AN ANALYSIS OF TREMOR

—ALTERATION OF PARKINSONIAN TREMOR
BY L-DOPA AND SURGICAL TREATMENT—

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Parkinsonian tremor was analysed by accelerometers and electromyogram. Measurement was made during rest, posturing, finger-finger test and finger-nose test of the upper limbs and parkinsonian tremor in different status was characterized by pattern of tremor provocation by above procedures. L-Dopa treatment did not alter parkinsonian tremor markedly, whereas thalamotomy markedly reduced the tremor, especially its resting component. Postoperative residual tremulous movement was dominated by postural and dysmetric components. This residual tremulous movement was correlated to the intrathalamic therapeutic lesions and discussion was made as to the mechanism of tremogenesis.

INTRODUCTION

An analysis of tremor has been handicapped by difficulty in its qualitative and quantitative measurement. Standard textbooks of neurology describe the various kinds of tremor as to their appearance such as pill rolling, fine, coarse, etc. or as to specific situations in which the tremor is characteristically observed and classify the tremor accordingly, i.e., resting, postural, intention, etc. (Mc Dowell and Lee, 1973). This well established classification of tremor is well suited for clinical application and sometimes suggests the possible neurological etiology and localization of the lesions. However, this classification is subjective and unless it is three dimensional and chronological the measurement cannot precisely and objectively tell us subtle qualitative and quantitative change which might undertake after various kinds of treatment.

The measurement of tremor by various kinds of mechanograms is one of the practical ways of knowing very precisely the exact frequencies, relative amplitude and regularity of tremor, and it would enable us to know precisely the alteration of tremor when the patient suffering from tremor is subjected to the various kinds of presumable provocation factors.

In this study parkinsonian tremor under various kinds of mental and mechanical stress was mechanographically analysed and the characteristics of the original tremor and its modification by l-dopa administration and surgical treatment were examined.

METHOD AND CLINICAL MATERIAL

The tremulous movements of the hand were recorded by accelerometers. Two accelerometers were used to record the tremulous movements of the each hand. One of the accelerometer was
applied to the dorsum of the hand and recorded unidirectional accelerating movement of the hand which was vertical to the palm. Another accelerometer was applied to the lateral aspect of the 2nd metacarpal bone rectangular to the above accelerometer and recorded unidirectional accelerating movement which was pararell to the palm and rectangular to the long axis of the metacarpal bone. The EMG of the flexor and extensor muscles of the forearms was simultaneously recorded using surface metallic electrodes in order to verify the presence of hand tremor based on reciprocal contraction of the agonist and antagonist muscles of the forearm. The above obtained electrical input was fed into an EEG apparatus and recorded on paper using ink writing pens with the time constant of 1.5 and 0.05 for accelerometery and EMG respectively. The amplitude of the tremor was arbitrarily classified as minimal, low, low to moderate, moderate, moderate to high, high, and extremely high on accelerometric recordings.

Recordings were obtained from parkinsonian patients who were clinically suffering from tremor. Sixty-seven recordings from 56 tremulous extremities of 34 patients were obtained. These were divided into three groups, i.e., 21 recordings from 15 preoperative patients who were off l-dopa, 25 recordings from 19 preoperative patients who were on l-dopa and 21 recordings from 17 postoperative patients.

With the patient in supine position the tremulous movements were recorded in resting, but in awake state (Rest). And the patient was asked to subtract 7 from 100 successively (Counting), to raise the forearm for 45 degrees without raising the elbow ipsi-, contra- and bi-lateral, respectively, to perform finger-nose test ipsi- and contra-laterally to the examined forearms (FN, I and FN, C—finger-nose test, ipsi- and contra-lateral, respectively) and to perform finger-finger test (FF).

The amplitude of the tremor under above mentioned various provocation tests was examined in each patient group and the characteristics of the original tremor and the modification by l-dopa therapy and surgical treatment were examined. In each patients group the percentage incidence of tremor by different amplitude in various conditions was tabulated. The amplitude was classified into four categories, i.e., none, minimum or more, moderate or more, and high to maximum. Although amplitude of tremor was expressed by arbitrary unit, this classification seemed to correlate very well to the one based on clinical impression. In order to clarify the role of each provocation (or suppression) factor the amplitude of tremor of each extremity among various conditions was compared and the incidence in percentage of larger amplitude in various conditions in comparison to that in rest, counting, ipsilateral half raise of the forearms and ipsilateral finger-nose test was examined.

