62

Reprinted from THE ANATOMICAL RECORD
Vol. 146, No. 1, May 1963

Spatial Variations between Certain Cranial and Cerebral Structures and the Anterior and Posterior Commissures of the Living Human

STEVEN BAUSERMAN,[1] RUSSELL MEYERS[1] AND WILLIAM J. FRY[2]
State University of Iowa, Iowa City, Iowa and University of Illinois, Urbana, Illinois

ABSTRACT Recorded are the quantitated empirical findings and statistical variations of spatial configurations prevalent among certain cranial and cerebral structures related to the intercommissural line as encountered in 50 stereotactically-performed, radio-opaque lateral ventriculograms of the living human. A physicomathematical technique of mensuration was devised to overcome the difficulties that regularly arise when fixed postmortem specimens are employed to study the same relationships. Clearly, the reliability of human stereotactic atlases is a function of the technique of mensuration employed.

Mean length of the intercommissural line was 24.50, and Range 20.90 to 30.90 mm. Mean distance from inferiormost aspect of sella turcica to posteriormost aspect of anterior commissure was 28.30, Range 23.80 to 36.60 mm. Mean length of line from "center" of external auditory meatus to anteriormost aspect of posterior commissure was 43.36, Range from 35.2 to 49.3 mm. Mean angle formed by "line" of orbital roof and intercommissural line was 19.78° and Range, 8.50° to 29.50°. Mean angle between Reid's base line and intercommissural line was +0.04°, Range, from −9.90° to +10.20°. Mean angle between line from "center" of external auditory meatus to anteriormost aspect of posterior commissure and Reid's base line was 97.93°, Range 85.40° to 120.45°.

The least variable relationships of the six studied were the distances (a) from the external auditory meatus to the posterior commissure and (b) from the floor of the sella turcica to the anterior commissure.

I. PROBLEM

This paper is a report of quantitative empirical findings and statistical data regarding variations of spatial configuration prevailing between (a) certain cranial and cerebral structures and (b) the anterior and posterior commissures and a constructed intercommissural line as encountered in a series of 50 stereotactically-performed, radio-opaque lateral ventriculograms of the living human subject. Specifically, the following were measured.

1. The length of an intercommissural line, defined here as the distance between the posteriormost "aspect" of the anterior and the anteriormost "aspect" of the posterior commissure.
2. The length of the line from the inferiormost "aspect" of the sella turcica to the posteriormost "aspect" of the anterior commissure.
3. The length of the midsagittal projection of the line from the center of the external auditory meatus to the anteriormost "aspect" of the posterior commissure.
4. The angle of intersection of (a) the intercommissural line and (b) the plane defined by Reid's base lines[3] (a "modified Frankfurt-Münich plane").
5. The angle formed by the intersection of (a) the plane determined by the "centers" of the external auditory meatuses and the anteriormost "aspect" of the posterior commissure and (b) that defined by Reid's base lines.

II. HISTORICAL BACKGROUND

Two basal horizontal planes have been employed in cranial anatomy, anthropology and surgery. The first described, known as the Frankfurt-Münich plane, passes through the lowermost margins of the infra-orbital ridges and the superior margins of the external auditory meatuses.

[1] Division of Neurosurgery, State University of Iowa, Iowa City, Iowa.
[2] Biophysical Research Laboratory, University of Illinois, Urbana, Illinois.

[3] In general, due to cranial asymmetry, the two Reid's lines do not lie in a single plane and therefore the plane considered here is one that "minimizes" the deviation of these two lines from the portion of the plane included within the cranium.

