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EXPERIMENTAL BASIS FOR USE OF ULTRASONIC SURGICAL INSTRUMENTS IN NEUROPHYSIOLOGY

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Improvement in surgical techniques and application of the latest advances in science have led to the development of instruments for working with biological tissue, whose cutting edge makes microscopic longitudinal oscillations of ultrasonic frequency, of between 23,000 and 70,000 Hz, with an amplitude of up to 0.1 mm or more [1]. More recently ultrasonic instruments (USI) have begun to be used in surgery. The reason is the many important advantages of USI over traditional instruments: reduction of the force required when working on solid tissues, the fact that they have a hemostatic effect, so that operations can be performed in regions difficult of access, and reduction of operative trauma [2, 3].

The study of the experimental physiological basis of the action of USI on the brain must lead to improvement in existing types of instruments and the development of new ones, and must widen the range of their application in neurosurgery [4, 5]. Meanwhile it is not yet clear what late aftereffects may arise following the use of USI on brain tissue.

The aim of this investigation was to study the results of the action of USI on the functional state of the brain 8-9 days after injury to brain structures.

EXPERIMENTAL METHOD

Chronic experiments were carried out on 11 adult cats weighing 3-3.5 kg. The somatosensory projection area (SI) and the visual area (VI) of the cortex were destroyed by ultrasound or extirpated with the aid of a curette. For ultrasonic destruction of the above projection areas, an experimental ultrasonic neurosurgical system, developed at the Department of Neurosurgery, Central Postgraduate Medical Institute, in conjunction with the Acoustic Institute, Academy of Sciences of the USSR, was used.

Electrodes were first inserted into the animals (under pentobarbital anesthesia, 40 mg/kg) under aseptic conditions into the following cortical and thalamic structures: symmetrical area SI and VI of the intact hemisphere; the parietal region (P) of both hemispheres, bilaterally into the thalamic nuclei — the specific nucleus ventralis posterolateralis (VPL), the specific optic nucleus — the lateral geniculate body (LGB), and the association nucleus lateralis posterior (LP). Evoked potentials (EP) were derived by a monopolar technique and subsequently averaged on an APT-1000 analog computer. Peripheral stimulation was carried out unilaterally. The skin of the forelimb was stimulated by electrical discharges (19-20 V; 0.5 msec) and flashes from an FS-02 photostimulator (0.3 J, 0.05 sec) also were used. After the end of the experiment the animals were killed, the brain was fixed in 10% formalin solution, and after postfixation in alcohols, paraffin blocks were made and sections cut to a thickness of 20 μ, and stained by Nissl's method.

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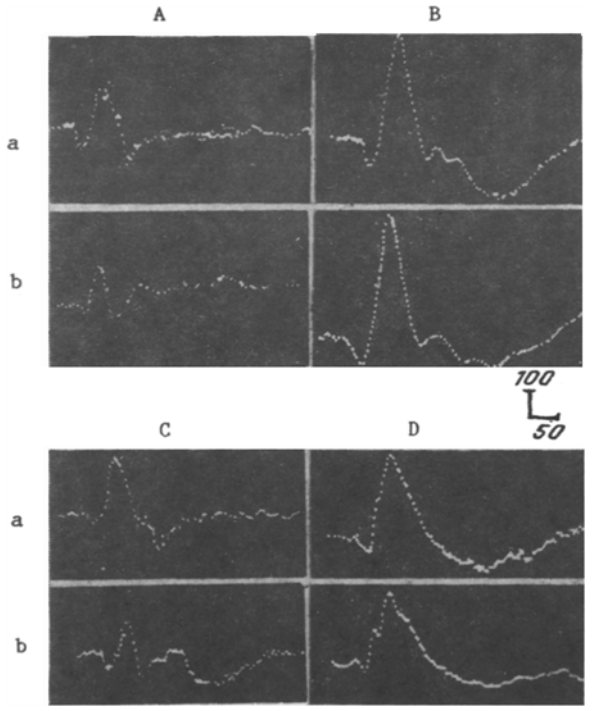

Fig. 1. EP in parietal cortex and nucleus LP on 7th day after extirpation of visual area VI of the opposite hemisphere. A) Before injury; B) after disintegration by USI; C, D) before and after extirpation by curette. a) Parietal cortex, b) nucleus LP. Calibration: 100 μV; 50 msec.

