HISTOPATHOLOGICAL CHANGES PRODUCED BY IMPLANTED ELECTRODES IN CAT BRAINS

COMPARISON WITH HISTOPATHOLOGICAL CHANGES IN HUMAN AND EXPERIMENTAL PUNCTURE WOUNDS*

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With the introduction of the Horsley-Clarke stereotaxic instrument in 1908, a method became available for the investigation of the physiology of the central nervous system which has the advantage of precise localization to specific structures. Implantation of electrodes provided neurophysiologists with a useful method in studying neuronal mechanisms. With the development of the chronic electrode technique by Loucks and its wide application in animals by Hess, it became possible to study the relation of functions to structures of the nervous system in animals avoiding anesthesia, chemical restraint and extensive trauma. This technique has been further extended recently to humans suffering from neurological and psychiatric diseases.

One of the questions that has arisen out of the technique of implanting electrodes, and which has stimulated the present work, is the extent and the amount of tissue destruction and reaction caused by the insertion of electrodes into brain tissue and the effect of the prolonged presence of such a foreign body. This problem has assumed paramount importance since features of this destruction must be kept to a minimum if analyses of the physiologic results are to be meaningful, particularly in reference to possible residual damage in humans.

Although of prime importance to investigators, a review of the literature has failed to reveal a detailed chronological study of the finer microscopic changes in the central nervous system that take place consequent to implanted electrodes. The neurophysiological literature contains a paucity of detailed histopathological examinations of sacrificed experimental animals. Many investigators have described the pathology in such general and non-descriptive statements as a "slight," "moderate," or "mild" gliosis for varying distances around the electrode track, while others have given no account of the histopathological characteristics of the electrode tracks and surrounding tissue. Fisher and Sayre found evidence in studies on animals that the reaction around the electrode may occur within 1 mm. from the track. Dodge et al. have recently reported minimal microscopic changes in 1 human 19 months after intracerebral electrography.

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In view of the lack of chronological studies concerning the extent of mechanical destruction and reaction caused by implanted electrodes in the brain, it was felt that it would be both interesting and rewarding to investigate this problem in animals sacrificed after varying time intervals. It is planned to compare the data obtained in this experiment with studies reported in the literature dealing with puncture wounds of the brain in both humans and experimental animals.1,15,19,20,25,31,32

MATERIAL AND METHODS

Construction of Electrodes. The electrodes employed were of the multilead type described by Delgado.9 Enameled stainless steel wire 0.005 inch in diameter was used. Tension was applied to 3 feet of wire to detemper it and pieces 3 inches in length were cut. The enamel was removed from the tips for 1 mm. Six wires were bound together with liquid Plexiglas with the tips approximately 2 mm. apart. Care was taken to get the surface as smooth as possible. The tip of the lead electrode was balled. The outside diameter of the electrode along that portion that entered the brain measured no more than 0.6 mm. The electrodes were washed with soap and water and sterilized in 1:1000 Zephiran solution for 1 hour prior to insertion. They were then washed thoroughly with sterile physiological saline immediately prior to insertion.

Operative Procedure and Implantation of Electrodes. Healthy adult cats (1.8 to 3.6 kg.) were used as experimental animals. The Horsley-Clarke33 stereotaxic instrument was used for the placement of the electrodes. Aseptic technique was used throughout the procedure. Nembutal anesthesia was employed.

The hippocampal, caudate, mammillary, and septal regions were chosen as sites for implantation. Two electrodes were placed in each animal, one in each cerebral hemisphere. Those animals that had a hippocampal electrode on one side had a mammillary electrode implanted on the other. Septal and caudate electrodes likewise were implanted in the opposite hemisphere of the same animal.

Postoperative Course. Postoperatively the experimental animals were kept in cages with the electrodes in place until the time of sacrifice. All the animals, except for the 2 that died, remained in apparently healthy condition. The skin over the head usually remained dry and growth of hair was normal in the chronic animals. No antibiotic or sulfonamide powder was applied locally and no systemic antibiotic was given postoperatively. Local suppuration occurred minimally.

Sacrifice of Animals (Table 1). The acute animals were sacrificed at intervals of 24 hours, 3 days, and 7 days postoperatively. Chronic animals were sacrificed at intervals of 15 days, 1 month, 2 months, 4 months, and 6 months postoperatively. Two animals were included in each stage. It was hoped to include 1 cat with hippocampal and mammillary electrodes and 1 with septal and caudate electrodes in each stage. However, this was not possible because of the premature deaths of some animals. Only 1 animal is included in the 3-day and 4-month stages, because of the premature deaths of the other animals. All animals were sacrificed by first anesthetizing them and then perfusing them through the heart with bromformal solution. The electrodes were carefully lifted out of place. The skull was opened and the brain was removed and placed in bromformalin immediately.

Histological Techniques. After suitable fixation, frozen sections were cut at 20 micra through the longitudinal axis of the electrode track, using the method described by Marshall.17 Sections from each brain were stained by the following meth-