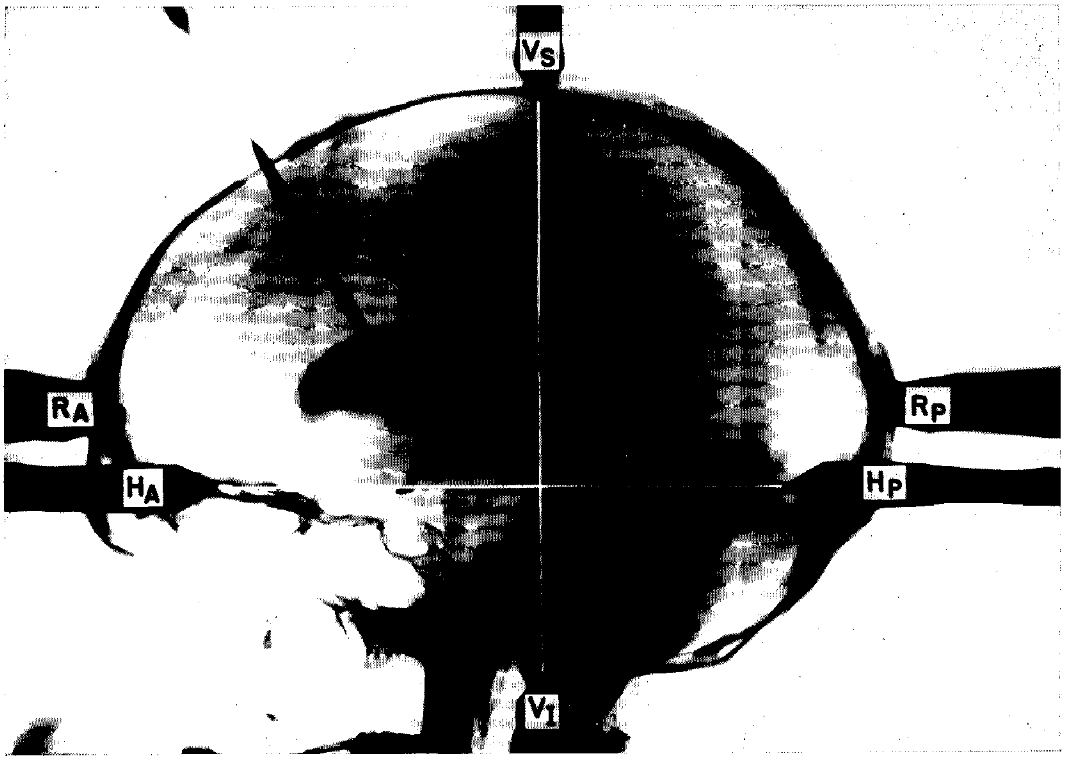

Fig. 1 Right radio-opaque ventriculogram showing ventricular cannula in left (uppermost) ventricle and shadows of thorium dioxide distributed throughout the lateral and third ventricles and the iter. The ventricular boundaries of the anterior and posterior commissures are clearly outlined. The vertical and horizontal coordinate axes, which have been "built into" the x-ray cassette as discussed in the text, are defined by the metallic pointers, V_S, V_I and H_A, H_P. The four heavy metallic rods ("pins") by which the cranium is held immobile in the head holder of the stereotaxic instrument are seen as overlying anterior and posterior pairs of R_A and R_P. (The small radio-opaque cross seen slightly above and posterior to the posterior clinoid processes should be disregarded.) (Compare with fig. 2.)

This plane was defined at a craniometric congress held in Münich in 1877 and formally adopted at the International Congress of Anthropology at Frankfurt-Am-Main in 1884. In the same year Robert Reid of London described two lines, each passing through the lowermost part of an infra-orbital ridge and the center of the ipsilateral external auditory meatus. These subsequently became known as Reid's base lines. Since they define a basal plane similar to but not identical with the Frankfurt-Münich plane, they have been similarly employed as an anatomic, anthropological and surgical referent.

In their classic paper on cranio-encephalic topography, Horsley and Clarke ('08) asserted that these and similar basal lines and planes "probably" correspond "to the least variable bony structure of the cranium." They referred to the plane they used as "a modification of the Frankfurt-Münich plane." In a later appraisal of Reid's work, Sir D'Arcy Power ('36) pointed out that the Horsley-Clarke "modification" corresponds to Reid's base line.

Since the work of Horsley and Clark ('06, '08, '20) an increasing interest in the variability of spatial relationships existing among intracranial structures in laboratory animals and human beings has become evident. Most such studies have been conducted on laboratory animals.

An excellent historical review of this subject was prepared by Carpenter and Whittier ('52). These workers concluded that (a) application of the stereotaxic method to human neurosurgery requires a precision unobtainable by orientation with respect to the basal planes of the skull and (b) the extent to which roentgen ray orientation might improve the accuracy, by providing accessibility to landmarks more closely correlated with brain structure position, "remains to be determined." They and others employed a basal line which is defined by points in the orbital roof and the center of the auditory meatus. This line is similar to but not identical with the orbital roof line employed in the present study.

Brierly and Beck's review ('59) indicates that in the cat, (Loewenfield and Altman, '56) as in the monkey (Olszewsky, '51), constant spatial relationships between cranial landmarks and cerebral structures are tenuous. Meyers and Hayne ('48) and, later, Spiegel and Wycis ('52) and Delmas, Pertuiset and Pineau ('57) documented the fact that human cranio-encephalic measurements exhibit very significant individual variations. This circumstance was verified by several others (Schaltenbrand and Bailey, '60; Talairach, et al., '49, '52, '57). Results of variability studies as well as suggestions concerning the principle sources of error were included in the atlas prepared by Spiegel and Wycis ('52).

