Reversible Heat Lesions with Radiofrequency Current

A Method of Stereotactic Localization

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When the surgeon places a stereotactic electrode into the structure of a cerebral target, he must be aware constantly of the possibility of directing the probe into the wrong location. Such errors can arise easily because of the variability in the relationships between the area of the target and those landmarks with which the surgeon orients his probe. Hence it is imperative to have some check on the final position of the electrode before it is used to produce the definitive lesion. Various physiologic techniques have been applied to this problem. One approach has been to stimulate through the stereotactic electrode before using it to destroy the area of the target. Although many areas produce no observable response when stimulated, this method does have the advantage that one can estimate the proximity of the electrode to certain excitable structures such as the internal capsule. Another approach to this general problem has been the tactic of reversibly blocking nervous conduction through the region of the target. Various techniques have been used to accomplish these ends, including local injections of anesthetic agents, inflating balloons, and local applications of cold.

Since our group has long used radiofrequency power to produce lesions of the central nervous system, the question arose as to the feasibility of using moderate amounts of radiofrequency power to reversibly block nervous conduction in a site proposed for permanent destruction. The use of reversible heat lesions produced in such a fashion would greatly simplify operative technique while sacrificing none of the features of safety associated with reversible cold blocks, the technique we have used previously.

Materials and Methods

Twenty-four adult cats were used in these experiments, each being anesthetized with 35 mg. Nembutal per kg. and supplemented when necessary. The cats were fixed in a Kopf stereotactic apparatus for both the experiments on the central nervous system and those on peripheral nerve. Jasper and Ajmone-Marsan's atlas was used to locate points in the nervous system and the brains were saved following the experiments to provide a control for the placement of electrodes. Radiofrequency current was produced with the generator described by Aronow.

For the experiments on the 3rd-nerve (Edinger-Westphal) nucleus, radiofrequency current was led through a probe 1.5 mm. in diameter, insulated except for 5 mm. at the tip. Temperatures were monitored with either a thermocouple registering on a polygraph or a thermistor reading directly, these being attached to the probe with the tips 1.5 mm. apart. Permanent records of the pupillary changes were made photographically on Polaroid film.

The experiments on the internal capsule used a probe of the same type with the addition of a bipolar stimulating electrode also fixed to the probe. Stimuli were produced with a Grass S4 stimulator equipped with an isolation unit. When the responses to stimulation were movements of whiskers, permanent records were made with a motion-picture camera. When movements of the jaw were obtained, records were made with an accelerometer attached to the jaw and recorded on a polygraph.

For the experiments on peripheral nerve, the femur was fixed allowing free movement of the

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distal leg and these movements were recorded with an accelerometer. The sciatic nerve of that leg was stimulated with a bipolar electrode using the Grass S4 stimulator with stimulus-isolation unit. Proximal to the point of stimulation, the nerve was crushed; between the point of stimulation and the gastrocnemius muscle, the nerve was heated, the temperatures being monitored with a thermistor. Heat was provided in one of two ways: either warm water was forced by air pressure through a 15-gauge hypodermic needle bent so as to loop around the nerve or radiofrequency current was passed through the same hypodermic needle.

Results

The results are complicated by the fact that after a number of experiments had been completed and analyzed, it was found that there were certain inconsistencies. Upon investigation it was determined that the output of the radiofrequency generator passed through a voltmeter and that this arrangement produced a direct current. Several tenths of 1 mA were present when the radiofrequency generator was merely connected to the animal but not yet turned on. This direct current then increased, as the radiofrequency current was activated, to a maximum value in the order of 1 mA. Putting a capacitance in the output of the generator of the lesions solved this problem by eliminating the direct current. The experiments were repeated and consistent results were then obtained.

Peripheral Nerve. Fig. 1 shows the record of a typical experiment in which the motor fibres of the sciatic nerve were blocked reversibly with heat; that is, by running warm water through a coil near the nerve. The smaller size of the twitch following the heating of the nerve as compared with its size just before heating was a rather constant feature. The gradual return in conduction after heating occurred consistently. The temperature at which reversible block was achieved in like experiments varied between 40° and 45°C. Fig. 2 is taken from the same experiment a few minutes after the first record was made. This time, instead of hot water being used to heat the coil next to the nerve, radiofrequency current was led through the coil. However, when this record was made, there was still a direct current in the output of the radiofrequency generator. The temperature which was measured when the block occurred in this case was considerably lower than that when heat was produced by hot water. Furthermore, the onset of the current was marked by the sudden diminution in the size of the twitch and the twitch returned immediately as soon as the current was discontinued. Fig. 3 is taken from a different experiment and shows that the effects of radiofrequency current with no component of direct current are quite comparable to those produced by passing warm water through a coil next to the nerve. The block in this case occurred at 42.5°C, and became manifest and disappeared gradually.

Third-Nerve Nucleus. Fig. 4 shows the effects of heating the Edinger-Westphal nucleus to the point at which pupillary dilation occurs. In most cases, although not invariably, the pupil first constricted at about 2 degrees below the point at which it began to dilate. Needless to say, the temperatures required to produce these effects depended upon the distance between the electrode and the nucleus. In 4 animals in which blocks were produced with radiofrequency

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Fig. 1. Reversible heat block of sciatic nerve. Stimulus = 4 V. Duration = 1 msec. Frequency = 1/sec.

Fig. 2. Reversible block of sciatic nerve with radiofrequency current and DC component. Stimulus = 4 V. Duration = 1 msec. Frequency = 1/sec. Note: a) Low temperature at which block occurs. b) Sudden diminution in size of twitch with onset of current. c) Immediate return of twitch when current is stopped.

Fig. 3. Reversible radiofrequency block with no DC component. Stimulus = 0.5 V. Duration = 1 msec. Frequency = 1/sec. Note the similarity to pure heat block and difference from Fig. 2.