METHODS

THE CHOICE OF MATERIALS FOR BURIED ELECTRODES USED IN NEUROPHYSIOLOGY

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Despite the wide use of the method of buried electrodes, the literature concerning the morphology of this subject is small and contradictory. Some authors [11] consider that when electrodes remain in the brain for long periods only a slight neuroglial reaction takes place or there is no reaction whatever of the brain tissue. Others [1,4-6] have observed death and deformation of nerve cells, gliosis, and the formation of a connective-tissue capsule around the electrode. It has been found that if a capsule is formed, the amplitude of the recorded biopotential gradually falls [5]. In addition, Hild, Chang, and Tasaki [14] found in tissue culture, and Chang and Tasaki [15], in vivo, that the neuroglial reaction observed after implantation of electrodes modifies the pattern of the bioelectrical activity, for the astrocytic neuroglia is itself a source of slow electrical responses. Similar conclusions were drawn by Galambos [13].

Hence, two opposite views are held on the morphological changes in brain tissue associated with the use of buried electrodes.

The morphological changes in brain tissue associated with the use of buried electrodes have been described by A. B. Kogan [5], M. M. Aleksandrovskaya [1], and others, but these authors did not compare the histopathological changes in the brain tissue associated with the use of different electrode materials.

Various metals are used in neurophysiological investigations. The tolerance of brain tissue to some of them (silver, tantalum, zirconium) has been investigated by Bates and co-workers [8], and by Collias and Manuelidis [9]. The choice of metals for making the electrodes was the subject of an investigation by Fischer and co-workers [12]. They found that copper and silver are toxic to brain tissue. Zirconium, tantalum, and stainless steel produced no significant reaction in the brain tissue.

The choice of insulating material has been the subject of one or two investigations, but only a paper by Fischer and co-workers [12] gives a morphological assessment of the effect of certain insulating materials on the brain tissue. They found that the histopathological changes produced in the brain tissue are very slight.

However, these investigations are probably unknown to the majority of workers, because silver, Constantan, and other metals are used for making electrodes.

The author has made an experimental study of the reaction of brain tissue to the implantation of certain metals used for making electrodes. The different opinions on the morphological changes observed following the implantation of buried electrodes are evidently due to the fact that different authors have used different materials. Delgado [10], for example, made electrodes of stainless steel, A. B. Kogan [5], of silver, and M. M. Aleksandrovskaya [1], of Constantan.

EXPERIMENTAL METHOD

Experiments were carried out on 83 rabbits. The materials were implanted by the method of A. B. Kogan [5]. Pieces of wire 11-13 mm long and 0.2-0.3 mm in diameter were used. The animals were sacrificed at various times, 10, 20, 30, 60, and 90 days after the operation. Serial sections of the brain in the region of implantation were investigated (stained with hematoxylin-eosin, and by the methods of Nissl, Mallory, and Foot). Sections at the same level were compared.

The reaction to implantation of silver, stainless steel, Constantan, and "Elzhilloi" alloy* was studied. Tinplated copper electrodes† also were implanted. The reaction to the insulating materials: polyethylene, enamel,

*K40NKhM – a highly rust-resistant alloy invented in the Soviet Union.

†Other metals (silver) may also be tinplated, but under the microscope it is difficult to verify the quality of the tinplating, because these metals are the same color as tin.

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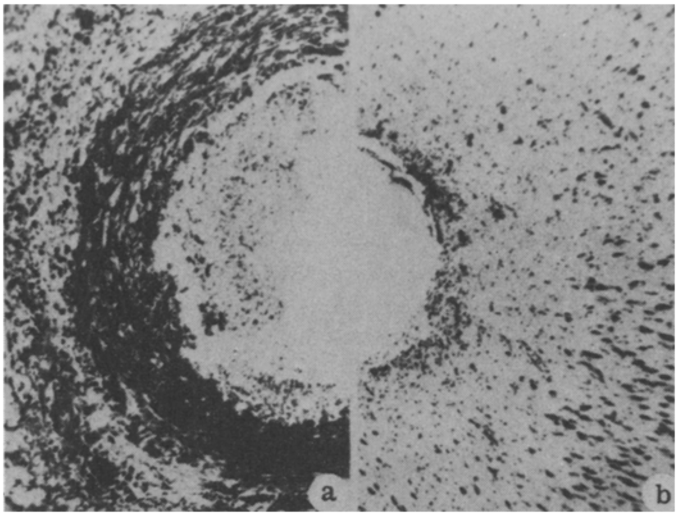

Fig. 1. Reaction of brain tissue to implantation of silver (on the left) and tinplated (on the right) electrodes. Diameter of electrodes 0.2 mm. Observation continued for 30 days. Stained by Nissl's method. Objective 90, ocular 7.