In six animals areas SI and VI were subjected to disintegration by USI or to mechanical extirpation (curette) without preliminary insertion of electrodes. These animals were killed 8-9 days after removal of the projection areas, and then underwent morphological investigation as described above.

EXPERIMENTAL RESULTS

A study of the electrical responses of the brain structures revealed both similarities and differences in the course of the recovery period after injury by USI and extirpation by curette. Both procedures were followed by a biphasic pattern of recovery: reduction of electrical activity for 2-3 days in cortical and subcortical structures followed by an increase, above the original level, in structures of the opposite, intact hemisphere: in the cortical and subcortical association structures (parietal cortex and nucleus LP) and in zones symmetrical to the site of injury. Electrical responses stabilized at the new, elevated level, by the 8th-9th day.

The difference between the two types of injury consisted of differences in the degree of enhancement of evoked responses in structures on the intact side of the brain. For instance, after disintegration of visual area VI by USI, on the 7th day of the recovery period the negative phase in responses of the parietal cortex of the intact hemisphere was increased by 2.2 times (Fig. 1, A and B, a); in responses of nucleus LP it was increased by 2.4 times (Fig. 1, A and B, b). After mechanical extirpation by curette the amplitude of EP in structures on the intact side of the brain was increased by a lesser degree. The negative wave of responses of the parietal cortex of the intact hemisphere on the 7th day of the recovery period was increased by 54-55% (Fig. 1, C and D, a), whereas in the nucleus LP it was increased by 43-44% (Fig. 1, C and D, b).

To analyze the character of damage to brain tissue produced by the two types of procedure, morphological investigations were undertaken. A study of the brain of cats whose cortical projection areas had been extirpated mechanically by means of a curette revealed extensive necrosis of brain tissue around the edges of the wound, forming a background for multiple

