Ultrasonic B-Scanning of the Brain*

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ULTRASOUND restricted to one-dimen-sional echo-ranging can provide little information other than the location of a plane reflecting surface. Its value in neurological diagnosis, therefore, is limited virtually to detection of a shift of midline structures of the brain. The purpose of the present paper is to report early experiences with a two-dimensional ultrasonic visualization system, and to discuss the possible uses of this method for more precise demonstration of various normal and abnormal intracranial structures.

The physical principles underlying the use of ultrasound as a diagnostic technique have been presented in numerous reports. Likewise, descriptions of the instrumentation of ultrasonic methods, including those used in this study, are readily available. Therefore, only certain fundamental details essential to understanding the clinical applications of this method will be repeated here.

Sound consists of mechanical vibrations propagated in a medium. Since sound travels in a wave form, it is subject to many phenomena well known in optics, including reflection, refraction, absorption and diffraction. When used for the purpose of delineating an object, the resolving power of sound, as in the case of light, is limited to about 1 wave length. Because the velocity of sound in most soft tissues, including brain, is approximately 1500 m./sec., frequencies well above audibility, i.e., ultrasonic, must be used to achieve useful resolution in these media. For example, with a frequency of 1.5 Mc./sec., the wave length in soft tissue is about 1 mm. and under optimal conditions the depth resolution, i.e., the resolution in the direction of the sound beam, would be of the same order. The higher the frequency used, the better the resolution. Unfortunately, the absorption of sound by tissue also increases rapidly with frequency, making penetration more difficult. The frequencies used for diagnostic work, therefore, represent a compromise between these two factors. Frequencies as high as 18 Mc./sec. have been used satisfactorily for detection of lesions in the eye. In contrast, because bone absorbs much more sound than does soft tissue, frequencies as low as 1 Mc./sec. may be necessary to achieve penetration through the intact skull of some adults.

For diagnostic purposes, pulsed ultrasonic in the shape of a narrow and fairly well defined beam is used. Extremely short pulses, consisting of a train of several waves, are used. Such pulsed beams are produced with a piezoelectric transducer, which is usually in the form of a disc 1 cm. or more in diameter. The transducer is distorted periodically by impressing high-voltage impulses across it; this causes it to vibrate transiently. By means of the opposite effect, i.e., the conversion of vibrations into electrical energy, the same transducer may be used for the detection of ultrasonic waves.

Ultrasonic diagnostic systems in common use depend on the fact that some waves are reflected back towards the source from the interface of two media whose acoustical properties differ. In the brain, for instance, such echoes are produced at cerebrospinal-fluid-brain and white matter-gray matter interfaces. Since the velocity of sound is for practical purposes uniform in soft tissues, the distance of the echo-producing interface from the source of sound is proportional to the time taken for the sound wave to travel from the transducer to the interface and back again. Using techniques largely developed for radar, these measurements of

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mechanically in a direction perpendicular to the ultrasonic beam. The trace is made to move up or down the cathode-ray screen in a corresponding fashion. A two-dimensional picture of the reflecting surfaces is thus formed on the screen and can be recorded photographically (Fig. 1). The end result is somewhat analogous to a roentgen-ray tomogram in that it depicts a cross section in the plane of motion of the beam.

Since all echoes returning to the transducer are displayed along a thin linear trace irrespective of the cross-sectional diameter of tissue in which they were produced, it is readily apparent that the resolution attained in the direction of movement of the transducer, i.e., lateral resolution, is dependent upon width of the beam. With a transducer of a given diameter, the higher the frequency the less the spread of the beam. The fact that absorption increases with frequency therefore limits the degree of lateral resolution just as it does depth resolution. This limitation of B-scanning can be overcome by more elegant methods such as compound scanning in which each interface is visualized from many directions. However, such techniques usually require immersion of the part to be examined in a liquid—a fact that makes their use for the day-to-day diagnosis of intracranial abnormalities impractical.

Equipment and Methods

A commercially built* ultrasonic scanning system was used in this study. This equipment, designed primarily for medical diagnostic work, permits both one-dimensional echo-ranging with A-scope presentation and two-dimensional intensity modulated scanning. Controls are provided to vary pulse damping, peak clipping, beam power, gain, range, and other parameters. Pulse-repetition rate is fixed at 379 pulses/sec. An electronic scale with markers every 2 mm. is provided for measurement of depth. Information displayed on the face of the cathode-ray tube is recorded with a camera on Polaroid film.

The transducer is mounted in the scanner on a swivel at the lower end of a vertical rod which is free to move up or down (Fig. 2). The vertical rod and therefore the transducer are moved back-

* Model 600, Hoffrel Instruments, Inc., South Norwalk, Connecticut.