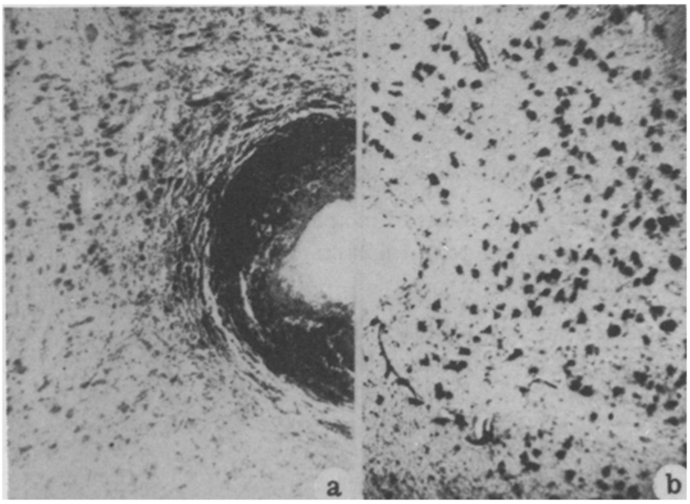

Fig. 2. Reaction of brain tissue to implantation of Constantan (on the left) and stainless steel (on the right) electrodes. Diameter of electrodes 0.3 mm. Observations continued for 30 days. Stained by Nissl's method. Objective 90, ocular 7.

Metalvin (a varnish possessing good electrical insulating properties and resistance to chemicals and heat), and Teflon (a macromolecular compound with high dielectric properties, practically resistant to all solvents, with no change in its properties in the range from 100 to 250°). The Teflon investigated was of the normal commercial quality, but the polyethylene was purified.

EXPERIMENTAL RESULTS

From the 10th day after the operation, a response reaction of the brain tissue was observed to implantation of the electrodes, and this depended on the character of the implanted material.

After implantation of silver electrodes, well marked histopathological changes were found in the brain tissue (Fig. 1). The defect in the brain tissue was larger than the diameter of the implanted electrode. Around the defect

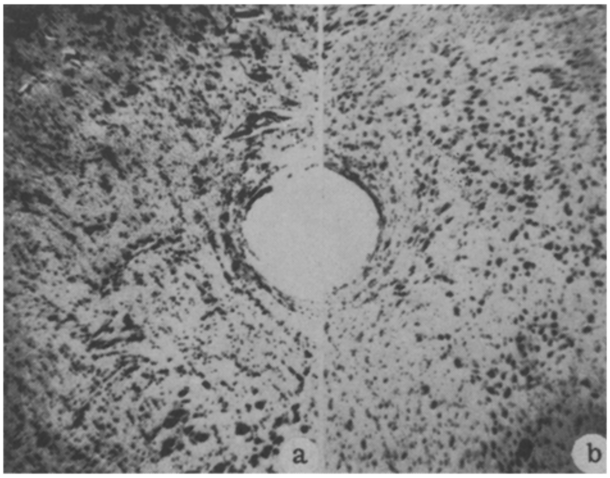

Fig. 3. Reaction of brain tissue to implantation of Teflon (on the left) and polyethylene (on the right). Diameter of electrodes 0.26 mm. Observations continued for 30 days. Stained by Nissl's method. Objective 90, ocular 7.

many leukocytes and granulocytes were found. Microscopic examination enabled three zones of morphological changes to be distinguished. In the innermost zone, the nerve cells were in a state of cytolysis. A considerable reaction of all the neuroglial elements was observed. In the next zone, nearer the periphery, many cells of connective-tissue origin of different stages of maturity were seen, and they formed concentric bands. The blood vessels were dilated and congested. Next followed the third zone, in which the degenerative changes in the nerve cells and the proliferative reaction of the neuroglia diminished as the distance increased from the track of the electrode. At the end of the first month, a capsule of argyrophilic and collagen fibers could be clearly distinguished around the electrode.

After implantation of Constantan, three zones of morphological changes again could be distinguished, but the destructive changes were more severe than after the implantation of silver (Fig. 2).

When Elzhilloi alloy and stainless steel were used, the defect in the brain tissue was equal to the diameter of the electrode. The reactive changes were very slight in intensity and took the form of moderate proliferation of neuroglial cells. The nerve cells remained intact, apart from one or two which showed signs of degeneration. No connective-tissue capsule formation was observed (Fig. 2).

The tinplated copper electrodes caused an extremely slight response reaction affecting the neuroglia*. The nerve cells remained intact. The diameter of the electrode and the width of the defect in the brain tissue were identical (Fig. 1). No connective-tissue capsule was formed.

After implantation of insulating materials, the morphological changes were roughly the same. The size of the defect in the brain tissue corresponded to the diameter of the electrode. The nerve cells remained intact, and only a slight neuroglial reaction was observed to implantation of the electrode. No connective-tissue scar was formed around the electrode (Fig. 3).

The least marked morphological changes in the brain tissue were seen after implantation of Elzhilloi alloy, tinplate, and stainless steel (type EYaIT)†. Minimal changes were observed after implantation of Teflon, enamel, Metalvin, and purified polyethylene. Considerable destruction and necrosis of brain tissue followed by the formation of a thick capsule took place when electrodes made of silver and Constantan were used.

For making electrodes to be used in chronic experiments, Elzihilloi alloy, stainless steel, and tinplate are recommended. Silver and Constantan should not be used for making electrodes. The choice of insulating material is determined by the function of the electrode. The author prefers Teflon insulation, because this substance possesses good electrical insulating properties and can be sterilized by simple oiling or autoclaving. Provided that the integrity of the insulation is verified, the electrode can be used repeatedly.

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*Copper electrodes produced morphological changes comparable with the reaction to Constantan.

†A similar reaction was observed when thin stainless steel injection needles were used.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of the first issue of this year.