Experimental Radiofrequency Brain Lesion Size as a Function of Physical Parameters

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Recently there has been increased attention focused on the therapeutic use of carefully controlled radiofrequency lesions in man. In particular, the cinematographic comparison between thermogenic radiofrequency lesions and cryogenic lesions by Mark and Ervin has demonstrated the superiority of thermal lesions for therapeutic purposes. In an earlier paper we quantitated the size of the lesion in terms of the related physical parameters, namely, the temperature at electrode tip, the time of maintenance of temperature, and the dimensions of the electrode. This brief report expands the parameters studied, providing a useful guide for tailoring the size of the lesion to the individual therapeutic problem.

We have now placed a total of 75 lesions in the brains of 14 monkeys (Macaca mulatta and Cercopithecus) using a method already described. Some animals were sacrificed immediately after the lesion was made, and others at intervals up to 14 weeks.

Results

Varying Brain Temperature Measured at Electrode Tip. Fig. 1 shows the average lesion size in the temperature range 50°–90°C. for a 19-gauge electrode (0.042 inch outside diameter [OD]), 5 mm. exposed tip, and 2-minute maintenance of temperature. The size range of lesions contributing to each point is indicated. Fig. 2 gives the same information for one monkey with a 24-gauge electrode (0.022 inch OD).

Lesion Size as a Function of Electrode Tip Exposure. Fig. 3 shows the lesion size for 1–5 mm. tip exposures, 60°C., 2-minute maintenance of temperature with a 19-gauge electrode. Fig. 4 gives similar information for a 24-gauge electrode.

Comment

Several interesting features emerged from these results. Lesion length (60°C., 2 min.)
FIG. 2. Thermal lesion size: length and average maximum diameter plotted against temperature (with 24-gauge electrode, 2.5 mm. tip, and 2-minute time of maintenance of temperature). Lesion length at 90°C could not be determined for technical reasons. Monkey No. 14: 26 days' survival time (370 kc. generator).

FIG. 3. Thermal lesion size: length and average maximum diameter plotted against electrode tip exposure (with 19-gauge electrode, 60°C, 2-minute time of maintenance of temperature). Monkey No. 12: eighteen days' survival time (370 kc. generator); Monkey No. 13: forty days' survival time (370 kc. generator).

can be calculated by adding approximately 2 mm. to the length of the exposed tip for a 19-gauge electrode; 0.3 mm. to the length of the tip for a 24-gauge electrode. The average lesion diameter using a 24-gauge electrode (60°C., 2 min.) was independent of the exposed tip, while for the 19-gauge electrode, longer exposed tips gave larger diameters. Lesion volume can be approximated by considering the lesion to be a prolate spheroid with the major axis equal to lesion length and the minor axis equal to lesion diameter.

Radiofrequency power produces heat by $P = \frac{I^2R}{2\pi r l}$ (I = current, R = resistance) loss in the brain tissue as opposed to heat transfer from the probe itself. The complexity of the physical system makes theoretical analysis very difficult. However, if the system is oversimplified by ignoring the inhomogeneity of the tissue and heat transfer by conduction

FIG. 4. Thermal lesion size: length and average maximum diameter plotted against electrode tip exposure (with 24-gauge electrode, 60°C., two-minute time of maintenance of temperature). Monkey No. 14: twenty-six days' survival time (370 kc. generator).

FIG. 5. Calculation of $\frac{dP}{dV}$ at distance $r$ from electrode axis (edge effects neglected).