Therapeutic use of ultrasound

As ultrasound we describe acoustic waves with frequencies higher than 20 kHz, which propagate through the material environment on the principle of particle densification and dilution. During its transmission, no electric current passes, so we refer to its therapeutic use as mechanotherapy.

Principles of the therapeutic effect of ultrasound

The therapeutic effect of ultrasound is due to the fact that it is absorbed to a different extent by different substances.

- **Absorption coefficient** is then directly proportional to the effectiveness of the treatment. It increases with increasing protein content in the tissue, and decreases with increasing water content. The absorption coefficient of a frequency of 1 MHz is three times smaller than the absorption coefficient of a wave of a frequency of 3 MHz and penetrates three times deeper. Therefore, ultrasound with a frequency of 3 MHz is used for more superficially located tissues, while ultrasound with a frequency of 1 MHz, on the other hand, has greater effects with deeper structures, and has almost no effect on the surface.
- At the tissue interface, **ultrasound waves** are reflected to varying degrees - the reason is the different specific impedances of the individual tissues. Air has a very high impedance, its 10 nm thick layer reflects up to 99% of ultrasound waves.[1]
- The **Effective radiating area (ERA) of the head'** is determined by the size of the piezoelectric crystal generating the ultrasound. As a rule, it reaches values of 1−10 cm^2. Based on the distance from the warhead, we distinguish an *ultrasound near field* characterized by low divergence of the ultrasound "beam" and relatively large intensity variations due to strong [[w:cs:interference|interference effects]] (i.e. strengthening or weakening of ultrasound energy). On the contrary, *distant ultrasound field* is characterized by high beam divergence and lower intensity.
- **Half-depth of penetration** is the distance at which the ultrasound intensity drops to 50% of its original size.[1]
- **Penetration depth** is the maximum depth at which a therapeutic effect can be expected (the wave intensity in this place is ten times smaller than the wave intensity close to the head).[1]

Usage examples

Use in stomatology

Magnetostrictive sources are used as the source of ultrasound waves, which distinguishes dentistry from other fields where ultrasound is used therapeutically. The source of the oscillations here is a ferromagnetic rod, which changes its volume in rapid succession due to the action of the magnetic field. The advantage of this method of generation is high performance, however, this can only be achieved with **frequencies up to 60 kHz'**[2]. Frequencies in the range of 24-42 kHz (*low-frequency ultrasound*) with an intensity of more than 10 W/cm^2[3], to remove tartar and cavity. Compared to manual removal, this method is disproportionately faster, less demanding and saves enamel. The main factor that destroys tartar is the formation of cavitation in the water that runs down the tool itself, which is made of titanium.[3]

Hyperthermia

Ultrasound is, in addition to microwave radiation, one of the ways to achieve overheating of the tumor and its subsequent damage (see hyperthermia for more). The tumor must be exposed to a temperature of 41-43 °C for about 20 minutes [3]. The targeted effect is achieved by *focusing*, i.e. by concentrating ultrasound waves coming from different directions to the tumor site; therefore, there is minimal damage to healthy tissue. A frequency of 1 MHz is usually used, the temperature is always controlled thermocouples.

Harmonic Scalpel

Harmonic scalpel works on the principle of longitudinal ultrasonic oscillation at a frequency of 55 MHz. This creates energy at low temperatures from 50 to 100 °C. It allows the cutting and coagulation of soft tissue, blood vessels and sealing of lymphatic channels in one moment. Bleeding is 4x to 6x less when using the harmonic scalpel than with other surgical methods. This is a very gentle surgical technique used especially in plastic and endoscopic surgery, near nerves and blood vessels.

Physical therapy

One type of physical therapy that is very widespread is *ultrasonotherapy*, which uses the acoustic energy of ultrasound. **Ultrasound** is applied using a special device equipped with a radiation head with an effective surface of various sizes from 1 to 10 cm^2. It forms mechanical waves with a therapeutic frequency of 0.7 to 3.3 MHz, which is maximally absorbed at a tissue depth of 2 to 5 cm. Therefore, it is used in the therapy of soft tissue damage. It has an analgesic, spasmolytic and vasodilating effect.

Application

We divide according to the **movement** of the head:

- static (the head is applied to one affected place and does not move with it);
- semistatic (circular movement around the affected area);
- dynamic (movement of the head, e.g. along the entire limb).

Next, we divide the heads according to **contact** with the skin:

- direct contact of the head with the skin (using gel or oil);
- contact through the aquatic environment.

The application usually takes a few minutes and is repeated several times over the course of consecutive days.

Indication

- myalgia - muscle pain after stretching or stiffness (back muscles)
- lumbago
- arthritis, joint swelling, Bechtěrev disease
- post-traumatic pain therapy (after joint dislocation or ligament distortion), enthesopathy (tennis elbow)
- therapy of postherpetic neuralgia
- leg ulcers, scars

Contraindications

- fresh bleeding
- fractures
- hematomas
- menstruation (vasodilation)

Transdermal application of drugs

The principle is the propagation of ultrasonic waves through a liquid, which is associated with the creation of **pseudocavitation** (tiny bubbles) that move chaotically and, after reaching a certain size, destabilize and collapse. At the same time, this creates a kind of **jet microflow** in the surrounding liquid, which causes abrasion of the upper layers of the skin. In addition to this abrasion, there is apparently also an **increase in permeability** of the phospholipid bilayer of biological membranes, which together results in a higher **permeability of the skin** even for high-molecular substances, which does not otherwise pass through her. Greater permeability of the skin is achieved by simultaneously **acting on it with waves of two frequencies** ***in the range from 20 kHz to 3 MHz.*** *High frequency ultrasound* ***creates additional bubbles that quickly burst in the presence of low frequency ultrasound waves. In addition, high-frequency ultrasound limits the movement of the bubbles to the sides and thus keeps them at the target location, which leads to a more uniform*** *abrasion*.

Such a liquid can be a liquid medicine applied to the skin. This is used (so far, rather experimentally) for chronic administration of drugs such as **insulin**, which previously had to be administered only by injection. The therapeutic effect thus lies in the minimal invasiveness of such an application. The **abrasive effect** of ultrasound is temporary and painless, the top layer of the skin (stratum corneum epidermis) regenerates quickly (within a few hours) from the basal layer of the epidermis.

Other uses

Furthermore, ultrasound is used to **accelerate the healing** of bone fractures, when joining bone fragments with a synthetic binder (the use of ultrasound shortens the setting time from days to seconds due to the local effect of higher temperature), removing **atherosclerotic plaques** in blood vessels, during the therapy of **prostate tumors**, procedures on the **ovaries** and in **plastic surgery** (removal of fatty tissue by extrusion).

Links

Related Articles

- Doppler echocardiography
- Ultrasound/Diagnostic applications of ultrasound
- Ultrasound
- Ultrasonic waves

External links

- WIKIPEDIA,. *Therapeutic ultrasound* [online]. [cit. 2013-10-31]. <https://en.wikipedia.org/wiki/Therapeutic_ultrasound>.

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2. ROSINA, Joseph. *Medical Biophysics.* 1. edition. Manus, 2000. ISBN 80-902318-5-3.
3. KUBÍNEK, Roman. *University of Palacky Olomouc* [online]. [cit. 2013-01-05]. <http://apfyz.upol.cz/ucebnice/details/ultrazvuk_terapie.pdf>.

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