TOXIC EFFECTS OF INTRA-CEREBRAL ELECTRODES*

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Abstract—Histological evidence is quoted which shows that certain metals are toxic when implanted deep within the brain. EEG evidence is presented showing widespread abnormal EEG activity caused by intra-cerebral silver electrodes.

1. INTRODUCTION

Recent correspondence in this Journal (Volume 3, p. 447 and Volume 4, p. 299) has revealed disagreement and misunderstanding about the chemical effects of electrodes when placed on the surface of, or implanted within, the brain for long periods. The purpose of this communication is to present evidence of brain reaction to the surgical introduction and chronic implantation of some different metal electrodes within the brain.

Depth and surface cerebral electrodes have been widely used in animal experimentation, the objects of which have been to further the understanding of brain function and behaviour and its modification by drugs. In man, intracerebral electrodes have been used for the investigation of epilepsy and other illnesses and in the treatment of psychiatric illness (Crow et al., 1961 and others).

In the investigation and treatment of patients we are all bound by a basic principle, primus non nocere—i.e. we must not hurt or endanger the patient more than is necessary for the best treatment of his ailment. In the scientific field we often find that conditions are disturbed by investigation. The effects of indwelling and cortical electrodes on the cerebral tissue with which they are in contact are therefore of great clinical and scientific importance.

The choice of electrode metal is determined by the electrical and mechanical properties desired for the particular use, and by possible toxic effects which might give rise to injury and misleading information.

The most common use of intra-cranial electrodes is to record the electrical activity of brain tissue. Study of the electrical characteristics of various metals shows that chlorided silver and copper are very satisfactory for this purpose but that silver, gold, platinum and stainless steel attenuate the very low frequencies and make d.c. recordings very difficult (Cooper, 1962). Thus from this point of view silver-silver chloride and copper are very desirable. However, these considerations have to be balanced against the toxic effects of these metals when implanted in brain tissue for periods longer than one or two days.

Fischer et al. (1957) investigated the histological reaction of silver, copper and stainless steel electrodes when implanted in the depths of the brain of cats for from one day to six months. Robinson and Johnson (1961) repeated this work and extended it to include gold, platinum, tungsten and tantalum.

Fischer et al. conclude: “Silver and copper are unsuitable materials for depth electroencephalography from the standpoint of safety, because they cause obvious damage which by itself may influence the accuracy of the recording. The inertness of stainless steel makes it the

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ROBINSON and JOHNSON summarize their paper thus, “Cat brains were implanted with like groups of metal rods, 125 μ dia. Stainless steel and gold rods caused the least tissue reaction over the experimental period of 6 months while platinum and tantalum rods caused a slightly larger lesion. The lesions resulting from tungsten rods were comparatively more extensive in that a heavier capsule was formed and the area of reaction was larger. Silver rods elicited a violent brain response as evidenced by toxic effects such as necrosis, edema, demyelinization, and the presence of many macrophages in the area of destruction. The greatest reaction to silver was observed in a brain with rods implanted 7 days. The reactive zone, as observed on H and E sections, extended to 2 mm dia. The astrocytic reaction, demonstrated with gold sublimate stain, extended to 3.75 mm. The evidence indicates stainless steel and gold are preferred metals for intra-cerebral electrodes from the standpoint of tissue reaction”. The reaction to silver (and silver-silver chloride) was not obvious after the first day, was maximal at the seventh day, and there were still some signs of reaction after a month.

COLLIAS and MANUELI DIS (1957), examining the histological brain reaction in cats, concluded that a stainless steel electrode, implanted from 1 day to 6 months, evoked little more reaction than one would expect from an uncomplicated puncture wound of comparable size.

2. CLINICAL OBSERVATIONS

At about the time when the first of these papers was being published we started using chronically indwelling electrodes for treatment of psychiatric illness. Sixty stainless steel electrodes (0.004 in. dia., 100 μ), in 10 bundles of 6 electrode wires, were implanted in the frontal lobes of the first patient. The trauma associated with implantation was slight and no abnormalities of the EEG were noted during the month of implantation. Coagulation produced good relief of symptoms for several weeks but the patient relapsed. It was then found that stainless steel electrodes of the size used could not pass the increased coagulation currents, which were thought necessary to provide long lasting relief of symptoms, without eroding and going into solution. A second implantation was therefore carried out using fine silver wire (99.9 per cent purity). The patient made a rapid recovery from the insertion of the wires, and the EEG had become normal at the end of the fourth post-operative day (Figs. 1 and 2). On the eleventh post-operative day the patient was confused in an organic way, disorientated in time and had a very poor memory for recent events. She was incontinent of urine. The EEG (Fig. 3), shows gross dysfunction throughout both frontal lobes with widespread low frequency activity supplanting the natural EEG rhythms. The acute dementia persisted for about a week then slowly regressed but it was 4 to 5 weeks before she appeared to be completely recovered. The EEG was improved but still showed an excess of low frequency activity even after 3 months (Fig. 4).

Silver electrodes were also implanted in another patient on the day following the second implantation described above. This patient also developed a notable degree of dementia, with accompanying EEG signs of the same type and time course as the first patient.

3. CONCLUSION

Since that time 40 patients have each had around 60 stainless steel or gold electrodes implanted in their brains for periods ranging from 2 to 8 months without any similar disturbances.

The evidence, both from our own experiences and the histological findings of others, demonstrates that a silver electrode, when chronically implanted within the brain, produces a toxic necrosis around itself, and when multiple can cause gross clinical signs and EEG abnormalities for at least a month.

We believe that the severe neuro-toxicity of silver, when in direct contact with the brain, is established. Whether or not it has a modified,