Further definition of the subthalamic target for arrest of tremor

Francisco C. Velasco, M.D., Pedro Molina-Negro, M.D., Claude Bertrand, M.D., and Jules Hardy, M.D.
Service of Neurosurgery, Notre Dame Hospital and University of Montreal, Montreal, Canada

During stereotaxic procedures for the treatment of tremor, the simple introduction of a 1-mm diameter electrode in the subthalamus may arrest the tremor on the contralateral side. Placement of the electrodes in relation to the ventricular system and intercommissural (AC-PC) line was studied radiologically in 88 cases operated on. The proximity of the medial lemniscus and pyramidal fibers was assessed by means of electrical monopolar stimulation. A proportional reduction of the AC-PC line was made in all cases by dividing it in 10 equal parts. The resultant 10ths were squared to divide the areas above and below the line. The place where the tremor was arrested corresponded to a small area that extended just in front of the area of sensory responses and medial to the area of motor responses. It seemed to have a topographical organization, as the tremor could be selectively arrested in the arm or the leg. Analysis of results on anatomical grounds showed the area in question corresponded to the prelemniscal radiations that extend caudally as far as the mesencephalic tegmentum and end at the level of the AC-PC line.

Key Words: attitude tremor, Talairach's parallelogram, Parkinson's disease

Bertrand, et al.,2,4 reported that, in cases of postural tremor and tremor of attitude, the introduction of an electrode within a small area of the subthalamus may cause arrest of tremor in the contralateral limbs. The area considered to be the “optimum target” was the place where the smallest lesion could cause a complete relief of tremor.

When the anterior commissure-posterior commissure (AC-PC) line on the x-ray film is divided in 10 equal parts, the area where this sudden effect occurs would usually be located in the subthalamus underneath the 8th posterior segment, 2 to 4 mm below the AC-PC line, and 13 mm from the midline plane (Fig. 1). This area corresponds in the subthalamus to the prelemniscal radiations running within the zona incerta.

The present report further delineates the topography and extent of the area as well as its relation to the surrounding structures identified by stimulation: the sensory and motor pathways. The study concerns the minimal critical zone sought during the beginning of the stereotaxic procedure; for practical therapeutic purposes, in all cases a large enough lesion was produced for permanent relief of the symptoms.

Materials and Methods

Ninety consecutive cases of Parkinson's disease (47 cases) and tremor of attitude (43 cases) were considered for this report.
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In 30 cases, mere introduction of the electrode for stimulation arrested tremor as assessed both clinically and by electromiography (EMG). In 10 others, tremor was only partially or temporarily arrested. Fifty cases in which introduction of the electrode at about the same place did not produce any modification of tremor were used as a control group. In some cases, initial placement of the electrode did not alter tremor but produced tingling or numbness within a segment of the body; a second trajectory directed more anteriorly produced the desired arrest of tremor. These cases were particularly useful to illustrate the relation between the optimum target and the sensory pathways (lemniscus). With square pulses of 60 cps and below 0.5 V, we considered the diffusion of electrical current in the brain tissue as minimal, since by withdrawing the electrode 1 or 2 mm the response to stimulation either disappeared or changed in character. This was used to delineate the relation of the medial lemniscus and ventralis posterolateralis nuclei and the motor fibers to the area in question.

Talairach's parallelogram was drawn on the films. According to Talairach's system, the AC-PC line extends from the lower margin of the posterior commissure to the superior margin of the anterior commissure and therefore has an angle of $10^\circ$ with the AC-PC line when traced from the center of one commissure to the center of the other as in Schaltenbrand and Bailey's atlas. The contour of the ventricular system, the AC-PC, VAC, and VPC lines were reproduced on millimetric paper to facilitate calculations. The AC-PC line in each case was divided into 10 equal parts whatever its length. One tenth of the line was then used as a unit to square the space above and below the line (Fig. 2 left). Using the same unit, we made the same proportional division on both sides of the midline (Fig. 2 right). For instance,
in a case where the AC-PC line measures 25 mm, each side of the unit square would be 2.5 mm in length. With such a proportional division, the data from all the patients can be superimposed and compared on a standard basis. Thus, a tridimensional space can be prepared as a master frame into which all the points from each individual case can be inserted.