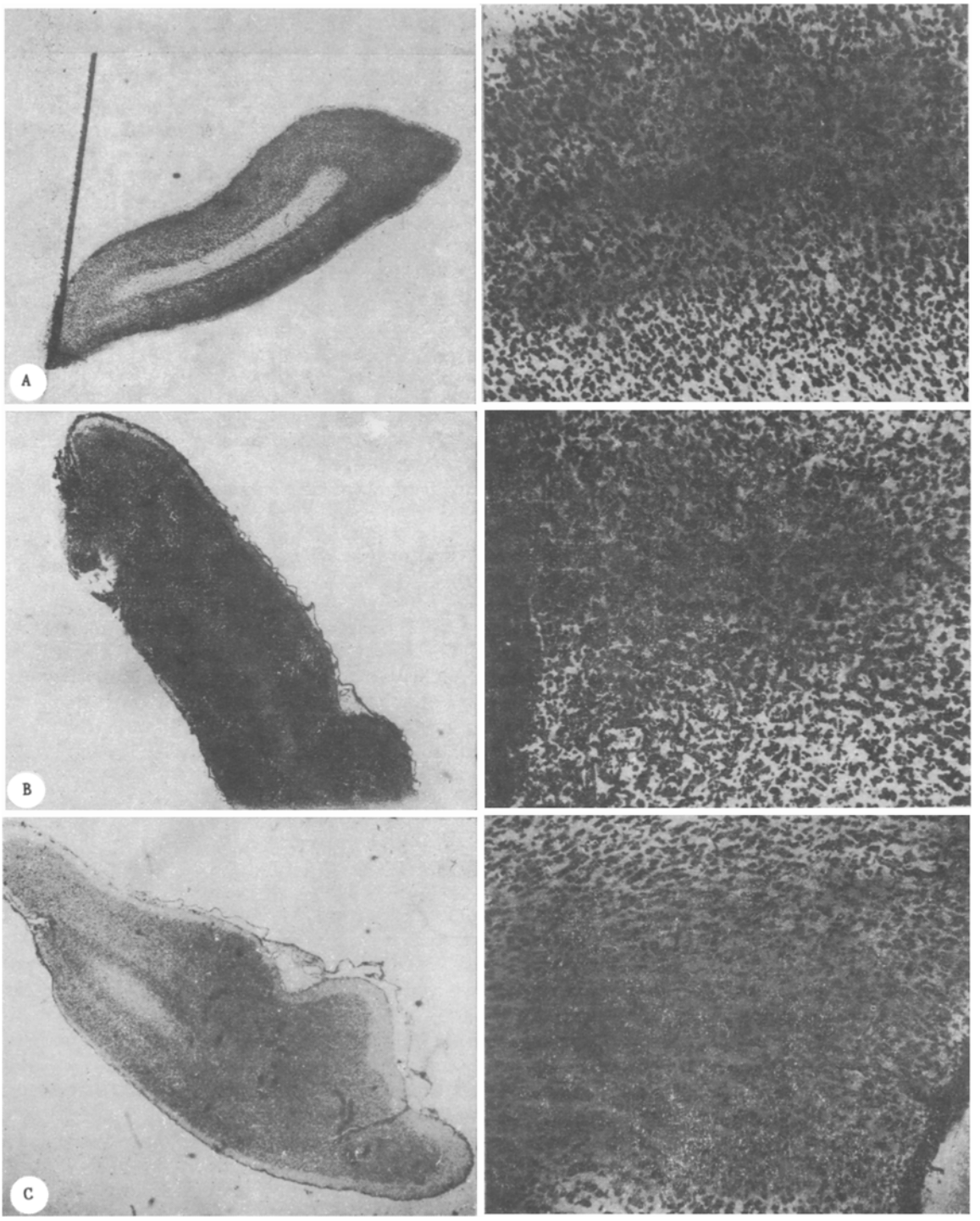

Fig. 2. Morphological changes in brain tissue after extirpation of cortex (area 17) by USI and by curette. A) Unchanged brain tissue; B) after extirpation by curette; C) after injury by USI. Magnification: 10 ×; 400 ×.

hemorrhages (Fig. 2B). Spherical granules were densely distributed in the thickness of necrotic tissue. The response of the astrocytes was productive in character, hyperplasia of the astrocytes being most marked around the wound. Close to the wound cortical cells showed hydropic changes, and were distinguished by their hyperchromic staining. Signs of chromatolysis were observed in the nerve cells. The zone of injury extended as far as the third layer of the cortex. Disturbance of the architectonics of the neocortical layers adjacent to the wound was found.

Examination of brain preparations from cats whose cortical areas were removed by USI revealed a much smaller area of necrotic tissue around the wound edges than after mechanical extirpation of the brain substances (Fig. 2C), single small and large spherical granules were distributed in the necrotic tissue, blood vessels were dilated and filled with blood, but unlike the picture observed after extirpation by curette, no extensive hemorrhages could be seen (Fig. 2C). After disintegration by USE, the nerve cells characteristically exhibited moderate hyperchromic staining, whereas after extirpation by curette, hyperchromic staining was intensive. Occasionally cells with partial segmental chromatolysis of their basophilic substance were seen. The productive reaction of the astrocytes was less marked and was less frequently observed than after extirpation of the cortex by curette. After extirpation of the cortex by USI, injury to the cortex was more local than after extirpation by curette, and it extended as far as layer 5 (Fig. 2C); moreover, the architectonics of the adjacent layers of the neocortex was not disturbed.

Electrophysiological investigations during the recovery period after the different types of injury revealed different degrees of increase of the amplitude characteristics of EP in the brain structures studied. The amplitude responses in structures on the intact side of the brain was increased much more after extirpation by USI than after extirpation of the projection area of one hemisphere by curette. This unequal degree of augmentation of electrical responses in the period of respiration of CNS functions can be explained by the much lesser degree of damage to the surrounding brain tissue in the case of extirpation of the projection area by USI. The less traumatic effect of USI on brain tissue than of other methods was demonstrated by other workers who studied electrophysiological responses at the time of action of USI on the brain [1, 6]. Because of the reduced trauma to surrounding brain tissues associated with ultrasonic removal of the cortical area, processes aimed at restoring integrative activity of the CNS can develop faster and more actively in the residual brain structures.

Analysis of the results of the morphological investigation revealed the more local and less traumatic action of USI on brain tissue when compared with extirpation. The reaction of the brain substance to destruction by USI is less extensive and more reversible than that to extirpation by curette, which indicates that the procedure is more physiological. Similar changes also have been found by other investigators [7].

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