Experimental Temperature Control of Radiofrequency Brain Lesion Size*

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The production of discrete, reproducible lesions in nervous tissue is one of the requirements of stereotaxic surgery. Radiofrequency power has been used for this purpose with considerable success and is an accepted technique in human stereotaxic procedures.

Percutaneous cordotomy, introduced by Mullan, et al., has extended the benefits of long-term pain relief to many patients previously considered unsuitable for such procedures because of debility. Radiofrequency current has been used recently to produce the lesions in the spinothalamic tract and allows discrete lesions to be made in a consistent manner.

The lesion needed to achieve pain relief by destruction of the spinothalamic tract is considerably smaller than that needed for stereotaxic thalamotomy. Lesion size is of prime importance in percutaneous cordotomy because the corticospinal tract and the anterior spinal artery are in the immediate vicinity. Destruction of those structures can lead to paralysis or death.

The use of rf current for percutaneous cordotomy has rekindled interest in its properties, safety and, most of all, its reproducibility. The last quality is dependent upon adequate control of lesion production. We have attempted to find the most reliable means for controlling the size of small lesions in nervous tissue produced by radiofrequency current.

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Methods

The electrode used for the experiment was constructed from a 20-gauge (0.036 inch) stainless steel tube measuring 12 cm in length and insulated with epoxylite§ in both its inner and outer surfaces except for the distal 2 mm on the outer surface (Fig. 1). The distal edge was filed, and the thermistor bead was cemented to the tip, plugging the open end and providing a smooth rounded tip. The contour of the finished electrode was elliptical. The temperature response curve of the thermistor was measured in saline. At 65°C the accuracy was 97%. The radiofrequency generator employed an ac power supply capable of emitting continuous sine waves at a frequency of 2 million cycles/sec.** The indifferent electrode consisted of an 18-gauge needle inserted into the temporalis muscle.

Eight dogs were selected for study. They were anesthetized with intravenous pentobarbital and secured to the stereotaxic apparatus.*** An extensive craniotomy was performed on each side and the dura opened widely. The exposed brain was protected by cottonoids and frequent saline irrigations. The site for each lesion was in the center of a gyrus, away from a sulcus or any large pial vessel. The active electrode was inserted perpendicularly through the pia to a depth of either 2 or 4 mm in an attempt to place the lesion either in the gray or white matter of the brain. When the electrode insertion itself produced gross bleeding, a lesion was not made.

Wattage was increased at a regular rate to bring the tip temperature to 65°C within 5 sec. During that period, voltage and amperage were higher than during the remainder

§ Methylon 75108-No. 6, G.E. Chemical Materials Department, Pittsfield, Massachusetts.
** Model RFG-2, Radionics, Inc., Burlington, Massachusetts.
*** David Kopf Instruments.
lesion. When it did not do so, the lesion was clearly demarcated from the surrounding tissue by changes in color, architecture, and consistency. Lesions that were hemorrhagic, poorly outlined, or in which a representative section through the center could not be obtained, were discarded.

**Results**

A total of 122 radiofrequency lesions were acceptable for study. The 2- and 4-mm depth lesions were combined into one group of observations as the difference in depths did not clearly separate them into lesions purely in the gray or white matter.

As seen from the surface, the gross lesions were discrete. They were characterized by an electrode tract at the center and were individually outlined by a bluish ring. The lesions were often mottled and slightly firmer than normal tissue. The deeper lesions did not always show the surface discoloration.

On sagittal section the lesions appeared as ovoid to rounded areas of coagulation corresponding roughly to the shape of the electrode tip (Fig. 2). Three zones were distinguishable grossly: a central core of dense dead tissue representing the electrode tract, a wide zone of coagulation necrosis, and a peripheral zone of liquefaction. There was no charring of the tissue, and in some cases architecture was not grossly disturbed so that one could still trace the junction between the gray and white matter. These findings are in agreement with those of Dieckmann, et al. The trypan blue outline was more dense and narrower in width in the cortex but became more diffuse and lighter in the white matter.

When lesion size was plotted against time and the temperature remained constant at 65°C, lesion size did not increase in a linear fashion (Fig. 3). The initial lesions at 2.5 sec were relatively large with a mean measurement of 7.5 mm². From that point there was a comparatively less rapid increase in lesion size up to 30 sec. The mean measurement at that time was 14.7 mm², approximately twice the size at 2.5 sec. Beyond 30 sec, the lesions did not vary much in size up to 75 sec. The mean lesion size from 30 to 75 sec was 14.1 ± 1.5 mm².

Lesion size was also plotted against time as a function of power output of the rf gen-

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**Fig. 1.** Diagram of 20-gauge (0.036 inch) stainless steel electrode coated with epoxylite except for its outer distal 2 mm. Temperature control is achieved with thermistor bead located at the tip.

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of the lesion production. Time was measured from the moment the temperature reached 65°C. Temperature was kept constant at 65°C, and time alone was varied. Lesions were made at 2.5-sec intervals up to 30 secs and 5-sec intervals from that point to 50 sec. Lesions were also made for 60 and 75 sec. Voltage and amperage recordings were simultaneously recorded.

After all the lesions were made, 15 cc of trypan blue were given intravenously, and the dogs were sacrificed with intravenous pentobarbital. The brains were removed and immediately frozen. Multiple sections of each lesion were made through the frozen brain and the lesion measured under the dissecting microscope.* Lesion size was taken as the product of the greatest depth and width and expressed in square millimeters. The actual measurements were used because the tissue was not placed in fixative. Trypan blue usually outlined the outer limit of the

* Carl Zeiss Neurosurgical Operating Microscope.