The following results were plotted on a master sheet:

1o. The points where tremor was arrested
2o. The electrode trajectories that produced no modification of tremor
3o. The points where a partial effect on tremor was obtained, that is, transient arrest, disorganization, or decrease in amplitude
4o. The areas where motor and sensory responses were obtained with low voltage monopolar stimulation.

Results

Since most of the points where tremor stopped on mere impact of the electrode fell in the same subthalamic area, we represented their location in the appropriate sagittal and frontal planes. Figure 3 A shows the section between 4.8 and 5.8 units from the midline in which most of the effective points were located; Fig. 3 B is just medial (3.8 to 4.8) and Fig. 3 C just lateral (5.8 to 6.8 units from the midline) to the former. In the coronal plane, this same critical area is also represented in three sections: most of the effective points are located at the level of the 9th posterior unit of the AC-PC line (Fig. 4 B). The 8th and 10th posterior units are shown in Fig. 4 A and C respectively.

Proportional Coordinates of the Optimum Target Point

Although the AC-PC line measurements varied from 22 to 32 mm in this series of 90 cases, with this proportional system of measurement it turned out that the points where tremor was arrested and where sensory or motor responses were obtained had a minimal dispersion in space. Figure 3 A shows the critical area where tremor was arrested. When the electrode placement was deviated only 1 or 2 mm anterior, posterior, medial,
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Fig. 3. Chart of sagittal planes. A. The plane at which the tremor was stopped at the subthalamus (L: 4.8 to 5.8/10). B. A plane just medial to A (L: 4.8/10); at this point the tremor was selectively stopped in the hand. C. Lateral to the target area (L: 5.8/10) only a transient effect on the tremor was observed in two cases. Dark circles represent the position of the tip of the electrode with regard to the AC-PC line at the moment the tremor was arrested; clear circles represent the planes where a temporary arrest of tremor was obtained; the arrows represent the trajectory of the electrodes that produced no modification on the tremor; shaded area is the one where we obtained sensory responses; dotted area is the one of motor responses.

or lateral to this critical area, it did not produce any modification of tremor (Fig. 3 B and C). Whenever a transient effect on tremor was observed, the electrode was close to the target point (Figs. 3 and 4 A, B, C).

**Extension of the Critical Area**

As outlined by the dark circles in Fig. 5 A, the target is not a single point but an area that has continuity and extends obliquely from the 7th to the 9th posterior unit in the anteroposterior direction, and from the AC-PC line 2 units below it vertically. This area is not wider than 2.5 mm in the lateral view and 2 mm in the frontal view. This may explain why the minimal mechanical trauma caused by an electrode that measures slightly more than 1 mm in diameter may arrest tremor only at a very critical point.

In practically all of the cases, arrest of tremor occurred both in the arm and leg si-
FIG. 4. Frontal planes (F) taken at \( A = 8/10, B = 9/10, C = 10/10 \) behind the anterior comissure. The presence of the electrode in the anterior part of the critical area produced a selective arrest of the tremor in the hand when it was medial and in the leg when it was lateral. The relation of the critical area to the areas of sensory and motor responses is illustrated.

multaneously. In one case, tremor stopped in the arm while persisting in the leg, and in another the opposite was true. These two cases corresponded to electrode placements in the anterior part of the target area and are marked in the diagrams with a hand and leg respectively.

Functional Relationship
From those electrode placements located just behind the target area, stimulation evoked sensory responses. From those located anterolateral and/or inferior to the target area, stimulation produced motor responses. These responses allowed us to out-
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Fig. 6. Superimposed on the anatomical sections are our frontal sections. A. 8/10 is superposed on the frontal posterior (FP) 5.0. B. 9/10 is superposed on FP 7.0. C. 10/10 is superposed on FP 9.0. The target point is located in front of the medial lemniscus.

line the functional relationship of the target area as follows: in the lower part the area is located in front and slightly medial to the sensory lemniscus and posterior to the motor fibers; from here it runs just in front of the former and medial to the fibers. As it reaches the AC-PC line, it is further away from the points from which sensory responses are obtained.