In 21 postoperative recordings residual tremulous movements were examined and correlated to the localization of the intrathalamic therapeutic lesions, which were determined by reviewing the operative notes and intra-operative X-ray films and were plotted on the Schaltenbrand and Bailey's atlas (1959).

RESULTS

Pertinent data of clinical materials are shown in Table 1. Except for slight
TABLE 1
Clinical materials

<table>
<thead>
<tr>
<th></th>
<th>number of patients</th>
<th>age mean ± s.d.</th>
<th>sex male/female</th>
<th>number of extremities*</th>
</tr>
</thead>
<tbody>
<tr>
<td>group without l-dopa</td>
<td>15</td>
<td>57.5 ± 10.9</td>
<td>9/ 6</td>
<td>21 (11)</td>
</tr>
<tr>
<td>group with l-dopa</td>
<td>19</td>
<td>56.6 ± 9.1</td>
<td>10/ 9</td>
<td>25 (12)</td>
</tr>
<tr>
<td>group with thalamotomy</td>
<td>17</td>
<td>54.1 ± 10.0</td>
<td>9/ 8</td>
<td>21 (15)</td>
</tr>
<tr>
<td>total patients</td>
<td>34</td>
<td>57.4 ± 9.8</td>
<td>19/15</td>
<td>56 (30)</td>
</tr>
</tbody>
</table>

* Parenthesis indicates the number of right extremities.

predominance of the right upper extremities in post-thalamotomy group these three groups seemed to be well matched. The male patient was slightly more affected by parkinsonian tremor. The same patient could belong to more than two groups depending on his status at the time of measurement or by different status of extremities between the right and left, and so there was a discrepancy between the simple addition of number of patients and extremities in three groups and the number which appears in "total patients".

The incidence of tremor by amplitude in various conditions in three groups appears in Tables 2 through 4, and the incidence of higher amplitude tremor in various conditions relative to that in resting, half raise and finger-nose test of the ipsilateral upper limb is shown in Tables 5 through 7.

TABLE 2
Incidence of tremor by amplitude in various conditions in patients group without l-dopa treatment

<table>
<thead>
<tr>
<th>amplitude</th>
<th>resting (21)</th>
<th>counting (21)</th>
<th>1/2R. I (21)</th>
<th>1/2R. C (21)</th>
<th>1/2R. B (21)</th>
<th>FN, I (21)</th>
<th>FN, C (20)</th>
<th>F-F (19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 &lt;</td>
<td>85.7</td>
<td>100.0</td>
<td>66.7</td>
<td>71.4</td>
<td>66.7</td>
<td>90.5</td>
<td>80.0</td>
<td>89.5</td>
</tr>
<tr>
<td>moderate</td>
<td>52.4</td>
<td>66.7</td>
<td>23.8</td>
<td>42.9</td>
<td>19.0</td>
<td>23.8</td>
<td>35.0</td>
<td>26.3</td>
</tr>
<tr>
<td>high</td>
<td>9.5</td>
<td>38.1</td>
<td>0.0</td>
<td>14.3</td>
<td>4.8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

( ) : actual number of measurements.
For abbreviations see text.

