The Use of Bony Landmarks of the Skull for Localization of the Anterior-Posterior Commissural Line*

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The procedure of ventrolateral thalamotomy is being widely used in the treatment of extrapyramidal disorders. In most neurosurgical centers, the method of locating the "target" nucleus involves air encephalography. There are many reasons why it would be desirable to eliminate the instillation of air from the procedure: 1) the potential danger for the patient (especially in view of the known electrocardiographic changes and the advanced age of many of the patients); 2) the "damping" of the involuntary movements often observed following the instillation of air; 3) the decreased level of awareness of the patient—who is later asked to report experiences during stimulation; 4) the vagaries of filling the ventricular system and the occasional technical difficulties in performing the air study; 5) the lengthening of the total procedure; and 6) the variable, but always present, absorption of part of the air during the procedure.

Despite these disadvantages, ventricular air is used almost universally. The basic reason for this is related to the variability of the human skull and the inconstancy of a readily visualized pineal body. Because of this variability, attempts to use bony landmarks in stereotaxic procedures have been almost abandoned and most of the work in the field of stereoecephalotomy has been in the refining of methods using intraventricular air or occasionally Thorotrust.

The purpose of the present study is to define some bony landmarks which have been used successfully together with careful physiological testing of responses to stimulation in the procedure of ventrolateral thalamotomy. The basic landmarks (Figs. 1 and 2) important in the method are: 1) the "notch" or acute angle formed by the junction of the base of the frontal fossa and the descending anterior wall of the frontal fossa (designated hereafter as AN) and 2) the superior tip of the posterior clinoid processes (designated C). It has been the empirical observation of one of us (G.A.) that the line connecting these points has a fairly constant relationship to the line connecting the anterior and posterior commissures (AC-PC line). The ventrolateral nucleus of the thalamus is quite near the midpoint of, and slightly superior to, the AC-PC line. 8

Method

Measurements of distances and angles were carried out originally on the roentgenograms of 32 patients on whom air studies had been done—16 of them in connection with ventrolateral thalamotomy or chemo-pallidectomy. The air studies were normal with the exception of moderate ventricular enlargement secondary to cerebral atrophy in 12 cases. It was recognized early that the data from the 6 patients under 50 years of age increased significantly the variability of the data and for that reason the final statistics are based on a population of 26 patients over 50 years of age with a mean age of 58.1. This implies that if the results of this study are applied to patients under 50, the error is slightly greater than that shown in our analysis.

The distance between the roentgen-ray tube and the patient is standardized at 40-42 inches; the distance between patient and film, unfortunately, was not standardized in these films which were taken over a number of years. The cassette was normally not against the patient's head and this accounts for our values being slightly larger than those of others. To use the method presented here, the mean distances should be measured on some films taken by whatever roentgenographic technique is being used. The effect of not having

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Localization of Anterior-Posterior Commissural Line

The intercommissural line was established as follows: the center of the anterior commissure was taken as 1 mm. anterior to the anterior border of the midportion of the foramen of Monro. The posterior commissure was located by measuring 4.5 mm. anteriorly from the center of the pineal calcification (along the AC-pineal line) then projecting a line perpendicularly and in an inferior direction for 4.0 mm. Obviously, any other consistent method of defining the anterior commissure and posterior commissure would not affect the variability of the data presented—only the absolute values would be different.

Using the above-mentioned landmarks (i.e. the "anterior notch," the superior tip of the posterior clinoid, and the intercommissural line), five distances and one angle were measured, as shown in Figs. 1 and 2. Initially, line AN-C is drawn. Then a perpendicular line is drawn on that line at a point from which it will extend to the center of the floor of the sella (this line divides the sella into two sections of equal area). The line (FS-G) is extended superiorly at least 30 mm. from AN-C. Next the intercommissural line is drawn, and the following measurements are made:

1) Angle Y—the angle formed by the AC-PC line and a perpendicular line from the AN-C line.
2) FS to AC-PC—distance from the floor of the sella to the AC-PC line.
3) O to P—the distance from the extension of line AN-C to the pineal calcification.
4) FS-G line to AC—the distance from the FS-G line (as described above) to the anterior commissure.

FIG. 2. Diagram showing measurements made on a series of films from air studies. See text for explanation.

5) E to AC-PC—the distance from AN-C to AC-PC as measured along the perpendicular FS-G line.
6) AC-PC—the measured distance from AC to PC.

