a point from which the shock waves then propagate more or less radially. In surface generators, the source of shock waves is the whole area, the propagation of shock waves is then conditioned by the shape of this area.

The second aspect is the physical principle of the shock wave. Common types of generators are:

- electrohydraulic
- electromagnetic

- piezoelectric
- laser **First definition of ecotoxicology (1969): René Truhaut: the study of the adverse effects of chemicals with the aim of protecting natural species and communities.**

Historically the first commercially available Dornier HM1 lithotripter

Rachel Carson (1962): the memoir The Silent Spring highlights the use of pesticides , especially DDT and other agrochemicals. The book led to the establishment of the US Environmental Protection Agency (EPA) in the USA. Introduction of methods describing the toxic effects of human-produced substances on the environment and the organisms contained therein. Systematic implementation of fish toxicity testing methods. In addition to direct toxic effects, the effects of bioconcentration and bioaccumulation are studied – increases in the concentration of foreign substances in the tissues of organisms as a result of exposure from the environment.

2004 EC ratification: Persistent Organic Pollutants Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution The aim of the protocol is to limit, reduce or eliminate the discharge, emissions and losses of persistent organic pollutants that have significant adverse effects on human health or the environment due to long-range transboundary air transport.

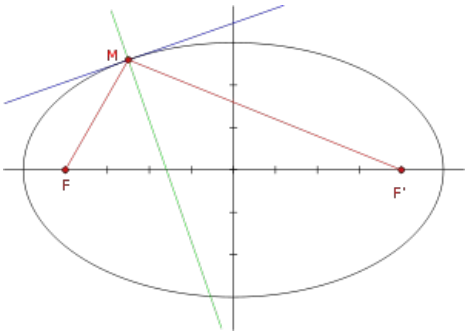
In 2006 , Regulation No. 166/2006 of the European Parliament and the EC Council was issued, establishing the **European Register of Releases and Transfers of Pollutants** . It represents a publicly accessible database of pollutant releases into the air, water and soil, information on wastewater, information on pollutant releases from dispersed sources.

In 2003 , the proposal for a new framework for legislation covering the safety of chemicals REACH (Registration, Evaluation and Authorization of Chemicals) was accepted by the European Commission and approved by the European Parliament . Enterprises and firms that import more than 1 ton of a chemical compound per year will be forced to register this chemical in a central data bank. The aim is to improve the protection of the health of nature, including people, to increase the innovation capacity and the ability of the chemical industry to compete in the European Union. The new measures concern not only new chemical substances introduced to the market, but also substances that have been used for a long time. The program aims to ensure that by 2020 at the latest, only chemical substances with known properties and in a way that does not harm human health and the environment are used.

Electrohydraulic generator

The electrohydraulic generator is the most common generator. The essence of the shock wave is a high-voltage electric discharge. Plasma is formed in the discharge channel, which pushes on the surrounding liquid and expands. The expansion cools the plasma and largely converts it back into liquid water. However, a radial shock wave is already spreading to the surroundings.

A simple knowledge of elementary geometry is used for focusing, namely that the joints of any point of the ellipse with one and the other focus form the same angle with the tangent of the ellipse. In the language of ray optics, this means that when a beam comes out of one focus in any direction, it bounces off the ellipse and passes through the other focus. The situation can be easily transferred to three-dimensional space by taking a rotating ellipsoid, a shape that arises from an ellipse by rotating along the major axis.



Rotating ellipsoid focusing principle

If a shock wave generator is placed in one focus of the rotating ellipsoid, the shock waves will be concentrated in the other focus. If only part of the ellipse is used, the efficiency will be sufficient to fragment the concretion located in the second focus.

A piezoelectric generator

A piezoelectric generator is a typical representative of surface generators. The physical nature is the piezoelectric phenomenon, ie the deformation of some crystalline substances when they are exposed to an electric field. A number of relatively small piezoelectric crystals with attached electrodes are distributed in the area, the control electronics then control the voltage at the electrodes. Due to the fact that the deformation of the crystal, and thus also the dynamics of the resulting pressure failure, can be influenced, for example, by the rate of voltage rise on the crystal, it is possible to choose the shape of the generated shock wave[pozn 2].