In patients group without l-dopa or thalamotomy the following observation was noted (Tables 2, 5). When the patient was at rest, but fully awake, some degree of tremor was noted in 85.7 % of cases, of which 9.5 % was of high or maximum amplitude (Table 2). On counting incidence of tremor rose up to 100.0 % and high or maximum tremor was noted in 38.1 %. On half raise of the forearm contralateral to the hand being examined, almost same amount of tremor was noted as in resting state. Less, but significant tremor was noted on half raise of the ipsilateral forearm, finger-nose test of the ipsi- and contralateral upper limbs and on finger-finger test than in resting state, and low amplitude tremor was relatively preva-
lent in the former four conditions. On half raise of the bilateral forearms less tremor was noted than in resting state, but there was 4.8% of high or maximum amplitude tremor in this condition. When the incidence of higher amplitude tremor in various conditions relative to resting and counting was examined, some of the above trends became more apparent (Table 5). When compared to the resting state the incidence of higher amplitude tremor was low in all other conditions except counting in which it was 85.7%. When compared to the counting the incidence of higher amplitude in other conditions was very low. This indicated that the state of being awake and mental stress inflicted by counting were two most important provoking factors in non-treated parkinsonian tremor although contribution of other conditions currently examined was not negligible for tremor provocation. When tremor in half raise of the ipsi- and contra-lateral forearm was compared, tremor was more prevalent in the latter condition and there was 66.7% incidence of higher amplitude tremor in half raise of the contralateral forearm than of the ipsilateral (Tables 2, 5). This means that muscular exertion necessary to raise the ipsilateral forearm is either suppressive or less provocative in non-treated parkinsonian tremor.

TABLE 3
Incidence of tremor by amplitude in various conditions in patients group with l-dopa treatment

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0 &lt; moderate</td>
<td>68.0</td>
<td>100.0</td>
<td>92.0</td>
<td>84.0</td>
<td>83.3</td>
<td>100.0</td>
<td>76.0</td>
<td>96.0</td>
</tr>
<tr>
<td>high</td>
<td>32.0</td>
<td>48.0</td>
<td>32.0</td>
<td>36.0</td>
<td>29.2</td>
<td>40.0</td>
<td>24.0</td>
<td>44.0</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

( ) : actual number of measurements.
For abbreviations see text.

In l-dopa treated group same tendency was noted as in non-treated group, but tremor seemed to be slightly more prevalent in half raise of the ipsi- and bi-lateral forearms, finger-nose test of the ipsi- and contra-lateral upper limbs and in finger-finger test than in non-treated group (Table 3). When relative amplitude was examined incidence of higher amplitude tremor relative to resting and counting was slightly higher in virtually all other maneuvers in this group as compared to the group without treatment (Table 6). When tremor in half raise of the ipsi- and contra-lateral forearms was compared, tremor was still prevalent in the latter condition, but the incidence of higher amplitude tremor in half raise of the contralateral forearm was decreased to 40.0% in l-dopa treated group (Table 6). So that although muscular exertion in l-dopa treated patient might become more provocative or less suppressive than in non-treated group, overall prevalence and pattern of provocation of tremor did not seem to be altered markedly by l-dopa treatment.

In post-thalamotomy group marked reduction in prevalence of tremor in
### TABLE 4

**Incidence of tremor by amplitude in various conditions in patients group with stereotaxic thalamotomy**

<table>
<thead>
<tr>
<th>amplitude</th>
<th>incidence (%)</th>
<th>resting (21)</th>
<th>counting (21)</th>
<th>1/2R. I (21)</th>
<th>1/2R. C (21)</th>
<th>1/2R. B (21)</th>
<th>FN. I (21)</th>
<th>FN. C (21)</th>
<th>F-F (21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0&lt; moderate</td>
<td></td>
<td>9.5</td>
<td>38.1</td>
<td>57.1</td>
<td>19.0</td>
<td>55.0</td>
<td>90.5</td>
<td>23.8</td>
<td>90.5</td>
</tr>
<tr>
<td>high</td>
<td></td>
<td>0.0</td>
<td>9.5</td>
<td>14.3</td>
<td>4.8</td>
<td>20.0</td>
<td>9.5</td>
<td>0.0</td>
<td>4.8</td>
</tr>
</tbody>
</table>

( ) : actual number of measurements.
For abbreviations see text.

