INVESTIGATION OF THE POSSIBILITY OF LOCAL TREATMENT WITH FOCUSED ULTRASOUND THROUGH PART OF THE SKULL IN MAN AND ANIMALS

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Experiments to visualize the ultrasonic field during passage of focused ultrasound through part of the skull in animals and man demonstrated that the local treatment of brain structures by ultrasound without opening the skull is a possibility.

Several workers [3, 4, 6] have established the possibility and developed techniques for the creation of local foci of destruction and temporary functional changes in structures of the central nervous system by means of focused ultrasound. This is a more promising procedure than others of a similar nature (lasers, focused infrared radiation, proton beams, etc.) and possesses many advantages.

An important defect of methods so far developed for clinical or experimental neurosurgery using ultrasound, preventing the extensive use of this promising method, is the need to have a large trephine hole (up to 10 cm in diameter), which leads to considerable displacement of the brain, thereby complicating the location of its anatomical structures by existing methods.

The object of the present investigation was to study the possibility of treating local brain structures through the closed skull in animals and man with focused ultrasound.

Investigations [3,5] have shown that the resistance of the brain and skull in the living and dead states to acoustic waves differs only very slightly: the geometry of the focal spot remains constant during the spread of ultrasound in the brain, water, or physiological saline [5]. By taking advantage of this fact, the problem has been solved in parts of the skull of human and animal cadavers placed in distilled water. Pieces of skull were taken from animals (not later than 2-3 h after death) and man (not later than 10-12 h after death). The skull was opened under water to prevent air from entering the cancellous layer of the bone.

Visualization of the ultrasonic field was based on the use of Töpler's optical effect. A photograph of the ultrasonic field (without the cranial bones) obtained by this method is shown in Fig. 1.

Radiation with a frequency of 1 MHz was used in the experiments, and the angles of opening of the focusing system ranged from 30 to 70°.

The focal spot was spindle-shaped, 4 mm in diameter and 18 mm long for an opening angle of 30° and 3 and 15 mm respectively for an angle of 70°. By means of this method 200 areas of 90 human skulls from persons aged 18-19 years, 10 areas from 4 dogs' skulls, and 5 areas from 3 cats' skulls were examined.

During passage of the focused ultrasound through the animals' (cat, dog) skull, some distortion of the geometry of the ultrasonic field was observed as the result of variations in thickness of the cranial bone and in the radii of curvature in the region of irradiation, causing displacement of the focal spot from the

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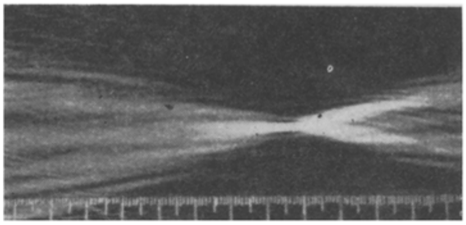

Fig. 1. Photograph of ultrasonic field obtained by means of Töpler's optical effect.

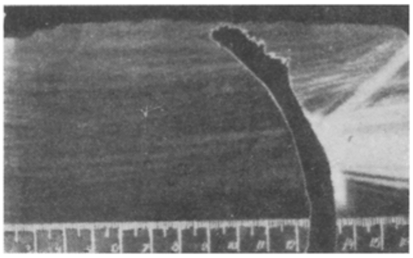

Fig. 2. Reflection of focused ultrasonic beams when the angle of incidence exceeds the limiting value.

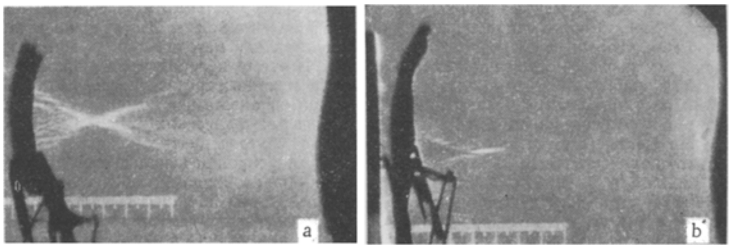

Fig. 3. Passage of focused ultrasound through part of the human skull from a person aged (a) 23 years and (b) 71 years.

theoretical distance, an increase in the size of the focal spot, and sometimes the existence of several foci. However, the human skull shows less severe variations in thickness and curvature of the individual areas, so that areas of irradiation with an approximately constant radius of curvature and thickness could be chosen. When irradiation was given through these areas, no distortion of the field geometry was observed.

The limiting angle of incidence, amounting to 26°, any excess over which led to total reflection (Fig. 2), was calculated theoretically and confirmed experimentally (Fig. 2).*

The essential fact was that the field geometry was unchanged if a layer of brain 40-50 mm thick was placed in the path of the ultrasonic beam. With an increase in the angle of opening, focusing of the ultrasound through the part of the skull was improved.

Ultrasound was shown to pass more readily through the cranial bones from younger subjects evidently because of the wider cancellous layer in them (Fig. 3a), whereas in the older skull (Fig. 3b) the compact layer, in which the water content is smaller, is of considerable thickness [2].

In the older skull there were areas with a reduction in thickness of the bone to 1.5-2 mm. During irradiation through these areas, passage of the focused ultrasound was improved (passage of ultrasound was not observed through museum specimens of bone, kept in the air for a long time, even after prolonged soaking in water). Analysis of the experimental results showed that, in principle, local treatment of the human brain through the skull by focused ultrasound is possible, in principle.

The degree of distortion of the geometry of the focal spot, and also of displacement of the focal zone from the calculated values during passage of ultrasound through parts of the human skull lay within acceptable limits for the neurosurgical and neurophysiological use of this method.

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*The velocity of spread of ultrasound in water was taken as 1500 m/sec, and in bone as 3350 m/sec.

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