USE OF FOCUSED ULTRASOUND FOR LOCAL DESTRUCTION OF BRAIN STRUCTURES WITHOUT DAMAGE TO THE SKULL

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By means of a special technique it is possible to produce local destruction in the deep structures of the brain by irradiation with focused ultrasound through the intact skull. Histological investigations revealed no pathological changes in the brain along the pathway to the lesion, in which a focus of coagulation necrosis was observed.

Operative methods used at the present time to destroy deep brain structures are attended by the need to damage brain tissues along the path to the focus of destruction and with the possibility of postoperative complications.

According to the literature, focused ultrasound can produce local foci of brain destruction without injury to structures on the path to the lesion. The vascular system remains intact in the zone of destruction, which cannot be said for any of the methods used in neurosurgery [4, 6-10]. Another distinguishing feature of ultrasound is its ability (with certain doses of irradiation) to act reversibly on parts of the brain without producing structural changes in the tissue [6, 7]. These properties combine to make the use of focused ultrasound a promising technique in neurosurgery and neurophysiology. As yet the method has not achieved popularity because of the need for trephining large holes in the skull (up to 100 mm in diameter for irradiation of deep structures) where the sound rays enter the brain [9]. Trephining holes of this type is accompanied by severe disturbances of the brain tissue and complicates the use of a stereotaxic method for determining the coordinates of the focus of destruction as a result of the considerable displacements of the brain [2, 9].

The writers' earlier experiments to study a focused acoustic field after passage through different parts of the cadaver skull (opened under water not more than 8-10 h after death) demonstrated that local action on the brain by ultrasound through the intact skull is possible in principle [1].

The object of the present investigation was to develop a method by which local damage can be produced in the depth of the animal brain without injury to the skull. Operations were performed on 20 chinchilla rabbits weighing 2.5-3 kg.

To produce the ultrasonic field a focusing generator with the following parameters was used: frequency 1 MHz, apex angle of ultrasound rays 70°, focal distance 70 mm, focal spot an ellipsoid of rotation 3 mm in diameter and 15 mm long. The intensity at the focal spot in the experiments was 1,500 W/cm^2. Irradiation was given as 3 and 5 pulses, 1 sec in duration, with the same intervals between them. The operations were performed stereotaxically using the coordinate system designed by Meshcherskii [3]. The place of the electrode was occupied by the generator to which was fitted a rubber bag, made of thin elastic rubber 0.1-0.3 mm in thickness, filled with distilled water (Fig. 1). The losses of acoustic energy during passage through the rubber sheet were determined in preliminary experiments and did not exceed 1-3% of the total quantity of energy. Acoustic contact between the rubber bag on the generator and the skull was

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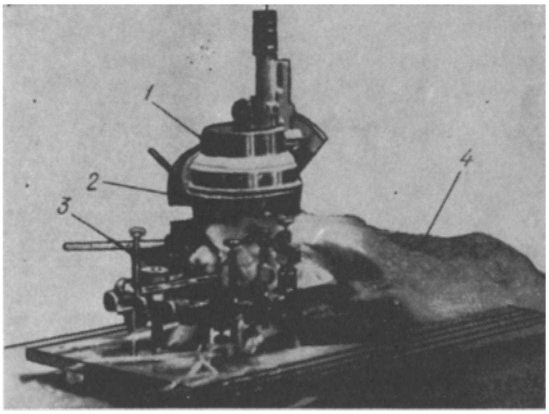

Fig. 1. The use of focused ultrasound in a stereotaxic apparatus: 1) generator; 2) rubber bag filled with distilled water; 3) stereotaxic apparatus; 4) rabbit.

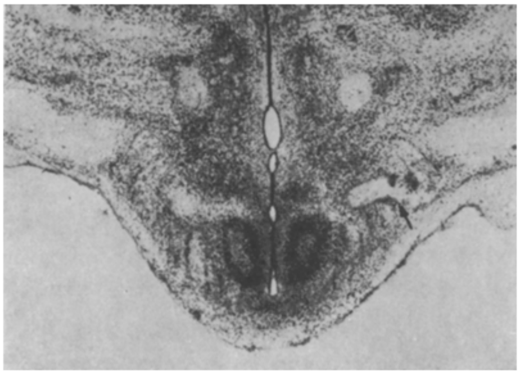

Fig. 2. Focus of destruction in hypothalamic region of a rabbit's brain (arrow), Nissl, 15 ×.

achieved through distilled water or mineral oil, contained in a hollow on the skull formed after removal of an area of skin. To secure better wetting of the skull with water or mineral oil and, consequently, better acoustic contact, the skull in the zone of irradiation was exposed on the day before the operation. During the operations areas of the brain located at a depth of 16-20 mm from the surface of the skull in the region of the hypothalamus and mesencephalon were irradiated [5]. The animals were killed 3-6 days after irradiation.

The brain was extracted from the skull of the experimental animals and examined morphologically. Thin frontal sections were cut and examined in reflected light by means of the MBS-1 stereoscopic microscope with a magnification of 4-8 times (ocular 8, objective 0.6-2). The foci of destruction were located at different levels of the segmental portion of the mesencephalon or in the hypothalamic region. After a single irradiation foci 0.2-1 mm in diameter and 1-3 mm long were observed in the brain. The zone of brain destruction was much smaller than the focal spot of the generator in water [1], presumably because of the considerable losses of acoustic energy during passage through the skull. The foci were elongated in shape, repeating the geometry of the focal spot in water. This showed that defocusing of the sonic beam during passage through the cranial bond was negligible. In the case of repeated ultrasonic irradiation of the brain, when the focal spot in the brain was displaced (by ±0.5 mm) the foci of destruction were elongated in a direction perpendicular to the spread of the sonic waves, showing that foci of destruction of the brain of any desired shape and size can be obtained by repeated irradiation.

Histological investigations of frontal sections of the brain of the experimental animals revealed a focus of coagulation necrosis in the zone of irradiation (Fig. 2). Nerve cells with gross destructive changes were seen in the perifocal zone. The size of the focus of necrosis in a dorso-ventral direction in sections treated with celloidin in both cases was 0.25 mm, and together with the perifocal zone the region of pathological changes extended to 0.85-0.90 mm. No pathological changes could be found anywhere along the path of the sonic waves to the focal spot.

This investigation demonstrates that focused ultrasound can be used in principle to produce local destruction of the deep structures of the brain without injury to the skull.

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