### TABLE 5

**Incidence of higher amplitude tremor in various conditions when compared to each of four conditions in patients group without L-dopa treatment**

<table>
<thead>
<tr>
<th>&quot;Four Conditions&quot;</th>
<th>incidence (%)</th>
<th>resting (21)</th>
<th>counting (21)</th>
<th>1/2R. I (21)</th>
<th>1/2R. C (21)</th>
<th>1/2R. B (21)</th>
<th>FN. I (21)</th>
<th>FN. C (21)</th>
<th>F-F (19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>rest</td>
<td></td>
<td>-</td>
<td>85.7</td>
<td>14.3</td>
<td>19.0</td>
<td>14.3</td>
<td>38.1</td>
<td>30.0</td>
<td>31.6</td>
</tr>
<tr>
<td>counting</td>
<td>9.5</td>
<td>-</td>
<td>4.8</td>
<td>0.0</td>
<td>0.0</td>
<td>19.0</td>
<td>5.0</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>1/2R. I</td>
<td>76.2</td>
<td>90.5</td>
<td>-</td>
<td>66.7</td>
<td>23.8</td>
<td>66.7</td>
<td>45.0</td>
<td>47.4</td>
<td></td>
</tr>
<tr>
<td>FN. I</td>
<td>52.4</td>
<td>76.2</td>
<td>14.3</td>
<td>42.9</td>
<td>23.8</td>
<td>-</td>
<td>25.0</td>
<td>15.8</td>
<td></td>
</tr>
</tbody>
</table>

( ) : actual number of measurements.
For abbreviations see text.

### TABLE 6

**Incidence of higher amplitude tremor in various conditions when compared to each of four conditions in patients group with L-dopa treatment**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>rest</td>
<td></td>
<td>-</td>
<td>76.0</td>
<td>48.0</td>
<td>48.0</td>
<td>50.0</td>
<td>64.0</td>
<td>40.0</td>
<td>56.0</td>
</tr>
<tr>
<td>counting</td>
<td>0.0</td>
<td>-</td>
<td>12.0</td>
<td>8.0</td>
<td>12.5</td>
<td>32.0</td>
<td>4.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>1/2R. I</td>
<td>32.0</td>
<td>64.0</td>
<td>-</td>
<td>40.0</td>
<td>20.8</td>
<td>48.0</td>
<td>32.0</td>
<td>48.0</td>
<td></td>
</tr>
<tr>
<td>FN. I</td>
<td>24.0</td>
<td>48.0</td>
<td>4.0</td>
<td>24.0</td>
<td>4.2</td>
<td>-</td>
<td>16.0</td>
<td>16.0</td>
<td></td>
</tr>
</tbody>
</table>

( ) : actual number of measurements.
For abbreviations see text.
resting and counting was noted (Table 4). Although tremor was more prevalent in counting than in resting, the study of relative amplitude indicated that incidence of higher amplitude in counting as compared to the resting state was only 33.3% in this group. Despite residual presence of low amplitude tremor, marked reduction in prevalence of tremor was also noted in half raise and in finger-nose test of the contra-lateral upper limb, in neither of which conditions no direct muscular exertion was required in the limbs examined. On the other hand in conditions in which direct muscular activity was essential, i.e., half raising of the ipsi- and bi-lateral forearms, finger-nose test of the ipsilateral upper limb and finger-finger test, tremor was prevalently noted. The relative amplitude study also showed high incidence of higher amplitude tremor in above conditions in which muscular exertion was needed when compared to resting and even counting (Table 7). Also noted was only 4.8% incidence of higher amplitude tremor in half raising of the contra-lateral upper limb as compared to half raise of the ipsilateral. Also noted was 4.8% incidence of higher amplitude tremor in finger-nose test of the contra-lateral upper limb as compared to that in finger-nose test of the ipsilateral. So that in postoperative cases tremor was markedly reduced in non-exersional conditions, but seemed to be relatively persistent in exersional state and possibly in precision procedures with resultant change in tremor provocation pattern, although overall surgical effect was clinically satisfactory.

### TABLE 7

**Incidence of higher amplitude tremor in various conditions when compared to each of four conditions in patients group with stereotaxic thalamotomy**

