PHYSIOLOGY

CAPSULAR EFFECTS DURING STIMULATION OF THE VENTROLATERAL THALAMIC NUCLEUS DURING STEREOTAXIC OPERATIONS FOR HYPERKINESIA

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During determination of the lateral boundary of the ventrolateral nucleus of the thalamus during 32 stereotaxic operations for parkinsonism, methods of recording the motor response (EMG and tremorography) to electrical stimulation were used. The investigations showed that analysis of the duration of latent periods of evoked motor responses enables the capsular responses arriving through loops of current when the tip of the stimulating electrode lies in the ventrolateral nucleus to be clearly differentiated from responses associated with direct stimulation of the internal capsule.

However accurately the coordinates of the electrode tip are calculated from intracranial roentgenologic reference points during stereotaxic operations, it is nearly always necessary to introduce an additional correction in order to determine the point of destruction more accurately. In most cases this additional correction is based on changes in some physiological indices in response to electrical stimulation of particular subcortical structures.

In operations on the thalamus for various types of hyperkinesia, determination of the lateral boundaries of the ventrolateral nucleus is bound up with the problem of differentiation between motor responses obtained by stimulation of the ventrolateral nucleus itself and responses arising from stimulation of the internal capsule. To solve this problem, the writers have used several methods of recording motor responses, notably electromyography and tremorography.

The special features of capsular effects have been described previously [4-8], and Guiot et al. [4] and Skorpil [8] have investigated the time and velocity of conduction of excitation along the pyramidal tract following its direct electrical stimulation with single pulses 1-2 msec in duration.

EXPERIMENTAL METHOD

This paper analyzes the results of monopolar stimulation of the ventrolateral nucleus during stereotaxic operations on 32 patients with different types of hyperkinesia. The operations were performed under local anesthesia.

Stimulation was applied with a stilet electrode (diameter 200 μ), introduced at right angles for a controllable distance of up to 7 mm. The electrode was moved along a circular path at intervals of 45°. Stimulation was applied at 3 levels of the ventrolateral nucleus, situated 3 mm apart (Fig. 1).

Square pulses, from 0.2 to 5 V in amplitude and with a constant frequency of 50 Hz, were used as stimuli. In the first stage of the investigation, the effects of stimulation over a wider frequency range

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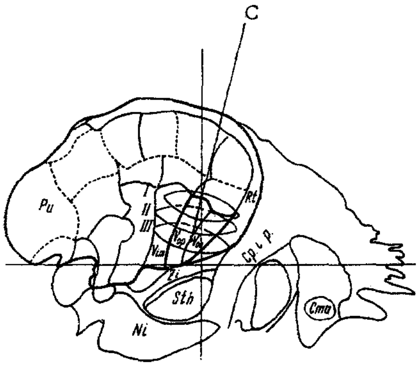

Fig. 1. Scheme of circular electrical stimulation of ventrolateral nucleus of the thalamus. C–trajectory of stereotaxic cannula in thalamus; I, II, III) levels of electrical stimulation; Voa – anterior ventrolateral nucleus; Vop – posterior ventrolateral nucleus; Vim – intermediate ventral nucleus; Rt – reticular nucleus of the thalamus; Pu – pulvinar; Cp.ip. – internal capsule; Cma – anterior commissure; Zi – zona incerta; Sth – subthalamic nucleus; Ni – substantia nigra.

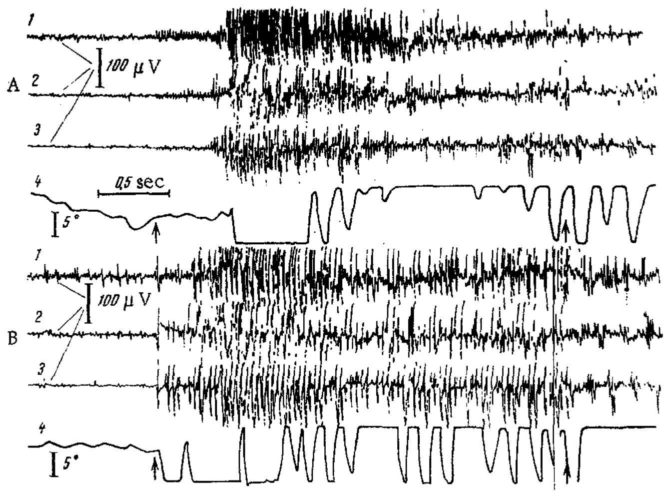

Fig. 2. Decrease in latent period as stimulating electrode moves closer to the internal capsule. A) Electrode 5 mm from internal capsule; latent period exceeds 300 msec; B) electrode at border of capsule; latent period not exceeding 20 msec (accuracy of measurement of time limited by properties of electromyograph); 1) EMG of extensors of elbow; 2) EMG of flexors of wrist; 3) EMG of extensors of wrist; 4) tremorogram of wrist. Arrows denote beginning and end of stimulation.

(from 1 to 100 Hz) were studied. These observations showed that, with the electrode in the ventrolateral nucleus, application of single pulses was ineffective. It was therefore decided to stimulate with series of pulses 3 sec in duration, the duration of each single pulse being 1 msec.

