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BRIEF COMMUNICATION

Comparison of DC and RF for Lesioning White and Grey Matter[1]

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DICARA, L. V., L. WEAVER AND G. WOLF. *Comparison of DC and RF for lesioning white and grey matter.* PHYSIOL. BEHAV. 12(6) 1087–1090, 1974. – The morphology of brain lesions produced by anodal direct current and by radio frequency current was compared. The lesions were placed within or adjacent to a number of myelinated fiber tracts of the forebrain and brain stem using a range of common current parameters. It was found that with the parameters used anodal current was relatively ineffective for destroying fiber tracts while radio frequency was equally effective for fiber tracts and cellular areas. Thus, differential applicabilities of these two lesion methods are indicated. Additional observations were made on the effect of cathode location upon the shape of anodal direct current lesions. There was a tendency for the anodal lesion to be drawn in the direction of the cathode but the effect was small and inconsistent and therefore its usefulness for controlling the shapes of anodal lesions seems minimal.

Methodology DC lesions RF lesions Morphology

THE present study continues a program of evaluation and improvement of brain research methodology [14,15]. We have been particularly concerned with methods of induction and evaluation of brain lesions. The lesion method constitutes one of the classical and most popular experimental techniques of physiological psychology, and has thus received considerable methodological study [1, 2, 3, 4, 6, 7, 9, 12 13]. However, there is still much work to be done in gaining better understanding and control of the various lesion techniques. In our previous work we showed that the apparent size of brain lesions and the shape of surrounding structures may undergo profound changes as a function of post-operative survival time [15]. The present study is concerned with certain peculiarities in the morphology of lesions induced by the passage of direct anodal and radio frequency currents.

Direct (DC) and radio frequency (RF) currents passed through needle electrodes produce tissue damage whose extent can be fairly well controlled by varying the intensity and duration of the current flow [1, 9, 12, 15]. Consequently these are the most widely used techniques for producing lesions in deep brain structures. The exact mechanism by which DC produces tissue damage is not fully understood but from our review of the literature, it seems that it is most likely due to a combination of effects including deposition of metallic ions, formation of gas bubbles, and/or disruption of charged cellular particles via polarization. On the other hand, RF current is thought to induce damage by generating high temperatures in the tissue surrounding the electrode tip. These two techniques are generally used indiscriminately without regard to the nature of the brain structure to be destroyed. In this paper we show that using standard current parameters, anodal DC lesions are relatively ineffective for damaging myelinated fiber tracts while RF lesions are very effective for this purpose. Also we explored the possibility that the shape of anodal DC lesions could be controlled by varying the position of the cathode and found that cathode position has only a small and inconsistent effect which could generally afford little practical advantage.

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METHOD

Comparison of DC and RF Lesions

Anodal DC and RF lesions were placed in the forebrain or brain stem of 20 adult male and female rats. All lesions were made by passing current through stereotaxically positioned stainless steel 00 ga insect pins insulated except for either 0.3 or 2.0 mm at the tip. The ground electrode was a needle inserted under the skin of the back. DC current was varied from 0.8 to 2.0 mA for 6 to 20 sec. RF current from a Grass LM-4 lesion maker was varied from 10.0 to 40.0 mA for 5 to 60 sec. These current parameters were chosen because they represent the ranges most commonly employed in producing brain lesions from 0.5 to 2.0 mm in diameter.

Unilateral DC or RF lesions of varying sizes were made in the brainstem of 12 of the rats. These lesions were aimed adjacent to dense myelinated fiber tracts such as fasciculus retroflexus, medial lemniscus, cerebral peduncle, or mammillothalamic tract. The 0.3 mm tip electrodes were used. We intentionally aimed the electrode tips adjacent to rather than directly in the fiber tracts so that damage from the penetration would not be confounded with damage from the passage of the current.

Forebrain lesions were made in 8 rats. In 4 rats the lesions were bilateral (DC on one side and RF on the other side) and in the other 4 rats a single unilateral DC or RF lesion was made. The 2.0 mm tip electrodes were used for the forebrain lesions. The electrode was inserted so that it penetrated through the corpus callosum by approximately 0.7 mm. In this way the bared portion of the electrode contacted the neocortex above the corpus callosum and the caudate nucleus below as well as the body of the corpus callosum itself.

The rats were sacrificed from 4 to 7 days after induction of the lesions and following perfusion with formalin the brains were removed for histologic study. Sections through the lesions were stained for cells and fibers by several methods described elsewhere [14]. Selected sections from 8 brains with brain stem lesions and 2 brains with forebrain lesions were stained with the Nauta method using several degrees of suppression of normal fiber staining in order to reveal both normal and degenerated axons in the tracts damaged or spared by the lesions.