<table>
<thead>
<tr>
<th>&quot;Four Conditions&quot;</th>
<th>resting (21)</th>
<th>counting (21)</th>
<th>1/2 R, I (21)</th>
<th>1/2 R, C (21)</th>
<th>1/2 R, B (20)</th>
<th>FN, I (21)</th>
<th>FN, C (21)</th>
<th>F-F (21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>rest</td>
<td>–</td>
<td>33.3</td>
<td>57.1</td>
<td>14.3</td>
<td>55.0</td>
<td>85.7</td>
<td>23.8</td>
<td>85.7</td>
</tr>
<tr>
<td>counting</td>
<td>0.0</td>
<td></td>
<td>42.9</td>
<td>14.3</td>
<td>45.0</td>
<td>66.7</td>
<td>14.3</td>
<td>66.7</td>
</tr>
<tr>
<td>1/2 R, I</td>
<td>0.0</td>
<td>19.0</td>
<td></td>
<td>4.8</td>
<td>10.0</td>
<td>61.9</td>
<td>4.8</td>
<td>57.1</td>
</tr>
<tr>
<td>FN, I</td>
<td>0.0</td>
<td>9.5</td>
<td>23.8</td>
<td>9.5</td>
<td>25.0</td>
<td>–</td>
<td>4.8</td>
<td>19.0</td>
</tr>
</tbody>
</table>

( ) : actual number of measurements.
For abbreviations see text.

According to a pattern of contribution of each provocative factor postoperative residual tremor was further categorized into three group.

**Group 1**: No resting tremor. In this group no tremor was noted either in resting or in counting although tremor might be seen in other conditions. Thirteen postoperative extremities were noted in this group.

**Group 2**: Dysmetric type. The tremor in this group was characterized by dysmetric or non-dysmetric tremulous movement on finger-nose test of the ipsilateral upper limb while the tremor in half raise of the ipsilateral upper limb was either absent or minimally present. There were 9 extremities in this group.

**Group 3**: Postural type. This group
was characterized by presence of tremor of higher amplitude on half raising of the ipsilateral forearm than on raising of the contralateral forearm and absence of grossly dysmetric movement on finger-nose and finger-finger tests. There were 9 extremities in this group.

Location of intrathalamic therapeutic lesions on the Schaltenbrand-Bailey's Atlas (1959) in each group was examined (Table 8). No solitary lesions confined to the v. o. a. nucleus were noted and these were always accompanied by lesions in either v. o. p. or V. im. nucleus. The tremor in rest and in counting seemed to be equally well controled by v. o. p. and V. im. lesions. When groups 2 and 3 were compared, there was a preponderance of V. im. lesions in the dysmetric group and v. o. p. lesions in the postural group although the difference was not statistically significant (P = 0.12).

**TABLE 8**

*Location of intrathalamic therapeutic lesions in each group*

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of extremities</th>
<th>VOA</th>
<th>VOP</th>
<th>VIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (no resting tremor)</td>
<td>13</td>
<td>3 (23.1)</td>
<td>10 (76.9)</td>
<td>6 (46.2)</td>
</tr>
<tr>
<td>Group 2 (dysmetric type)</td>
<td>9</td>
<td>1 (11.1)</td>
<td>4 (44.4)</td>
<td>7 (77.8)</td>
</tr>
<tr>
<td>Group 3 (postural type)</td>
<td>9</td>
<td>1 (11.1)</td>
<td>7 (77.8)</td>
<td>3 (33.3)</td>
</tr>
</tbody>
</table>

Number in parentheses are percentages.

**DISCUSSION**

Tremor has been measured by various methods. These include cinematography (Cooper, 1969), EMG (Bishop et al., 1948; Cooper, 1969; Lance et al., 1963), accelerometer (Boshes, 1966; Cooper, 1969; Lance et al., 1963; Salzer, 1972), small core wound with wire placed in the magnetic field (Nashold, 1966), optical system (Paci et al., 1973), pulse generated by involuntary contacts of the stylus (Karkalas et al., 1972), and Eck work adder on a spring-balanced platform (England and Schwab, 1961). These are designed to measure rate, extent and orientation of tremulous movements. In this study accelerometer and surface EMG were used, both of which are probably the most commonly and conveniently in use today for the measurement of tremulous movements. In this presentation particular emphasis was made to elucidate how the tremulous movement would be modified by various provoking or suppressive procedures and to find out importance of each provoking factor in tremor generation. This allowed us more comprehensive classification and characterization of parkinsonian tremor. Tremor is a dynamic phenomenon and is influenced by so many factors on the part of the patients that, unless this dynamic characteristics are taken into consideration, it will defy efforts for quantitative and qualitative measurement (Bishop et al., 1948; Cordeau et al., 1960; Lance et al., 1963; Schwab and Young, 1972).

