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TRIGEMINAL NEUROTOMY AND BLOOD PRESSURE RESPONSES FROM STIMULATION OF LATERAL CEREBRAL CORTEX OF *MACACA MULATTA**

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INTRODUCTION

FOR SEVENTY-FIVE years blood pressure responses obtained from stimulation of various areas of the cerebral cortex have been the subject of considerable attention. The earlier work was thoroughly reviewed by Bucy in 1935 (2). Analysis of these autonomic effects of stimulation of the lateral surface was extended by Kennard (6), Hoff *et al.* (4), and Pinkston and Rioch (10). More recently attention has been focused on those changes resulting from stimulation of the anterior cingulate, orbital, insular and anterior temporal regions (1, 3, 5, 7, 11, 12, 13). The present study is an attempt to ascertain the entire extent of lateral neocortex from which these responses are obtainable by using the stimulating techniques now available, and to begin to investigate whether or not a common mechanism links these various areas.

MATERIALS AND METHODS

Ten rhesus monkeys (*Macaca mulatta*), 2-4 kg. in weight, were the subjects of these experiments. Five of these animals were operated upon under sodium pentothal anesthesia and the cortex explored after the administration of d-tubocurarine in sufficient quantity to necessitate artificial respiration. The remaining five experiments were performed under light dial anesthesia. The cerebral cortex was exposed unilaterally in six cases by a wide removal of the cranium. A seventh animal had a bilateral exposure and trigeminal nerve section on the left side at the same time. A left retrogasserian neurotomy was performed on the other three animals from four days to two weeks prior to bilateral exposure and stimulation. Supportive measures consisted of artificial respiration when curare was used and intravenous administration of 10 per cent glucose in distilled water and normal saline solution. A square-wave stimulator designed by Mauro (8), utilizing a wide range of control of frequency, amplitude and pulse duration, was employed. Bipolar silver electrodes insulated except at the tips with interelectrode distance of 1.5 mm. were used. Arterial pressure was recorded from the femoral artery by use of a mercury manometer. Considerable care was taken to insure constant humidity and temperature of the exposed cortex by use of a chamber made of dental impression wax covered by moist gauze irrigated with warm saline solution.

RESULTS

Those blood pressure responses of a magnitude greater than 10 mm. of mercury which resulted from stimulation of the cortex of those subjects whose trigeminal nerve was intact appear in Figure 1. The responsive cortex was found to be far more extensive than had previously been reported. The responses varied in direction and were inconstant from many

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of the areas explored (also see Fig. 1). However, they were invariably obtained from the region around the dorsal part of the central fissure extending forward above the superior limb of the arcuate sulcus and the cortex lying below the inferior limb of the arcuate sulcus, especially toward the sylvian

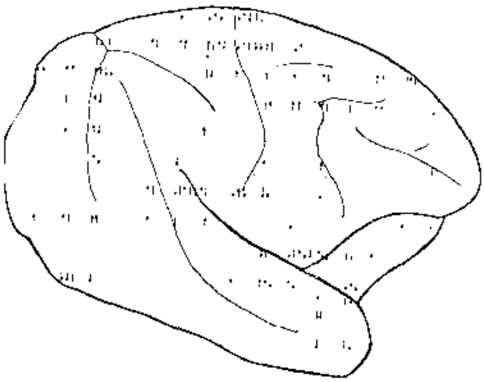

FIG. 1. Lateral view of cortex of macaque monkey. Arrows represent results on 11 monkeys. Each arrow represents a change of blood pressure (in one of the monkeys) in area on which arrow is placed and changing in direction shown by arrow. In those areas where changes were always found only five grouped arrows are placed on diagram.

fissure. In some animals responses were consistently obtained from other regions such as the anterior bank of the lunate sulcus, the angular gyrus and the inferior occipital regions.