Results

The results of the measurements in terms of means, standard deviations and standard deviation of the means* are shown in Table 1.

Discussion

The usefulness of the measurements depends on whether or not the observed variability is prohibitive as compared with other methods. There is variability in all of the presently used methods, as is demonstrated

* As given by \( \sigma_M = \frac{\sigma_x}{\sqrt{N}} \) (so 95 per cent of means of other samples would fall within \( \frac{\sigma_x}{2\sqrt{N}} \)).

TABLE 1

Results of measurements of roentgenograms in which the foramen of Monro and/or the pineal calcification were visualized

<table>
<thead>
<tr>
<th>Measurement</th>
<th>No. of Measurements</th>
<th>Mean (mm.)</th>
<th>Standard Deviation S.D. (mm.)</th>
<th>Standard Deviation of Mean S.D. (mm.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle Y</td>
<td>22</td>
<td>95.0°</td>
<td>2.41°</td>
<td>1.15°</td>
</tr>
<tr>
<td>FS to AC-PC line</td>
<td>23</td>
<td>34.2</td>
<td>2.08</td>
<td>0.56</td>
</tr>
<tr>
<td>E to PC line</td>
<td>23</td>
<td>25.4</td>
<td>2.82</td>
<td>0.79</td>
</tr>
<tr>
<td>FS-G line to AC</td>
<td>25</td>
<td>1.4</td>
<td>2.83</td>
<td>0.57</td>
</tr>
<tr>
<td>E to AC-PC line</td>
<td>25</td>
<td>23.5</td>
<td>2.27</td>
<td>0.45</td>
</tr>
<tr>
<td>AC-PC line</td>
<td>22</td>
<td>30.2</td>
<td>3.54</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Fig. 1. Lateral roentgenogram of skull showing bony landmarks used. AN = anterior notch. C = tip of posterior clinoid process. P = pineal body.
Fig. 3. Diagram showing the expected inferior-superior variation (X) of T' from T when the pineal body is not visualized.

by the excellent studies of Spiegel and Wycis, which include studies of autopsy specimens and roentgenograms. Because there is an unavoidable variability in the position of the ventrolateral nucleus in relation to the intercommissural line (and the midline), any attempt to define its position by measurements involves a statement of probabilities. When the final position of the electrode is chosen, the operator is, in effect, stating that this is the most probable position of the nucleus.

With elementary arithmetic and the theory of probability we can state in simple terms the amount of "inaccuracy" involved in using the above measurements for calculating the position of the ventrolateral nucleus on lateral roentgenograms. It can be seen from Table 1 that the number of observations is significantly large in relation to the variance so that the means are quite reliable. Based on the means and the assumption that 68 per cent of the measurements will be within one standard deviation, we can use the data to: 1) plot the midpoint of the intercommissural line in the case in which the foramen of Monro and anterior commissure are visualized with the use of air, but no pineal calcification is seen; 2) plot the same point in the case in which the pineal calcification is visualized and no intraventricular air is used; and 3) plot the same point in the case in which no air is used and the pineal calcification is not visualized.

I. To plot the midpoint of the intercommissural line in the case in which the foramen of Monro and anterior commissure are visualized by using air, but no pineal calcification is seen (Figs. 1 and 2). This calculation involves the use of the angle designated "Y" in the above measurements. A perpendicular line is made from the AN-C line to AC; from this line (at AC) a line is projected posteriorly at an angle of 85°; i.e. the value of angle Y. At first glance, the standard deviation (S.D.) of 5.41° (or 5° 24') seems large; however, the effect of this variability on the calculation of the target position is not excessive because of the small radius involved. If the acute angle formed by the AC-PC line and a line perpendicular to line FS-G is designated as angle θ (which is equal to 90°—angle Y), then the superior-inferior variation of the plotted target may be calculated by using $\sin \theta = x/(AC-T')$—where $x$ is the expected variation from the "true" location of the target and AC-T' is one-half the mean AC-PC distance (Fig. 3). Using this formula, $X = 2.7$ mm. for one S.D.: that is, the plotted T' will fall within 2.7 mm. of "true" T (the target as plotted when both AC and the pineal calcification are visualized) in 68 per cent of the cases.

