Confusion and Disturbance of Speech from Stimulation in Vicinity of the Head of the Caudate Nucleus

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The effective treatment of certain disorders of movement by lesions in the thalamus and pallidum has opened a new chapter in human neurophysiology. Since the physiological verification of the anatomical placement of the surgical instrument in the depths of the brain forms an important clinical safeguard, such studies form an integral part of the surgical protocol. From an investigational point of view, this research is hampered by the lack of direct anatomical proof of the sites of stimulation, and indirect measurements derived from various ventricular landmarks must be accepted as a substitute. These in turn are subject to individual anatomical variations which are mentioned below and have been reviewed in greater detail elsewhere.25

The present report concerns observations made with electrodes placed in the mesial segment of the globus pallidus and the inferior portion of the nucleus ventralis lateralis thalami for study of these areas prior to treatment of disorders of involuntary movement. The electrodes were inserted through a burr hole well forward in the frontal region and passed through or close to the head of the caudate nucleus. Since the electrodes were provided with stimulating points at regular intervals along the shaft, the caudate nucleus and its vicinity could be studied by stimulation.

Method

The following 10 patients participated in the present study:

E.B. Male, 58 yrs. Right hemiparkinsonism for 2 yrs.
T.B. Male, 51 yrs. Severe progressive tremor of right hand for 1 yr. Present with voluntary movements but absent at rest.
A.C. Male, 59 yrs. Right hemiparkinsonism for 2 yrs.
J.C. Female, 9 yrs. Progressive dystonia of both legs and the right arm for 2 yrs.
E.S. Female, 52 yrs. Progressive dystonia affecting the trunk and left extremities for 20 yrs.
L.S. Male, 58 yrs. Bilateral parkinsonism for 6 yrs.
V.S. Female, 62 yrs. Right hemiparkinsonism for 2 yrs.
H.T. Female, 53 yrs. Bilateral parkinsonism for 8 yrs.

All of the patients were right-handed by test and history. None had suffered from epilepsy with the exception of E.S. who had a 4-year history of occasional brief periods of confusion and sharp waves were recorded from the right temporal region by electroencephalography.

In order to test the accuracy of the stereotaxic placements physiologically, depth electrodes were placed in targets of possible therapeutic value. After demonstrating the positions of the anterior and posterior commissures as well as the midline of the third ventricle by pneumography, a burr hole was placed just behind the hair line in the frontal region about 2–3 cm. from the midline. One electrode was directed to the medial segment of the pallidum at R or L 15, I 2 and P 6 (according to the coordinate system to be mentioned below) and the other to the basal portion of the nucleus ventralis lateralis. In the latter instance, the coordinates employed varied from time to time but in general fell in the vicinity of R or L 10, S 0 and P 15. The electrodes were retained in position for a period of 7 to 10 days.

The electrodes (Fig. 1) consisted of 22-gauge “Teflon” tubing down the bore of which was threaded .006 inch stainless-steel wire insulated with Kel-F plastic. At sites selected as areas of stimulus the wire was led out a small hole in the side of the tubing, passed around the tubing, then back into the same hole so that the stimulating area was a wire ring about the outside of the “Teflon” tubing. In order to present a smooth outer surface, the “Teflon” tubing was coated with “Tygon” (U. S. Stoneware Co., Akron, Ohio)

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which was cleared away from the wire of the ring electrodes. Seven rings were used on the electrode at 2, 4, 12, 14, 22, 32, and 42 mm. from the tip. Since the electrodes were directed to the medial segment of the pallidum and the basal portion of the nucleus ventralis lateralis, most of the responses in the present study were obtained from stimulating between rings 22 to 32 mm. or 32 to 42 mm. from the tip of the electrode. Despite a distance of 10 mm. between the stimulating rings the responses by stimulating between the rings generally were more discrete (and this method was used generally) than if one of the rings was used with the indifferent electrode placed under the buttocks. The resistance between two of the electrodes with an ordinary battery-operated ohmometer lay in the vicinity of 40,000 to 50,000 ohms.

Stimulation was carried out with unidirectional 2.5 ms. square waves at 60/sec. frequency. None of the stimuli was followed by an overt motor seizure. During the stimulation the wave form and the current and voltage were observed directly with appropriately placed oscilloscopes on the output circuit. The impedance of the patient was estimated for each stimulation by having the stimulating current run continuously through a calibrated variable mechanical resistance which was adjusted until the amplitude of the waveform on the oscilloscopes did not change when the patient was substituted for the mechanical resistance. When the current is given, peak current is implied. The resistance for the particular current employed is given in thousands of ohms (K). It will be noted, in general, that at the levels used in the present study the resistances lay in the vicinity of 3 to 5 K as opposed to the 40–50 K obtained with the low-current meter cited above.

For charting purposes, a coordinate system was used which has been described elsewhere,25 and the basic zero planes were defined as follows: 1) Sagittal: A vertical plane bisecting the third ventricle and the brain stem. 2) Horizontal: Perpendicular to the sagittal plane and passing through the center of the anterior and posterior commissures. 3) Transverse: Perpendicular to both the above planes and passing through the center of the anterior commissure. All coordinates are labeled right (R) or left (L), superior (S) or inferior (I), anterior (A) or posterior (P) with respect to these planes. The numbers refer to distance in millimeters. The broad lines shown on Figs. 2, 3 and 4 connect the coordinates of the two points of stimulation used in the particular instance. When the electrode lay oblique to the plane of the sagittal chart (as most of them did) and it was necessary to use two adjacent charts to show both ends of the pair of stimulating electrodes, a tear-drop symbol is used with the pointed end indicating the direction in which the second electrode of the pair lay. In plotting points, loci 8–12 mm. from the midline were recorded on the chart depicting the brain in sagittal section 10 mm. from the midline. In a similar fashion points at 13–17 mm. were drawn on the 15 mm. chart and points at 18 and above were drawn on the 20 mm. chart. The error caused by individual anatomical variation in this region is considerable as measured from the zero planes defined above and 2 standard deviations amount to about 4–5 mm.25

**Fig. 1.** The flexible depth electrode used in the present study showing the small ring at the end which fits over the beak of the electrode guide shown below and the distal 5 ring electrodes. A millimeter scale is included below.

**Fig. 2.** Diagram of sagittal section of brain 10 mm. from the midline upon which electrode coordinates from 8–12 mm. from the midline are plotted. The heavy vertical axis passes through the lateral projection of the anterior commissure and the heavy horizontal axis passes through the lateral projections of the anterior and posterior commissures. The squares measure 1 cm. Where both electrodes of a stimulating pair are included in the plot the interval is indicated by a broad bar. When but one of the electrodes is included, it is indicated by a tear-drop symbol and its mate is indicated by a similar symbol pointed in the opposite direction on an adjacent diagram. The patient's initials may be compared with descriptions in the text.

**Results**

A. **Responses to Stimulation.** Because of the use of implanted electrodes time could be