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.2-12 In particular, the cinematographic comparison between thermogenic radiofrequency lesions and cryogenic lesions by Mark and Ervin8 has demonstrated the superiority of thermal lesions for therapeutic purposes. In an earlier paper10 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.10 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°C–90°C for a 19-gauge electrode (0.042 inch outside diameter [OD]), 5 mm. exposed tip, and 4-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 (270 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 (270 kc. generator); Monkey No. 13: forty days' survival time (270 kc. generator).

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 (270 kc. generator).

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

Radiofrequency power produces heat by \( I^2R \) (\( I \) = 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...
and circulation, a crude model emerges. If one considers the electrode to be a cylinder and assumes current flow to be perpendicular to the shaft, then the temperature rise at any distance \( r \) from the axis of the electrode is proportional to \( (I/\rho r)^2 \) where \( I \) is the current, \( \rho \) is electrode tip length (Fig. 5).

If we then assume we are dealing with 2 electrodes with the same length of exposed tip, one twice the diameter of the other, it is seen that twice the current is necessary to bring the tissue affected by the larger diameter electrode to the same temperature as that at the smaller electrode. A given temperature rise occurs twice as far from the axis of the large electrode as from the smaller electrode if tip temperature is the same in each case. Thus one can predict that for the same tip temperature, lesions made with the larger electrode would have twice the diameter of those made with the smaller electrode. Aronow\(^1\) predicted a similar result assuming spherical geometry. The data show that, in fact, for 19-gauge (0.042 inch OD) versus 24-gauge (0.022 inch OD) electrodes, lesions are somewhat greater than twice as large. It should be noted that these results, both theoretical and experimental, are in disagreement with results presented elsewhere\(^3\) in which it is assumed that the temperature gradient in brain is dependent only on temperature at the electrode tip.\(^3\)

**Summary**

We have reported data indicating that the size of radiofrequency lesions in the monkey brain can be predicted and controlled by the consideration of related parameters. We have also predicted the value of these considerations in the control of comparable therapeutic lesions in man.

**Acknowledgment**


**References**