The above mentioned and comparable studies were carried out on formalin-fixed brains, some of which were fixed *in situ* before removal from the head (Schaltenbrand and Bailey, '60) while others were fixed subsequent to removal. Experience abundantly confirms the circumstance that postmortem changes imposed by extrinsic mechanical and intrinsic chemical factors are of considerable magnitude and affect different structures (e.g., gray and white matter) to different degrees. For this reason, uniform distortion along all spatial coordinates does not occur.

Up to the present, relatively few cranio-encephalic studies of the sort referred to have been made on living subjects. However, improved radioencephalographic techniques have recently opened up the possibility of studying living material in series of sufficient size to provide reliable data. Thus, filling the third ventricle with gas or radio-opaque material permits clear, simultaneous[4] delineation of intracerebral structures, e.g., the ventricular boundaries of the anterior and posterior commissures. The latter may then be used as cerebral reference landmarks to define lines and planes comparable to the use of Frankfurt-Münich and Reid cranial lines and planes. Spiegel and Wycis, ('52), Talairach et al., ('57), and others have employed these techniques to fashion atlases of the human brain in which it is assumed that certain landmarks, e.g., the posterior commissure and pineal shadow, bear constant spatial relationships to basal ganglionic, thalamic and other diencephalic structures. Although such atlases are fashioned from a relatively small number of specimens, they provide the best currently available structure-localizing information.

The recent atlas of Schaltenbrand and Bailey ('60) overcomes many of the limitations of antecedent atlases; however, it is based on necropsy material in which perforce artefacts of fixation are implicit.

The study of greater numbers of living subjects by the improved techniques referred to above opens new opportunities to investigators confronted with the need for ever more accurate evaluations of the variability which characterizes cranio-encephalic and intracerebral spatial relationships. The present study is intended to contribute to the growing fund of information concerning this variability as encountered in living human subjects.

III. METHODS AND MATERIALS

Measurements were made on the trans-illuminated, lateral radio-opaque ventriculograms accomplished in the lateral horizontal position in conjunction with the human ultrasonic neurosurgical technique employed by Meyers, the Frys et al. ('58, '59, '60), from '57 to the present. The contrast material used to fill the third ventricle and delineate the sites of the anterior and posterior commissures was thorium dioxide (25.6%) in dextran colloidal dispersion ("Thorotrast"). An average of 3.0 ml, with a range of 2.5 to 6.0

[4] The techniques described by Talairach et al. ('52) required separate films for radiographic visualization of the anterior and posterior commissures, whereas each film in the present study demonstrates both commissures.

ml, was injected into the upper of the two lateral ventricles. The Thorotrast disseminated thence and gravitated into the third ventricle, aqueduct of Sylvius and lower of the two lateral ventricles.

The radiograms were studied as follows. Six landmarks were identified as accurately as the detail of radiograms permitted. These consisted in:

(1) the posteriormost aspect of the anterior commissure,
(2) the anteriormost aspect of the posterior commissure,
(3) a straight line representing the direction and "average" position of the shadow corresponding to the orbital roof,
(4) the inferiormost aspect of the floor of the orbit,
(5) the projected center of an external auditory meatus, and
(6) the inferiormost aspect within the sella turcica.

Points defined by these features were used to determine the following:

(1) the intercommissural line,
(2) Reid's base lines, and
(3) the line of the orbital roof.

The "ray" of the beam which projected into a circular spot on the film (as contrasted with a line), was used to establish the zero of the coordinate system. Horizontal and vertical coordinate axes through this zero were permanently "built into" the x-ray cassettes and were thus invariant throughout the series. Corrections were made for the magnification which results from the divergence of the x-ray beam. The measured radial magnification of the beam resulted in a scaling factor of 0.924 for the configuration employed. (This value of the scaling factor applies accurately only to position-correcting of structures in the midsagittal plane.) However it was also used for correcting the projected positions of other structures and