The point of the target corresponding to the center of the ventrolateral nucleus was determined relative to a system of coordinates consisting of the intercommissural line and the perpendicular drawn through its center, using Schaltenbrand's [7] stereotaxic atlas for the calculations, and allowing for the degree of hydrocephalus and constitutional peculiarities of the skull. This point was located 2 mm posterior to the midpoint of the intercommissural line, and 4 mm superior to it. The circular stimulation began in the plane of the target point (mean level of stimulation, Fig. 1).

Objective control of the muscle responses was provided by the electromyogram and tremorogram. Electromyographic electrodes were placed superficially on various muscle groups in the limbs. The tremorogram was recorded by the method developed and described previously [1].

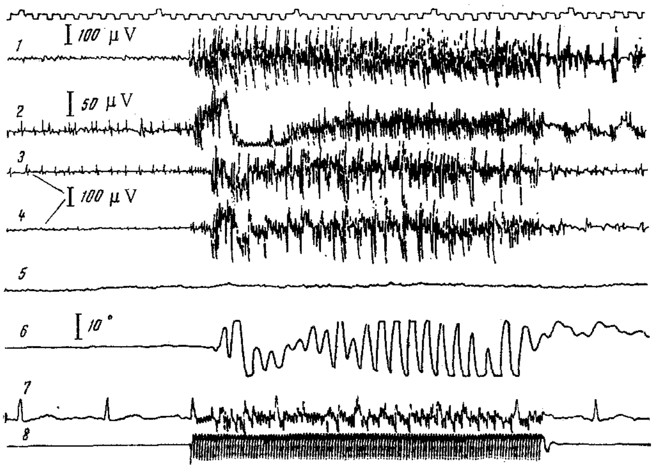

Fig. 3. Latent periods in muscle groups of upper and lower limbs during stimulation of internal capsule. 1) EMG of straight head of quadriceps femoris muscle; 2) EMG of gastrocnemius muscle; 3) EMG of flexors of wrist; 4) EMG of extensors of wrist; 6) tremorogram of wrist; 7) ECG; 8) marker of stimulation.

EXPERIMENTAL RESULTS AND DISCUSSION

The physiological index used to define the position of the electrode tip relative to the internal capsule was the latent period of the muscle response to stimulation. Measurement of the latent periods of muscle responses of the hand during stereotaxic operations for parkinsonism [8] showed that during monopolar stimulation of the internal capsule the latent period varied between 15.5 and 21 msec (13 patients), and in the case of bipolar stimulation between 17 and 19.5 msec (4 patients). The latent period for flexors of the foot with bipolar stimulation was 25-32 msec (4 patients). Guiot et al. [4], in an earlier investigation, determined the mean latent period of responses of different muscles to electrical stimulation of the internal capsule: 29 msec for extensors of the ankle, 14.5 msec for the rectus abdominis muscles, 18 msec for flexors of the fingers, and 9 msec for the facial muscles.

The latent period of the muscle responses to stimulation of the internal capsule thus does not exceed 35 msec. For this reason, when this index was higher than that upper limit of the capsular response, it was assumed that the electrode was outside the capsule. According to data in the literature and the writers' observations, the latent period to stimulation of the ventrolateral nucleus of the thalamus is much higher than this value [2, 3].

Previously, when the latent period was not measured actually during the operations, the main criterion used to assess the position of the electrode relative to the capsule was visual estimation of the character of the muscle responses. The capsular response is manifested by clonico-tonic spasms of muscles on the opposite side of the body in the rhythm of stimulation.

In some cases it was possible to observe outward manifestations of muscle responses which corresponded visually in character to the capsular response described above. However, as the calculated data showed, in these cases the electrode was at the point of the target corresponding to the center of the ventrolateral nucleus, 4-5 mm away from the internal capsule.* The latent periods here were much greater than that of the capulsur responses. These responses, resembling capsular in character, were evidently associated with the action of loops of current.

Changes in muscle responses during successive movement of the electrode from the center of the ventrolateral nucleus to the internal capsule (direction 90°) were investigated. Characteristically, when the electrode was located 4 mm away from the internal capsule, and when it was actually on the boundary of the internal capsule, in some cases the visual and electromyographic picture were identical, whereas

*In this report, motor effects in response to stimulation specific for the ventrolateral nucleus, affecting mainly tremor and muscle tone, are not examined.

the latent periods as a rule differed shaprly from each other, diminishing as the electrode moved closer to the capsule (Fig. 2).

Anatomically, the internal capsule can be subdivided somatotopically from its anterior portions to its posterior. Guiot [5] showed, using the method of electrical stimulation, the precise segmental differentiation of the capsule.

In these investigations, during stereotaxic operations it was possible to observe the responses described above during recording of the tremorogram and electromyogram of muscles of the upper and lower limbs, in which they developed simultaneously. If, however, the electrode at the boundary of the capsule was located in the somatotopic zone of the upper limb and the latent period corresponded to the capsular time, the latent period for the lower limb was considerably greater, and frequently this could not be detected by visual observation. The reason for this was evidently that the capsular somatotopic zone of the lower limb, located some distance away, was involved secondarily through loops of current, and vice versa (Fig. 3).

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