The focusing of shock waves from a piezoelectric generator can best be done by the geometry of the surface on which the piezoelectric elements are located. One option is to shape the surface as a spherical canopy and place the stone in the center of the corresponding sphere.

Electromagnetic generator

The physical nature of the electromagnetic generator is the deformation of the magnetic membrane during a sharp change in the magnetic field. Changes in the magnetic field are usually achieved by discharging a high voltage capacitor through a sufficiently large solenoid coil.

Focusing is achieved either by means of an acoustic lens or by a combination of the shape of the membrane and the reflection of waves into the focus.

Laser

Laser is not used in practice in extracorporeal lithotripsy, however, laser-induced shock waves play an essential role in contact (!) Endoscopic fragmentation of stones.

Binding environment

The coupling environment is the environment in which the shock wave propagates from the generator to the patient's body. It is basically a degassed water whose acoustic characteristics are relatively close to soft tissue.

Localization

For a successful procedure, it is necessary to place the focus in the concrete, otherwise the procedure would not be effective. Two systems are used to locate the stone, X-ray and Ultrasound.

X-ray localization

Such devices include an X-ray C-arm, which allows you to obtain an image in two perpendicular projections. The advantage is greater accuracy, the disadvantage is the patient's radiation exposure and applicability only to sufficiently calcified (so-called X-ray contrast) stones.

Ultrasound localization

Ultrasonic localization does without radiation exposure, but the ultrasonic targeting of the concrete is less accurate.

Clinical use

- renal stones - suitable for 70% of cases
- gallstones - suitable for 20% of cases
- orthopedics:
  - locomotor calcification
  - entezopathia a tendinitids
- physiatry:
  - significantly lower acoustic pressures - "shock wave"
  - treatment of muscle injuries, fractures and inflammation
  - joint and tendon pain

Note: For some clinical applications in the treatment of the musculoskeletal system, there is a lack of scientific explanation of the alleged effect and credible experiments demonstrating clinical efficacy. The use of shock waves in these applications is thus approaching the field of alternative medicine.

Stones in the pelvis

Extracorporeal shock wave lithotripsy stone therapy is suitable in about 70% of cases, the therapeutic success rate is between 70 and 98%.

Indications

- free concrete of a maximum size of 2 cm
- permeable upper urinary tract
- X-ray contrast stone (when located by X-ray)

Contraindications

- pregnancy
- bleeding disorders
- assumption of spontaneous departure
- noncontrast concrete

Complications

- urethral obstruction crushes from the leaving stone (so-called steinstrasse)
- hematuria and kidney damage

Notes to the actual performance

- the path of the shock wave through the patient's body must be chosen so that it passes exclusively through soft tissues and passes through solid tissues (ribs, spine, ...) as well as the interface of soft tissues and air (in the respiratory and digestive tracts). At these acoustic interfaces, the energy of the shock wave would otherwise be released and cause them to be traumatized.
- The procedure is usually not performed under anesthesia, but sometimes it is necessary to proceed to analgesia because it is not completely painless and lasts for tens of minutes.
- The shock waves synchronize with the ECG, because the shock wave propagates throughout the body and there would be some risk of arrythmia if the heart hits a vulnerable phase of cardiac evolution.
- The concretion is only fragmented, it must leave in a natural way. Therefore, regime measures are necessary after enforcement.

Gallstones

Only about 20% of cases are suitable for ESWL solutions. The fragmentation itself only serves to increase the surface area for the subsequent dissolution of the stones by means of preparations based on chenodeoxycholic acids (CDC) and ursodeoxycholic acids (UDC).

References

Footnotes

1. Acoustic waves and shock waves can be well described by rays under certain limitations.
2. The possibility of influencing the shape of the shock wave looks interesting, but it is not known whether such a thing would be clinically relevant

Related Articles

- Cholelithiasis
- Concrements
- Urolithiasis

External links

- J.Šrámek: Litotripse extrakorporální rázovou vlnou prezentace (http://www.med.muni.cz/biofyz/doc/NMgr/ESWL.pdf)

References

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- ROZMAN, Jiří, et al. *Elektronické přístroje v lékařství.* 1. edition. Praha : Academia, 2006. 410 pp. ISBN 80-200-1308-3.
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