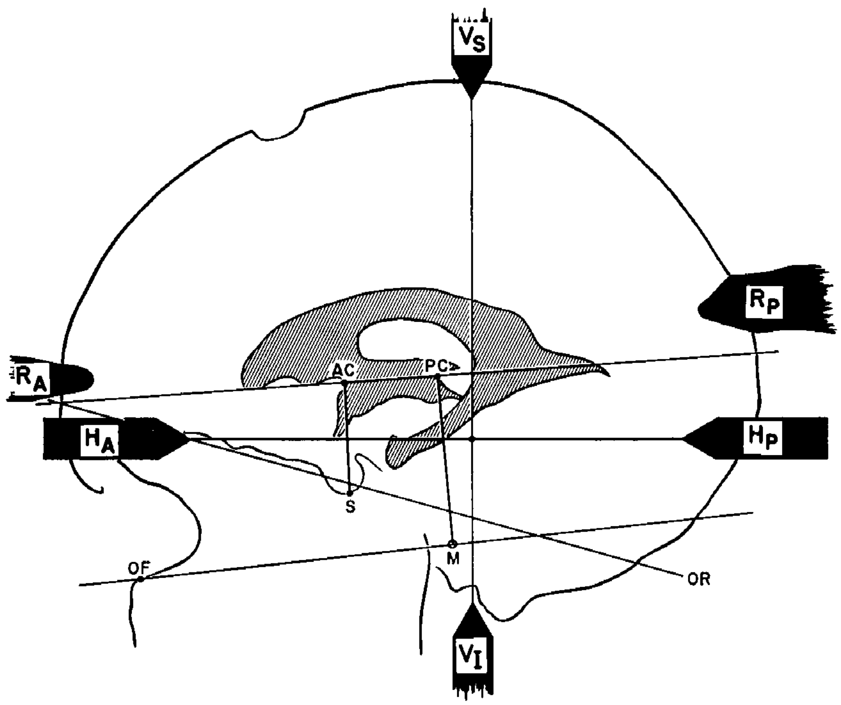

Fig. 2 Diagram illustrating typical loci of the several landmarks of interest in this study, the constructed lines between them and angles formed by their intersections. AC = posteriormost aspect of anterior commissure. PC = anteriormost aspect of posterior commissure. S = inferiormost aspect of sella turcica. M = external auditory meatus. OF = inferiormost aspect of orbital floor. OR = line of the orbital roof. (Compare with fig. 1.)

TABLE 1

Measurement	Range	Median	Mean	Mode
Length of ICL (in mm)	20.90 to 30.90	24.45	24.50	22.54 to 26.46
Angle of ORL on the ICL (in degrees)	8.50 to 29.50	20.10	19.78	15.32 to 24.24
Angle of ICL on RBL (in degrees)	−9.90 to +10.20	−0.45	+0.04	−6.53 to +6.61
Base of Sella to Anterior Commissure (in mm)	23.80 to 36.60	28.00	28.30	25.65 to 30.95
Distance from auditory meatus to posterior commissure MPC (in mm)	35.20 to 49.30	43.00	43.36	40.46 to 46.26
Angle of MPC on RBL (in degrees)	85.40 to 120.45	97.45	97.93	91.79 to 104.07

ICL = Intercommissural line from the anteriormost point of the posterior commissure to the posteriormost aspect of the anterior commissure.
MPC = Line from center of the external auditory meatus to the anteriormost aspect of the posterior commissure.
ORL = Line of the orbital roof.
RBL = Reid's base line.

consequently an error in position of up to 3% of the coordinate value was introduced here. However, since the positions of interest of non-midplane structures were no more than 7.0 cm from the coordinate axes a maximum position error of 2.1 mm could have resulted.[5] Inasmuch as the "line" of the orbital roof was of necessity fashioned as an "average" of representative but, in a strict sense, non-aligned points distributed along the roof, the method of correcting for it consisted in identifying the two points at which the line of the orbital roof intersected (a) the horizontal and (b) the vertical coordinate.

The line of the orbital roof, thus corrected, was extrapolated as necessary to its point of intersection with the scaling-corrected intercommissural line position. The angle between these was measured by use of a protractor.

Other lines were drawn between position-corrected sites of interest, e.g., that between the posteriormost aspect of the anterior and the anteriormost aspect of the posterior commissures, the center of the external auditory meatus and the anteriormost aspect of the posterior commissure, and the inferiormost aspect of the sella turcica and the posteriormost aspect of the anterior commissure. Angular measurements pertinent to these lines were made.[6]

RESULTS

The significant data are recorded in table 1.

LITERATURE CITED

Brierly, J. B., and E. Beck 1959 The significance in human stereotactic brain surgery of individual variation in the diencephalon and globus pallidus. J. Neurol. Neurosurg. & Psychiat. N. S., *22:* 287–298.

Carpenter, M. B., and J. R. Whittier 1952 Study of methods for producing experimental lesions of the central nervous system with special reference to stereotaxic technic. J. Comp. Neur., *97:* 73–131.

