ULTRASOUND THERAPY

DEFINITION

Ultrasound refers to mechanical vibrations, which are essentially the same as sound waves but of a higher frequency. Such waves are beyond the range of human hearing and can therefore be called ultrasonic.

PRODUCTION OF THERAPEUTIC ULTRASOUND

Piezo-electric effect: The production of a small electro motive force(e.m.f.) across certain substances on being subjected to external pressure. Such substances are known as piezo-electric substances

Reverse piezo-electric effect: Production of mechanical waves or vibrations due to the application of e.m.f.

Many types of crystal can be used but the most favored are quartz, which occurs naturally, and some synthetic ceramic materials such as barium titanate and lead zirconate titanate (PZT). These crystals deform when subjected to a varying potential difference – a piezo-electric effect. In order to apply the electric charges, metal electrodes must be fixed to the crystal. If a suitable metal plate is fixed to one surface of the crystal while the opposite surface is in air, then almost all the vibrational energy is transmitted from the crystal to the plate and hence to any solid or liquid to which it is applied.

The other essential parts of a therapeutic ultrasound generator are a circuit to produce oscillating voltages to drive the transducer, which can turn the oscillator on and off to give a pulsed output.

A suitable circuit can maintain a constantly oscillating electric charge to cause the piezoelectric crystal to change shape at the same frequency

So drive the metal plate backwards and forwards also at the same frequency in any medium with which it is in contact. This amplitude is referred to as the intensity and is the energy crossing unit area in unit time perpendicular to the sonic beam. It is therefore measured in watts per square centimeter.

References:

• Agents in Rehabilitation, From research to practice; Michelle H. Cameron, 2nd Edition
• Electrotherapy Explained, Low, J. & Reed, A, 4th Edition.

Current supplied to the oscillator circuit can be automatically switched on and off to produce a pulsed output, typically giving ratios 1:1 or 1:4. A meter is often included which measures the electrical oscillations applied to the crystal but not the vibration of the crystal

BOUNDARIES BETWEEN MEDIUM

Sonic waves involve vibratory motion of molecules so that there is a characteristic velocity of wave progression for each particular medium. It depends on the density and elasticity of the medium and together these specify the acoustic impedance of the medium. Acoustic impedance = density of medium x velocity of wave. Some of the energy is reflected back. The amount of the energy reflected is proportional to the difference in acoustic impedance between the two media.

Refraction also occurs with sonic waves due to the difference in acoustic impedance. The beam of sonic energy that passes through the second medium does not continue in a straight line but changes direction at the boundary because of the different velocities in the two media. If the acoustic impedances are closely matched little refraction will occur.

Absorption of Sonic waves • Kinetic energy is converted to heat energy as it passes through the material. The energy will decrease exponentially with distance from the source because a fixed proportion of it is absorbed at each unit distance so that the remaining amount will become a smaller and smaller percentage of the initial energy. The conversion of sonic energy to heat is due to increased molecular motion

Half value depth: depth of tissue at which the US intensity is half its initial intensity. Absorption of sonic energy is greatest in tissues with largest amounts of structural protein and lowest water content. Blood – least protein content and least absorption. Bone - greatest protein content and greatest absorption

Attenuation of Ultrasound in the Tissues: The loss of energy from the ultrasound beam in the tissues is called attenuation and depends on both absorption and scattering. Absorption accounts for some 60 – 80% of the energy lost from the beam. The scattered energy may also be absorbed other than in the region to which the ultrasound beam is applied. Scattering is caused by reflections

References:
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• Electrotherapy Explained, Low, J. & Reed, A, 4th Edition.

and refractions, which occur at interfaces throughout the tissues. This is particularly apparent where there is a large difference in acoustic impedance.

Transducer: ultrasound unit that contains the crystal

Power: amount of acoustic energy per unit time (watts).

Intensity: power per unit area of the ultrasound head (watts/cm^2)

Spatial average intensity: Average intensity of the US output over the area of the transducer

Spatial peak intensity: Peak intensity of the ultrasound output over the area of the transducer. The intensity is usually great in the centre of the beam and lowest at the edges of the beam.