Discussion
The most interesting finding in this study

Fig. 7. The area where the tremor was arrested extends caudally medial to the area of sensory responses (Lm), in close relation to the mesencephalic tegmentum (Ttc). A. 3/10 below AC-PC line (HV-6.0). B. Below 4/10 HV-8.5.
was the fact that, once a proportional division of the reference lines on the x-ray was made, the points where tremor was stopped or sensory and motor responses were obtained appeared to be in the same relative position in all 90 cases. This suggests that in this area individual anatomical variations are less pronounced than had been believed. Work in progress seems to confirm this statement not only for the subthalamus but also for the thalamus.16

In Fig. 5, the areas delineated in this study are superimposed on an anatomical map taken from the Schaltenbrand and Bailey atlas, adjusting the intercommissural line according to Talairach's method. The sagittal planes from the 5.0 to 5.8 and 4.6 to 5.0 unit are superimposed. The critical area for the arrest of tremor does not overlap any surrounding structure and remains confined to the prelemniscal radiations. On the contrary, the area where sensory responses were obtained corresponds to the medial lemniscus or its immediate vicinity; the area where motor responses were obtained corresponds to or is very close to the motor fibers in the subthalamic portion of the internal capsule.

In Fig. 6 A, B, and C, the frontal projection is superimposed on the anatomical atlas. The target again corresponds to the prelemniscal radiations (Fig. 6 B). This critical area corresponds precisely to the zone where, using a microelectrode, we have recorded7 electrical cellular activity with an autonomous rhythm of 5 cps. With the same technique, we have also recorded1 autonomous rhythms in a broader area of the thalamus.9

With the frontal parasagittal approach, the introduction of the electrode has never produced arrest of tremor at the thalamic level. This is probably due to the fact that the thalamic relay of the tremorogenic circuit is much larger than the subthalamic one. The topographic arrangement of these related functional areas can be compared to a funnel, with its narrow collar formed by the posterior portion of the subthalamus, and its spreading portion located anterosuperiorly, corresponding to the anterior portion of lateral thalamus.5 At this level, a lesion of several millimeters, such as that produced with the wire leucotome, is needed to obtain the same effect.

From an anatomical point of view this zone does not seem to belong to a specific sensory or motor pathway, for low-voltage monopolar stimulation at the target point does not produce motor or sensory responses.4 This is evidence against the claim that, in order to obtain permanent relief of tremor, it is necessary to involve the pyramidal fibers6 or the afferent sensory pathways.8 On the contrary, it appears to have a specific function in relation to tremor.

The tremorogenic subthalamic area corresponds to the most posterior and inferior limit of the zona incerta. This part of the subthalamus is not well known because it is difficult to make selective lesions for fiber degeneration studies. Nevertheless, it seems to contain ascending fibers from the reticular formation.9-11,13,14,17

If one traces this system lower in the mesencephalon (Fig. 7 A and B) one may see that its fibers come to lie medial to the lemniscus and in close relation to the mesencephalic tegmentum. Further experimental as well as clinical studies are in progress to clarify this point.

Summary

Ninety consecutive cases of Parkinson's disease and tremor of attitude were reviewed from the point of view of the "optimum target," that is, the point where mere introduction of a stimulating electrode arrested tremor. To obtain comparative data, the AC-PC line was divided in 10 equal parts used as units for measurements in all three planes.

In 30 cases, introduction of the electrode produced sudden arrest of tremor, and these points were all situated between 4.8 and 5.8 units lateral to the midline, within the ninth posterior segment or its immediate vicinity and from 0 to 3 units below the intercommissural line. In 10 cases of partial or temporary arrest of tremor, introduction was in the immediate vicinity of the area described above. In the 50 cases outside this zone the tremor was not modified by the introduction of the electrode.

This critical area is located anterior and slightly medial to the sensory lemniscus and posterior to the motor fibers inferiorly, being further in front of the medial lemniscus and
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medial to the motor fibers as it reaches the AC-PC line.

The tremorogenic subthalamic area corresponds to the most posterior and inferior portion of the zona incerta (prelemniscal radiations).

References

Received for publication March 3, 1971.

Dr. Velaso was formerly a research fellow in stereotaxic surgery at the University of Montreal.

Address reprint requests to: Francisco Velasco, M.D., Department of Scientific Research, Division of Neurophysiology, Centro Médico Nacional, IMSS, México, D.F.