The current data indicated the prevalence of tremor in resting, but awake state and the tremor became even more prominent on counting. This justifies the classification of parkinsonian tremor to be of resting type. However, as DeJong (1926) pointed out, parkinsonian tremor is usually absent...
in “complete rest” i.e., when the patient is asleep, and the state of being awake can be sufficient for activating tremor generating mechanism. In this sense parkinsonian tremor is of “action” type which is provoked by state of being awake and further more by mental stress, and the intensity of tremor is determined by vulnerability of the individual parkinsonian patient to various tremor provocative “actions” (Dejong, 1926).

The current data indicated parkinsonian tremor was also observed in posturing of the forearm, but since it was more prevalent in raising of the contralateral forearm than in raising of the ipsi- or bilateral forearms, it is presumed that input from peripheral proprioceptive mechanisms involved in posturing of the forearm is important in tremor provocation and muscular exersion necessary to raise the ipsilateral forearm itself acts rather as suppressive for tremogenesis.

Relative scarcity of tremor in finger-nose and finger-finger tests indicates that the component of peripheral input from these dynamic and precision procedures is less important in tremor provocation.

These phenomena could be explained by effect of change in muscle tone on production and modification of tremor (Narabayashi, 1972), but the author is more inclined to stress the importance of peripheral input for production of parkinsonian tremor, be it psychological stress or tonic or dynamic proprioceptive activity, that will possibly result in change in general alertness and ultimately in muscle tonus. For tremor mechanism most seem to postulate disturbed servomechanism (Bucy, 1942; Cooper, 1969). The current data disclosed how parkinsonian tremor was affected by different kinds of peripheral inputs into this servomechanism. There are two kinds of anatomicophysiological receptors in gamma afferent system that respond to tonic and dynamic stretching (A and B receptors) which might correspond to responsible mechanism for peripheral input from posturing and precision procedures currently examined (Copper, 1969; Patton, 1965). It was recently reported that thalamic and subthalamic lesions for control of tremor resulted in a state of “inattention” in the contralateral hand, which was clinically manifested by neglect of the use of the treated hand for manipulation and exploration (Velasco and Velasco, 1979). The corticoreticulo-cortical pathway involving the thalamus was proposed for this proprioceptive attention. This motor inattention and the role of thalamic mechanism in maintenance of attention and alertness might be the underlying mechanism for current data (Ojemann, 1979).

On the other hand the final common pathway of this tremor mechanism to reach spinal cord seems to be corticospinal tract. This was evidenced by data from the therapeutic effects on tremor obtained by section or ablation of the corticospinal tract at various levels (Bucy, 1942) and by elimination of tremor by intracarotid injection of Amytal (Obrador et al., 1961). On experimental setup Cordeau et al. (1960) noted tremor synchronized burst discharge in cerebral sensorimotor cortex in tremor monkey with midbrain lesion. So that the tremor mechanism seems to lie in structures which link this sensory input system and the corticospinal tract.

Parkinsonians are known to have degenerative lesions pathologically and biochemically located in the substantia nigra and its efferent dopaminergic pathway to the striatum (Greenfield and Bosanquet, 1953; Heath, 1947; Hornykiewicz, 1963; Yoshida, 1975).
This implies direct involvement of these structures in the tremor mechanism. However, l-dopa therapy is very effective for rigidity, but less effective for tremor as current data indicated (Mosso and Rand, 1975; Nitter, 1974; Ojemann and Ward, 1971), and there is a difference in effect on tremor of lesions in the thalamus and the globus pallidus (Cooper, 1965; Selby, 1968), the latter receiving afferent fiber from the striatum (Nauta, 1966). It was reported that tremor in monkey produced by VMT lesion was abolished by VL lesion, however, dopamine deficient state in the striatum produced by ipsilateral VMT lesion was not relieved by VL lesion (Battista et al., 1969). All these findings suggest that the nigrostriatal system is closely related to, but not directly participating in tremor mechanism. Moreover this dopaminergic nigrostriatal system is an inhibitory one (Yoshida, 1975) and it is more likely that this system gives some bias to the tremor generating mechanism and tremor is produced as a possible release phenomenon by degeneration of this nigrostriatal system.

