Sensory-Motor Responses from the Diencephalon

Electrical Stimulation in Man*

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The object of this study was to determine whether or not various parts of the diencephalon could be functionally differentiated by recording the motor and sensory responses elicited during electrical stimulation. The ultimate purpose of this investigation was to determine the value of electrical stimulation in this part of the brain as a technique of localization in stereotaxic surgery.

Technique

One hundred twenty patients with Parkinson's disease were utilized for this study. Only patients who were capable of answering questions, had intelligible speech, and did not require any systemic sedation or analgesia during surgery were selected. Observation of stimulation effects preceded the placement of lesions in the diencephalon as previously described.  

Operation. Operations were done with patients in the supine position. One per cent Xylocaine was used for local anesthesia of the scalp. The patients remained awake throughout the procedure and were not premedicated. A frontal burr hole, ½ inch in diameter, was placed 1½ cm. from the midline and 7½ to 8 cm. posterior to the glabella. A ventriculogram was performed and utilized for calculating coordinate measurements. These were supplemented with preoperative pneumoencephalograms. A roentgen-ray tube-plate distance of 40 inches was used for both lateral and frontal views. The central beam was directed just above the sella in the lateral view and proper corrections were made for distortions.

Coordinate System of Measurement. Horizontal zero consisted of a plane extending from the mid-posterior margin of the anterior commissure to the anterior margin of the posterior commissure. The frontal zero plane was at a point midway between the anterior and posterior commissure at right angles to the horizontal plane. The sagittal zero plane was identified by a vertical line passing through the center of the 3rd ventricle in the frontal projection. For the purposes of this study, the localizations were expressed in terms of the electrode-tip position. However, it must be emphasized that the electrode was oriented in an approximately 40 degree angle with the horizontal zero plane in the sagittal projection.

Electrical Stimulation. Bi-polar electrical stimulation was used. The electrode tip was a bare metal tube 4 to 8 mm. in length and slightly larger than 1 mm. in diameter with the central electrode projecting 1 mm. from its tip. Thus, the total effective stimulation length of the bi-polar electrode was 5 to 9 mm. in length. A Grass square-wave stimulator was used. The sensory and motor responses utilized were those obtained with the least stimulus strength. Parameters of stimulation consisted of 0.5 to 50 volts with the majority ranging from 3 to 10 volts. A 1-msec. pulse applied for a period of 5 secs. duration was used in all stimulations. All points were evaluated in 3 ranges of frequency: (a) 1 to 5/sec., (b) 50 to 100/sec. and (c) 500 to 700/sec. Most points were evaluated with 5/sec., 60/sec., and 700/sec. The intervals between stimulations varied from 30 seconds to several minutes. The majority ranged between 1 to 3 minutes. The sequence of evaluating a given point with various frequencies was random. Most points were evaluated with 10 to 20 stimulation.

Evaluation of Motor and Sensory Responses. The head, neck and extremities were allowed to remain exposed during the period of stimulation. The observations were made with the patient lying in the supine position with arms, legs and neck extended. Motor movements were observed by the operator and his associates. When necessary, observers were assigned to specific parts of the body in order to determine the details of movements. The sensory experiences of the patient were evaluated by asking the patient, "Did you feel anything?" or "what did you feel?" Care was taken not to ask questions which would be suggestive to the patient. However, after a patient related an experience or a sensory response, specific questions were asked in order to elicit further characteristics of that sensory experience. A sensory experience which obviously was associated with an objective movement of a body part was not considered in this analysis as a sensory response. The character of the sensory and motor responses were immediately recorded following each stimulation.

Sagittal Planes for Presentation of Results. Since

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the long axis of the stimulating electrode is oriented in the sagittal plane and sensory representation in the thalamus has a lamellar orientation, it was thought best to present the results in terms of composite sagittal planes. The coordinate system of Schaltenbrand and Bailey was used. The stimulated points were grouped in 7 composite sagittal planes representing a fixed mm. distance lateral from the midline, as follows: (1) 4 to 5.9; (2) 6 to 7.9; (3) 8 to 10.4; (4) 10.5 to 12.4; (5) 12.5 to 14.4; (6) 14.5 to 17.4; (7) 17.5 to 22.5. The stereotaxic frontal and horizontal extent were not similar for each of the composite sagittal planes (Table 1).

Method of Analysis. Only those points in the brain which gave positive motor or sensory responses were utilized in this study. A given point which produced a motor or sensory response in more than one body part was credited as representing each of those body parts. To evaluate the representation of a given body part in a particular sagittal plane, the percentage of points from which a positive response was obtained for a given body part was calculated. This was obtained by using the total number of points stimulated within that plane as a divisor. The percentages obtained were then plotted and compared. A comparative percentage frequency was then utilized in order to evaluate the degree of body representation in various sagittal planes.

Results

Motor Responses. Movements usually elicited by low frequencies (5 per sec.) were manifest as jerks occurring in rhythm with the stimulation pulse. The movements occurring with the higher frequencies were usually sustained and tonic in character. The higher frequencies in comparison to the lower ones had a tendency to implicate a greater number of body parts simultaneously.

A motor response elicited from a given body part occasionally implicated a contiguous body part during subsequent stimulations of the same point. In such instances, both body parts were credited as representing that point in the analysis. The threshold for eliciting motor responses was lowest in the more lateral sagittal planes. Once a pattern of motor response was established, it invariably was repeatable with very slight, if any variation.

Character of Movement Response. Eyelid responses were primarily those of elevation. Forced eyelid closure was not observed. Ipsilateral head movements consisted primarily of lateral flexions of the neck with occasional concomitant extension and slight rotation. The contralateral head movements were primarily lateral flexion and rotation. Hand movements consisted of total hand or individual finger displacements. Arm movements were combinations of either flexion,

![Figure 1](image_url)

The laterality of motor responses observed in various parts of the body were evaluated in terms of the cumulative percentage of positive points obtained by combining the values of each body part within a given sagittal plane. Refer to Table 1 for the mm. distance, from the midline, represented by each of the 7 sagittal planes. Zero signifies no response.

**TABLE 1**

*Boundaries of stimulated areas in seven composite sagittal planes of the diencephalon*

<table>
<thead>
<tr>
<th>Composite Sagittal Plane (in mm. from midline)</th>
<th>FrONTAL Extent</th>
<th>Horizontal Extent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (4-5.9)</td>
<td>Fp 11 to Fa 5</td>
<td>+2.5 to -5</td>
</tr>
<tr>
<td>2 (6-7.9)</td>
<td>Fp 11 to Fa 2</td>
<td>+0 to -5</td>
</tr>
<tr>
<td>3 (8-10.4)</td>
<td>Fp 11 to Fa 2</td>
<td>+2 to -11</td>
</tr>
<tr>
<td>4 (10.5-12.4)</td>
<td>Fp 12 to Fa 2</td>
<td>+3 to -10</td>
</tr>
<tr>
<td>5 (12.5-14.4)</td>
<td>Fp 12 to Fa 3</td>
<td>+3 to -5</td>
</tr>
<tr>
<td>6 (14.5-17.4)</td>
<td>Fp 12 to Fa 3</td>
<td>+3 to -6</td>
</tr>
<tr>
<td>7 (17.5-22.5)</td>
<td>Fp 5 to Fa 3</td>
<td>+3 to -5</td>
</tr>
</tbody>
</table>

Fp = Frontal Posterior  Fa = Frontal Anterior