To plot the anterior-posterior position of T', the mean of the measured AC-PC line is used and the mean of

$$AC-T' = \frac{\text{mean AC-PC line}}{2} = 15.1 \text{ mm.*}$$

with

$$\text{S.D.} = \frac{\text{S.D. of AC-PC line}}{2} = 1.77 \text{ mm.}.$$  

The plotted anterior-posterior position of T' will fall within 1.77 mm. of T in 68 per cent of the cases.

II. To plot the midpoint of the AC-PC line (T'), in the case in which the pineal calcification is visualized but the foramen of Monro is not visible. Lines AN-C and FS-G

* The method of arriving at PC in relation to P will not affect the variability but will slightly affect the mean AC-PC distance used.
are constructed as shown in Figs. 1 and 2 and the AC' is plotted at a point 23.5 mm. above AN-C as measured along the FS-G perpendicular (this is the mean "E to AC-PC line" distance given in Table 1 and the S.D. is 2.27 mm.) and 1.4 mm. posterior to the FS-G line. The PC is then plotted in its fairly constant relation to the pineal calcification (see above) and a line is drawn from PC to AC'. The midpoint of this line is T', or the plotted target. It can be seen from Fig. 4 that the variation of T' in the superior-inferior plane is one-half that of the "E to AC-PC line" measurement since triangles PC, Q, R and PC, W, Z are similar triangles and PC-T'=(AC-PC)/2. From this, it is seen that 68 per cent of the measurements of T' will fall within 1.14 mm. of T.

The anterior-posterior position is again plotted by using one-half of the mean of the measured AC-PC lines as in "T" above and once again 68 per cent of the measurements of T' will fall within 1.77 mm. of T.*

III. To plot the midpoint of the AC-PC line in the case in which neither the foramen of Monro nor the pineal calcification is visualized. The AN-C line and FS-G perpendicular line are drawn as described above.

* The degree to which these measurements are affected by the known variability in the AC-PC distance is negligible.

A distance of 23.5 mm. is measured from point E superiorly along the FS-G line to point K (Fig. 5). From this point, a perpendicular line is drawn to extend 1.4 mm. (the mean FS-G to AC distance) posterior to K; this is AC', or the plotted position of the anterior commissure. From AC', a perpendicular is dropped to AN-C (this line is parallel to E-K). Then the procedure is carried out exactly as in "T" above, using AC' instead of AC.

The error of T' in the superior-inferior plane involves that resulting from the variability of the E to AC-PC distance and of angle Y. One S.D. of angle Y introduces an error of 2.7 mm.; one S.D. of the E to AC-PC distance either adds or subtracts a variation of 2.27 mm. These errors will, of course, be additive in 25 per cent of cases. The probability of both measurements being one S.D. from the mean in the same direction so as to directly add to each other (and produce an error of 4.97 mm.) is (1/6 X 1/6) + (1/6 X 1/6) or 1/18. Furthermore, since 40 per cent of the values will fall within ½ S.D. of the mean, the chance of both measurements varying from their means by ½ S.D. in the same direction is 0.18. That is, 82 per cent of the time, T' will be within 2.5 mm. of T in the superior-inferior direction.

By the same reasoning, the expected varia-
tion of $T'$ from $T$ in the anterior-posterior direction may be calculated using the S.D. of the FS-G line to AC measurement and one-half of the S.D. of the AC-PC line measurement (one-half because the line is bisected as above). In this case, 17 out of 18 times $T'$ will fall within 4.6 mm. of $T$ and 82 per cent of the time it will be within 2.3 mm. of $T$.

The use of this method in cases in which either the pineal calcification or the anterior commissure (or foramen of Monro) is seen, involves a sufficiently small error to make it practical—especially in the former instance. Its use in patients in whom neither the pineal body nor the foramen of Monro is visualized involves a degree of error which may seem excessive in all but special instances. (We have used this method successfully in cases in which the anterior commissure was not visualized by air.) It is hoped that refinement of the technique will reduce the error, and that additional attempts at utilization of bony landmarks will produce measurements with even less variability. Again, it must be emphasized that the use of this technique is suggested only for stereoeencephalotomy in conscious patients.

Summary

1. A series of measurements, with their means and standard deviations, was carried out on a group of roentgenograms in which either the pineal calcification or the foramen of Monro or both were seen.

2. A method is presented of plotting the midpoint of the intercommissural line on films when either the anterior commissure, the pineal body, or both are not visualized, and the computations of the error involved in each instance are discussed.

References