The lesion in the brain stem tegmentum is well known for tremor production in animal experiments (Cordeau, 1961; Cordeau et al., 1960; Kaelber, 1963; Poirier, 1966). Tremor was also elicited on stimulation of the mesencephalic or pontine tegmentum after lesion was made in the mesencephalic tegmentum (Wycis et al., 1957). According to Poirier (1966) the anatomical structures in brain stem tegmentum responsible for experimental tremor production in monkeys were combined destruction of the pars compacta of the substantia nigra and the rubro tegmental grey area or else with the interruption of their respective efferent pathways. The tremor produced in monkeys by this lesion was reported to be more like parkinsonian tremor in human subjects (Cordeau, 1961; Cordeau et al., 1960; Poirier, 1966; Wycis et al., 1957) and was similarly abolished by VL lesions as mentioned above (Battista et al., 1969). Exact mechanism for production of tremor by these lesions is not clear, but since these are destructive lesions, it might as well be explained by release phenomenon of tremor mechanism which is situated elsewhere in telencephalic or diencephalic region (Cordeau, 1961; Kaelber, 1963).

It is of interest that each component of currently characterized parkinsonian tremor was differentially affected by intrathalamic therapeutic lesions when postoperative tremor was examined, and further that there was a tendency of preponderance of v.o.p. and V.im. lesions in the groups of patients with postoperative residual tremor of "postural" and "dysmetric" types respectively. This suggests that these two nuclei are functionally different and are important as a site of possible entry of two different sensory inputs (Bertrand and Jasper, 1965; Narabayashi, 1968).

Using semi-microelectrodes the Montreal group found, in the vicinity of V.im. nucleus, cells which responded to deep sensations of muscle tension and joint movement of the contralateral limbs (Bertrand and Jasper, 1965; Bertrand et al., 1967; Bertrand et al., 1969). These findings were also noted by others and the existence of so called kinesthetic cells in V.im. nucleus seems to be well established (Albe-Fessard et al., 1966; Ohye et al., 1972). Some of these kinesthetic cells with rather static character were exclusively activated during voluntary contraction, passive stretching or manual compression of a given muscle, while others with dynamic character during active or passive flection or extension of a
joint, but only during actual movement (Bertrand and Jasper, 1965). It might be speculated from current data that the former group of cells are located more anteriorly in the vicinity of v.o.p. and the latter more posteriorly in V.im. This seems to be compatible with data presented by Bertrand et al. (1967) who noted difference in localization of these two kinds of kinesthetic cells.

Presence of postural and action or dysmetric components in postoperative residual parkinsonian tremor in the absence of resting tremor in current data may be a result from possible adverse effects on these kinesthetic cells in the v.o.p. and V.im. nuclei. This speculation is supported by the previous report in which similar postoperative residual tremulous movement was noted after v.o.p. and/or V.im. lesions regardless of difference in type and etiology of preoperative tremor (Yoshida et al., 1976/77). It might be that these postoperative tremulous movements are based on entirely different mechanism from that of preoperative parkinsonian tremor, and if, on rare occasion, this sort of tremor is encountered in clinical setup, it might defy treatment by V.im. or v.o.p. lesions.

Semi-microelectrode exploration also revealed rhythmic burst discharge which might or might not be synchronous with tremor of the contralateral extremities (Albe-Fessard et al., 1966; Bertrand and Jasper, 1965; Bertrand et al., 1969; Ohye et al., 1972). Although there exists controversy in regard to the synchronousness of this burst discharge with peripheral tremor and hence its true relation to tremor (Albe-Fessard et al., 1966; Bertrand et al., 1969; Ohye et al., 1974), clinically significant alleviation of tremor by V.im. and/or v.o.p. lesions in virtually all types of tremor of various etiologies (Cooper, 1969) suggests direct participation of these nuclei in the hypothetical tremogenic mechanism as an important key structures in the majority of cases with clinically recognized tremor (Albe-Fessard et al., 1966; Bertrand and Jasper, 1965).

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REFERENCES