Effect of Cathode Location

Anodal DC lesions were placed in the basal forebrain, thalamus, or mesencephalon of 16 rats. The electrodes were as described above with 0.3 mm bared at the tips. Current parameters varied from 0.8 to 2.0 mAmps for 6 to 20 sec. In 4 rats the cathode was attached to the stereotaxic instrument which made contact with the mouth, ears, and feet of the animal. Another 4 rats were insulated from the stereotaxic instrument and the cathode was attached to a needle inserted under the skin of the back. In the final 8 rats the cathode was a second electrode inserted into the brain 3 to 5 mm rostral, caudal or lateral to the anodal electrode. The rats were sacrificed from 5 to 7 days after lesioning and the brains were stained for cells with cresyl violet.

RESULTS

Comparison of DC and RF Lesions

The morphological differences between the DC and RF lesions were striking and consistent at all lesion sizes and placements. The most obvious gross difference between the two types of lesions was the relative size of the central cavity in comparison to the surrounding field of gliosis – the RF lesions creating a somewhat larger central cavity. (Actually this cavity is filled with amorphous necrotic material which usually becomes detached during the histologic procedure.) Secondly, the RF lesions were always roughly spherical in shape regardless of the structure of tissue included in or adjacent to them, while the DC lesions did not invade peripheral fiber tracts so that their borders were often indented by them.

The above differences are clearly exemplified in Figs. 1A and 1B which show sections through DC and RF lesions centered in the corpus callosum. The DC lesion (Fig. 1A) takes on an hour-glass shape due to the much broader extent of destruction in the cellular areas above and below the fiber layer than within it. The corpus callosum sustains damage only immediately surrounding the point of electrode penetration, indicating that anodal DC will produce fiber destruction in the region of cavitation at the electrode tip but not in the surrounding field. The RF lesion shown in Fig. 1B indiscriminately invades cellular and fiber areas and thus is rounded through the corpus callosum rather than indented by it.

Figure 1C shows a striking example of the ineffectiveness of anodal DC lesions in damaging fiber tracts. The DC lesion completely encircles the fasciculus retroflexus in a field of cellular destruction. However, under higher magnification (Fig. 1E) the Nauta stain reveals only sparse degeneration within the tract (probably representing fibers entering from the surrounding cellular area where the fiber degeneration is quite dense). This is to be contrasted with an RF lesion of similar size and placement which encroaches only upon the ventral edge of the fasciculus retroflexus (Fig. 1D) but produces dense degeneration within the tract (Fig. 1F). These differential effects were apparent in Nauta stained section of brains with lesions encroaching on all fiber tracts studied here including corpus callosum, medial lemniscus, cerebral peduncle, and mammillothalamic tract.

Effect of Cathode Location

The shapes of anodal DC lesions were generally much more dependent upon the structure of the lesioned area (e.g. the presence of meylinated bounding structures) than upon the position of the cathode. There appeared to be a general tendency for the anodal lesion to be drawn towards the cathode but the effect was small at best and did not occur consistently at any of the sites investigated. Figure 1G shows an anodal lesion in the thalamus extended slightly in the direction of a cathode in the mesencephalon.

DISCUSSION

The results of the comparison of DC and RF lesions indicate differential applicabilities of the two methods. DC lesions are preferable for destruction of nuclei because they will tend to curve around and thus spare fiber tracts in the vicinity. In order to destroy a fiber tract by DC without substantial accessory damage to surrounding cells the electrode tip would have to be directly within the tract. Thus, DC is contraindicated for discrete tractotomies. The reason for the sparing of dense, heavily myelinated fiber