Effect of physiological state of animal. The responses produced by stimulating the motor area did not depend on movement produced, since the

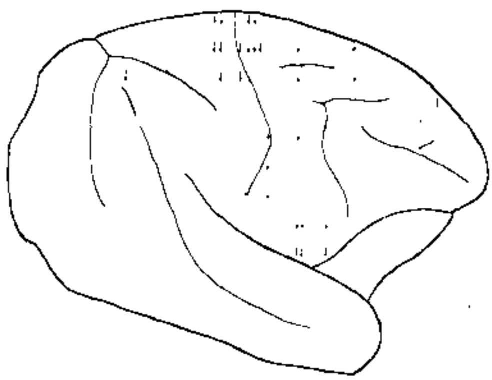

FIG. 2. Arrows represent changes of blood pressure in position and direction of changes found in five monkeys at various intervals after section of fifth nerve.

blood pressure changes persisted after all movements had been inhibited by curare. The deeper the level of anesthesia and the lower the blood pressure the more inconstant were the results. There was no apparent correlation between the direction of blood pressure change and these factors. Changes in the temperature of the irrigating saline solution on the cortex caused marked changes of blood pressure: solution 5° above body temperature caused a fall of as much as 20 mm. of mercury for several minutes whereas a solution 5° below body temperature was accompanied by a 5–10 mm. rise for a similar period of time.

Effect of section of trigeminal nerve. It was noted that many of the responses were maximal when areas around cortical blood vessels were stimulated. Since similar responses were obtained from dural stimulation which has a trigeminal innervation (9), the fifth nerve sections were carried out. Completeness of section was confirmed by absence of corneal reflex, insensitivity of dura to stimulation and post mortem examination. After this procedure had been carried out unilaterally in four animals, denervated and normal sides were alternately compared. (In three animals a period of

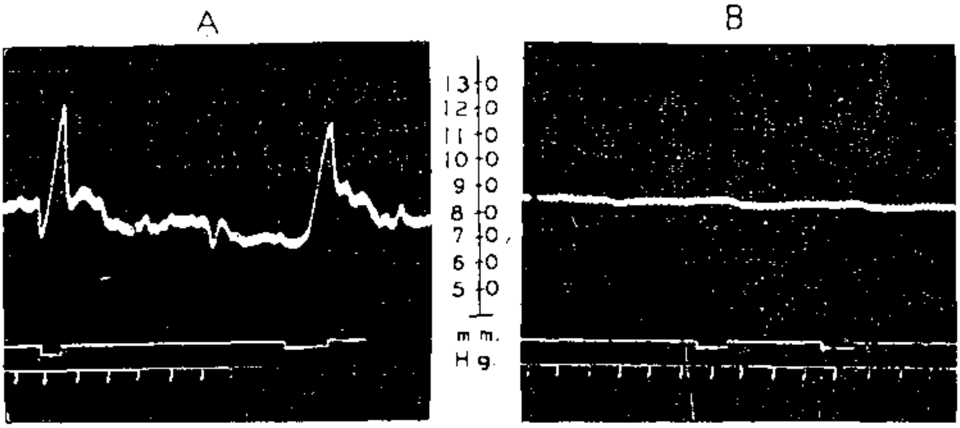

FIG. 3. A: Stimulation of lunate sulcus, first for 10 and then for 20 sec., with square-wave stimulus of 5 volts for .10 msec. 40 times per sec. resulted in marked rise of blood pressure. B: Stimulation of same area 10 days after section of fifth nerve produced no changes of blood pressure.

4–14 days was allowed to elapse after the section.) The sides which had not been denervated showed the same pattern of response already described. On the denervated side, however, blood pressure responses were evoked from a very much more limited area (see Figs. 2 and 3). After trigeminal section, stimulation of no part of the homolateral cortex led to a rise in blood pressure. (Parameters of stimulation had no influence on this effect.)

Effect of parameters of stimulation. The effects reported were all evoked by a voltage just sufficient to produce a muscle twitch (usually under 5 volts). The optimum frequency for the response was found to be between 10 and 40 per sec. The duration of the pulse used was 10 msec.

DISCUSSION

These results were obtained under the conditions usually present in acute experimental studies involving the cerebral cortex. Since stimulation of so many cortical points resulted in marked changes of blood pressure, such changes must be taken into consideration in evaluating the results of the effects of cortical stimulation on all physiological systems.

The most likely explanation of the effect of trigeminal section on the responsiveness of the cortex is that afferents from the cortical vessels have been interrupted. However, since, in unanesthetized humans no pain is elicited from stimulation of blood vessels on the lateral surface except near sinuses, it is somewhat surprising to find so widespread a distribution of afferents in the monkey. It is therefore possible that an intact trigeminal nerve potentiates cortical responses to stimulation either by an effect on cerebral circulation or a direct neural synergism. However the effect of trigeminal section is mediated, these results suggest that a separate autonomic mechanism involving the trigeminal nerve exists on the surface of the cortex.

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