Beam non-uniformity ratio (BNR): Ratio between peak intensity and average intensity in the beam. The lower the BNR the more uniform the beam. With BNR 5:1, when the spatial average intensity is 1W/cm2, the spatial peak intensity would be 5W/cm^2

Continuous ultrasound: continuous delivery of US through out the treatment period

Pulsed ultrasound: delivering US only during a portion of the treatment period. Pulsing reduces the thermal effects

Duty cycle: proportion of the total treatment time that the US is on. This can be expressed in percentage or a ration. 20% or 1:5 duty cycle, is on for 20% of the time and off for the 80% of time.

Spatial average temporal peak intensity: spatial average intensity of the US during the on time Clinically US displays SATP intensity and duty cycle • Spatial average temporal average intensity: The spatial average intensity of the US averaged over both the on time and the off time

SATP X duty cycle = SATA

Frequency: number of compression- rarefraction cycles per unit of time, usually expressed in cycles per second (Hertz). Increasing the frequency of US causes a decrease in its depth of penetration and concentration of the US energy in the superficial tissues.

Effective radiating area (ERA): The area of the transducer from which the US energy radiates. Since the crystal doesn't vibrate uniformly, the ERA is always smaller than the area of the treatment head.

Some waves cancel out, others reinforce so that the net result is a very irregular pattern of the sonic waves in the region close to the transducer face, called the **near field or Fresnel zone.**

References:

• Agents in Rehabilitation, From research to practice; Michelle H. Cameron, 2nd Edition
• Electrotherapy Explained, Low, J. & Reed, A, 4th Edition.

Beyond this, the **far field or Fraunhofer zone,** the sonic field spreads out somewhat and becomes much more regular because of the differing path lengths from points on the transducer.

The length of the near field depends directly on the square of the radius of the transducer face and inversely proportional to the wavelength of the sonic waves.

Length of Fresnel zone = r2 / λ

For practical purposes therapeutic ultrasound utilizes the near field. The relatively more energy on average is carried in the central part of the cross-section of the beam. The irregularity of the near field can be 'ironed out' to some extent by continuous movement of the treatment head during the therapy.

Proportional heating of 1 and 3 MHz ultrasound through tissues

Shear waves can be formed which transmit energy along the periosteal surface at right angles to the ultrasound beam. Due to the fact that this reflection is quite large (almost 25%) and that sonic energy is absorbed almost immediately in bone, there is marked heating at the bone surface. • This is considered to account for the periosteal pain that can arise with excessive doses of therapeutic ultrasound.

Heating in the tissues due to the Ultrasound:- The important factor for heating in the tissue due to ultrasound is the rate of tissue heating, which is, influenced both by the blood flow, which constantly carries heat away, and by heat conduction. In highly vascular tissues such as muscle it is likely that heat would be rapidly dissipated preventing any large temperature rise; on the other hand, less vascular tissue, such as dense connective tissue in the form of tendon or ligament, may experience a relatively greater temperature rise.

Moving the transducer head during the treatment is important because of following effects

To smooth out the irregularities of the near field • It reduces the irregularities of absorption that might occur due to reflection at interfaces, standing waves, refraction, and differences in tissue thermal conduction or blood flow. It also reduces shear wave formation and thereby reduces chances of periosteal pain. Thus resulting heating pattern is likely to be much more evenly distributed. It has been estimated that for an output of 1 W/cm^2 there is a temperature rise of 0.8°C/min if vascular cooling effects are ignored

References:

• Agents in Rehabilitation, From research to practice; Michelle H. Cameron, 2nd Edition
• Electrotherapy Explained, Low, J. & Reed, A, 4th Edition.

The effect is not the same because with pulsed treatment there is time for heat to be dissipated by conduction in the tissues and in the circulating blood. Therefore, higher intensities can be safely used in a pulsed treatment because the average heating is reduced. Ultrasound application can increase rates of ion diffusion across cell membranes; this could be due to increased particle movement on either side of the membrane and possibly, increased motion of the phospholipids and proteins that form the membrane.

References:

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