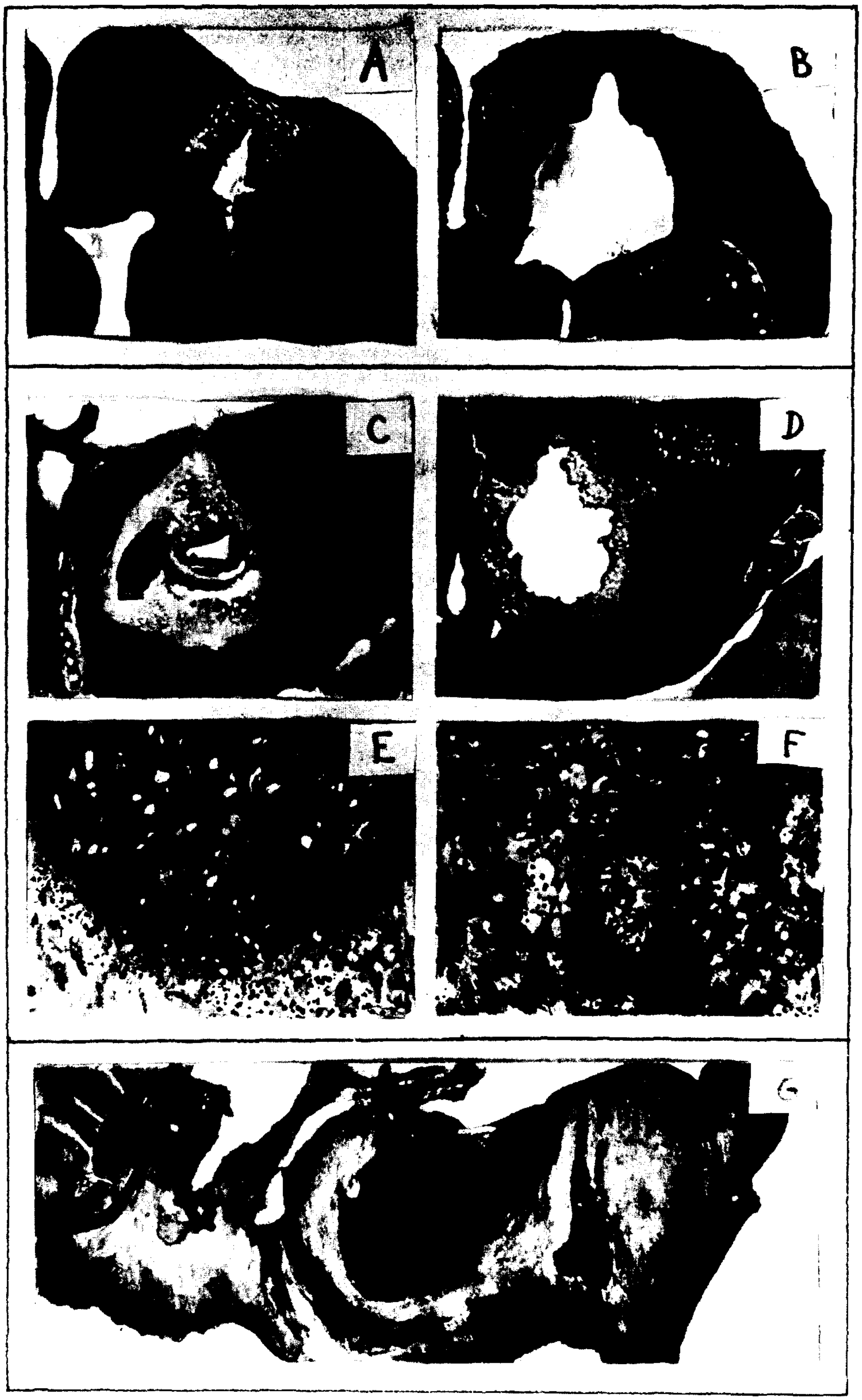

FIG. 1. Artist's illustrations of brain sections as they appear under microscope and microprojector. These illustrations depict the critical morphological phenomena more clearly than did photomicrographs. (A). Section through DC lesion in and adjacent to corpus callosum – Kluver stain. (B) Section through RF lesion in and adjacent to corpus callosum – Kluver stain. (C) Section through DC lesion adjacent to fasciculus retroflexus – Nauta stain. (D) Section through RF lesion adjacent to fasciculus retroflexus – Nauta stain. (E) Same section as C at higher magnification to show degenerated fibers within and adjacent to ventral portion of fasciculus retroflexus (area in rectangle). (F) Same section as D at higher magnification to show degenerated fibers within and adjacent to ventral portion of fasciculus retroflexus (area in rectangle). (G) Saggital section demonstrating an anodal DC lesion in the thalamus extended slightly in the direction of a cathode in the mesencephalon – Cresyl violet stain.

tracts by DC is probably that they have a higher resistance to current flow than surrounding cellular areas [11]. It is important to note in this regard that we have not observed such differential sparing of diffuse pathways such as the medial forebrain bundle.

RF lesions, on the other hand show no differential affinity for cells and fibers. This constitutes a disadvantage when the target region is a nucleus and peripheral tract damage confounds the results, (for example in the lateral hypothalamus which has the fornix, optic tract, and internal capsule at its borders) but it constitutes a clear advantage over DC for tractotomy since a direct hit is not necessary to destroy the fibers.

The cathode placement experiment was done to determine whether greater control over the shape of anodal DC lesions might be gained in this way. The results suggest that the locus of the cathode has only a small and inconsistent effect and thus is of little practical importance at the present stage of lesion methodology.

Finally, some cautions should be noted with regard to the generality of the conclusions presented here. It is entirely possible that current intensities and durations outside the range of those used here or electrodes made out of different materials may produce significantly different effects. Other problems outside the scope of the present paper must also be considered when choosing a lesioning procedure. For example, metallic deposits from anodal DC lesions may produce confounding results [5, 8, 10]. Clearly, further investigations of the biophysical bases and the specific pathomorphological effects of various types of lesioning procedures are called for.

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