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Physical aspects of medical ultrasonics - a review

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Ultrasonic techniques are complementary to other physical methods used in surgery, therapy and diagnosis. Most medical applications of ultrasound are based on the properties of longitudinal waves in the frequency range 1 - 15 MHz. Lead zirconate titanate is a widely used transducer material. In surgery and therapy, air-backed transducers are used to achieve maximum efficiency; but in pulse-echo diagnosis, the required bandwidth is usually obtained by mechanical loading of the transducer. Plane disc transducers are most common, although focusing is used when high intensity or enhanced resolution is required.

Ultrasonic waves travel at similar velocities (about 1500 m s^{-1}) in biological soft tissues. Absorption occurs chiefly due to relaxation processes, and leads to a loss of about 1 dB $cm^{-1}MHz^{-1}$. Thus, ultrasound may affect living systems by thermal effects. Mechanical effects, such as streaming and cavitation, are also important in certain situations, particularly at the lower frequencies.

Focused ultrasonic beams are used in neurosurgery, to cause damage deep in the brain without injury to superficial tissues. In ear surgery, ultrasonic irradiation is used routinely for the treatment of disorders of the balance organ, such as Meniere's disease; it can alleviate the symptoms without damage to the hearing.

Therapeutic applications include the treatment in physiotherapy of various soft-tissue ailments: the method seems to be effective mainly because of locally increased temperature, but more subtle changes may also occur. Ultrasonic nebulisers are used for the production of aerosols for inhalation therapy.

Ultrasonic diagnosis can provide information about the positions and extents of characteristic impedance discontinuities in soft tissues: this information cannot be obtained by any other method. Pulse-echo systems can be arranged to give A-scope and two-dimensional B-scope displays, and recordings of structure movements. Such systems are used routinely in examinations of the brain, the abdomen (including pregnancy) and the heart. They are also being developed to permit computer processing of the ultrasonic signals. Continuous-wave techniques include those based on the Doppler frequency shift of ultrasound reflected by moving structures. Range-gated and directionally-sensitive Doppler systems have been used to study various aspects of blood flow, including the determination of flow profiles.

Holographic techniques and the ultrasonic image camera are being developed, but have not yet been used in routine clinical practice.