Clarke, R. H., and V. Horsley 1906 A method of investigating the deep ganglia and tracts of the central nervous system (cerebellum). Brit. Med. J., *2:* 1799–1800.

Clarke, R. H. 1920 Investigation of the central nervous system. Methods and instruments. Johns Hopkins Hosp. Rep., *Spec. Vol.:* 1–162.

Delmas, A., B. Pertuiset and L. Pineau 1957 Topometrie cranio-encephalique. Relations entre les coordonees tridimensionelles de certains noyaux thalamiques et sous-thalamiques chez l'homme. Acta Anat., *30:* 254–268.

[5] A technique has been described by Mark, McPherson, and Sweet ('54) through which distortion in cranial roentgenograms may be corrected. In the present series the accuracy obtained by fixed positioning of the patients in the head holder was such as to make such correction unnecessary.

[6] Since the intercommissural line and the midsagittal projection of a Reid's base line commonly do not intersect each other on the radiogram, two independent methods were used to determine their angle of intersection. The simpler of these was the construction of a line parallel to the corrected position of Reid's base line in such a position as to intersect the extension of the intercommissural line at some point on the film.

Fry, W. J., R. Meyers, F. J. Fry, D. F. Schultz, L. L. Dreyer and R. F. Noyes 1958 Topologic differentia of pathogenetic mechanisms underlying parkinsonian tremor and rigidity as indicated by ultrasonic irradiation of the human brain. Trans. Amer. Neurol. Assn., *83:* 16–24.

Horsley, V., and R. H. Clarke 1908 The structure and functions of the cerebellum examined by a new method. Brain, *31:* 45–125.

Loewenfield, I. E., and R. Altman 1956 Variations of Horsley-Clarke coordinates in cat brains. J. Neuropath. Exp. Neurol., *15:* 181–189.

Mark, V. H., P. M. McPherson and W. H. Sweet 1954 A new method for correcting distortion in cranial roentgenograms. With special reference to new human stereotactic instrument. Amer. J. Roentgen., *71:* 435–444.

Meyers, R., and R. Hayne 1948 Tridimensional analysis of deep and superficial structures of the human brain. Trans. Amer. Neurol. Assn., (Abstr.), *73:* 175.

Meyers, R. 1958 Historical background and personal experience in the surgical relief of hyperkinesia and hypertonus, in Pathogenesis and Treatment of Parkinsonism. Ed. by W. Fields. Charles C Thomas, Springfield, Illinois, Chapter X, pp. 229–270.

Meyers, R., W. J. Fry, F. J. Fry, L. L. Dreyer, D. F. Schultz and R. F. Noyes 1959 Early experiences with ultrasonic irradiation of the pallidofugal and nigral complexes in the hyperkinetic disorders. J. Neurosurg., *16:* 32–54.

Meyers, R., W. J. Fry, F. J. Fry, R. Eggleton and D. F. Schultz 1960 Determinations of topologic human brain representations and modifications of signs and symptoms of some neurologic disorders by the use of high level ultrasound. Neurology, *10:* 271–277.

Olszewski, Jerzy 1951 Correction for the use of stereotaxic instrument for monkey skulls of different sizes. (Abstr.) Anat. Record, *109:* 332.

Power, D'Arcy 1936 Reid's base line. Brit. J. Surg., *23:* 697–699.

Reid, Robert W. 1884 Observations on the relations of the principle fissures and convolutions of the cerebrum to the outer surface of the scalp. Lancet, ii, 539–540.

Schaltenbrand, G., and P. Bailey 1960 Introduction to stereotaxis with an atlas of the human brain. W. J. Johnson, Inc., New York, Vol. I, 437–470.

Spiegel, E. J., and H. T. Wycis 1952 Stereoencephalotomy (thalamotomy and related procedures). I. Methods and stereotaxic atlas of the human brain. Grune and Stratton, New York, Part I, 38.

Talairach, J., J. Hecaen, M. David, M. Monnier and J. Ajuriaguerra 1949 Recherches sur la coagulation therapeutique des structures souscorticales chez l-homme. Rev. Neurol., *81:* 4-24.

Talairach, J., J. Ajuriaguerra and M. David 1952 Etudes stereotaxiques des structures encephaliques profonde chez l'homme. Presse Med., Paris, *60:* 605.

Talairach, J., M. David, P. Tournous, H. Corredor and T. Kvasina 1957 Atlas d'anatomie stereotaxique. Masson, Paris, 293.