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I.

THE CUBICAL CAPACITY AND SUPERFICIAL AREA
OF THE SPHENOID SINUS.*

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The sphenoid sinuses, although placed at the very center of the head, vary so greatly that it is incumbent upon those who are solving problems with reference to them, to study not only the relations which they bear to adjacent structures, but their form and size as well.

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In several papers already published, more particularly one on the "Relation of the Optic Nerve to the Nasal Sinuses,"¹ I discussed the linear measurements of the sphenoid sinus, that is to say, its anteroposterior, superoinferior, and lateral diameters, in fifteen heads. The variations in these thirty sinuses were as follows: Anteroposterior, 2 to 42 mm.; superoinferior, 4 to 38 mm.; lateral, 2 to 35 mm.

However interesting these facts are, elicited by careful reconstructions and accurate measurements, it must be remembered that the sphenoid sinuses are cavities, and hence present not only maximum diameters for study, but, far more, a surface covered with mucous membrane and a space enclosed by the walls of the sinus. It is to determine the area and the cubical contents of the sphenoid sinus and the possible relation between them that has impelled me to take up this study.

So far as I have been able to ascertain, no published report has been made of any observations looking towards the estimation of the area of the sphenoid sinus. In fact, little has been done in this particular, so far as any part of the nose is concerned. Dieulafé² measured the superficial area of the olfactory and the respiratory portions of the nose, respectively, by the laborious method of placing small squares of paper, 4 sq. mm. in area, one adjoining another, over the whole surface.

There has been more work done on the easier problem of determining the cubical capacity of the sinus. As far back as 1877, Braune and Clasen,³ by the volumetric method, found the cubical contents of four sets of sphenoid sinus from corrosion preparations, as follows:

Head.	Right, cc.	Left, cc.
I.....	4.0	1.8
II.....	0.5	0.5
III.....	2.8	1.6
IV.....	6.5	6.9

Brühl⁴ used an alloy composed of lead 8, tin 4, bismuth 15 and cadmium 3 parts, which melts at 65° C. After making casts of the sinuses in different heads, he then determined the

volume by noting the amount of displaced water. His results were as follows:

Head.	cc.
I	3.8
II	1.0
III	3.1
IV	1.6
V	1.9
VI	2.3
VII	1.8
VIII	1.8
IX	1.6
X	2.5
XI	2.1
XII	3.2

Important as these observations are, they lose much in consequence of the necessity for destroying the specimens in order to remove the casts. Hence, no study can be undertaken with the cast in situ.

The method which is here presented overcomes this objection, making it possible to obtain a mould of the sinus and at the same time to preserve the specimens for coincident or future study.

MATERIAL.

Heads that have been preserved by injecting a fifty per cent solution of formalin through the carotid were immersed in a three per cent solution of hydrochloric acid for three to five months. They were then sectioned horizontally by means of a sharp knife. Heads VII, VIII, IX, XI, XII, XIV have been described in a previous paper.¹ The remaining heads are here presented for the first time. They are from the dissecting room of the St. Louis University. All were adults, and in no instance has it been possible to ascertain any history of the individual.

METHOD OF MAKING PLASTER CASTS.

To obviate the destruction of the specimen in removing the mould, it was thought possible to use the method in vogue by dentists who take plaster impressions of the mouth and

teeth and patch any portion that is broken away in order to make them complete.

Plaster impressions were, therefore, taken of that portion of the sinus lying within the various adjacent sections, and these were then united at the proper place, resulting in a complete mould of each sinus.

PLASTER CASTS.

The plaster casts, twenty in number, give a clear idea of the size, form, variety and irregular contour of the sinuses.

The illustrations accompanying this paper show (a) the casts placed in the lowermost section of the corresponding head, with a view of graphically showing the extent of the cavities, (b) an anterior view of the right and left sinus of each head, (c) a superior, (d) external, and (e) internal view.

The exact relation of the two sinuses to one another is shown in each instance except in the external view, in which it would be manifestly impossible.

GROSS APPEARANCE.

When the plaster casts of the sinuses are placed in the most inferior of the horizontal sections in which the sinuses are found, their extent with reference to adjacent structures can easily be seen. The outlines of the latter are drawn faintly, so as to bring out the sinuses more forcibly.

Head VII. The two sphenoid sinuses project far back and lie closer to the torcular than those of any other head. All the sinuses of this head were unusually large. External wall most irregular. Anterior wall reaches a lower level of the right than that of the left.

Head VIII. The sphenoids are fairly small and regular. The section shown is quite thick, and more than half of the sinuses are concealed. All walls fairly smooth. External walls triangular in shape.

Head IX. Sphenoids, both small, project superiorly beyond the adjacent ethmoids. The larger portion of the sinuses lies above the section. All walls irregular in contour and more or less quadrilateral in shape.

Head XI. Very similar to head IX, except that sinuses are larger, especially in superoinferior direction. The shape is that of a prism.

Head XII. The left sphenoid overshadows the right, which appears as only a slight projection from its inner and anterior wall. It is in relation with the optic chiasm and both optic nerves, as well as the posterior ethmoid cells on the right side. The operative difficulties which such sphenoids might occasion can be well appreciated.

Head XIV. Right sphenoid much larger than the left, in relation with optic chiasm and both optic nerves. While the left sphenoid is of fair size, the right overtops it and extends some distance to the opposite side. External wall of the right sinus rhomboidal in shape; left sinus is a prism with rounded ends.

Head XXIII. Both sphenoid sinuses fairly uniform, having about the same relative extent. Larger portion lies above the section shown. Both quadrilateral in shape.

Head XXVI. Right sphenoid sinus much the larger, in relation with optic chiasm. A mere section gives no idea of relative size. Left, rhomboidal in shape; right, rhomboidal laterally, but otherwise more rectangular.

Head XXVII. Both sphenoids large and fairly uniform. Section shown contains the larger portion. External wall very irregular, but fairly rectangular in form.

Head XXXV. Both sphenoid sinuses very large, especially in the lateral direction. However, they are quite similar in size and extent. All the walls are triangular and very nearly equilateral.

It will thus be seen that few of the sinuses in the different heads resemble one another in size or form. While the two sinuses in an individual head may be similar, they are in the main different from those of another head. (Heads VIII, IX, XXIII, XXVII.) The greatest difference in size and form in a given pair is to be found in head XII. The difference is somewhat less in heads XIV and XXVI. Both sinuses in heads VII and XXXV are immense, while those in head XXVII, and the right sinus in heads XXVI and XIV, and the left in head XII are quite large. A great difference in size is to be noted between the right sphenoid of head XII and the left of head XXXV. The fairly smooth and regular contour of the sinuses in head VIII may be well contrasted with the projections and concavities and irregular shapes of the sinuses in heads VII and XXXV.

CUBICAL CAPACITY.

The measurement of the displacement of water resulting from the immersion of a body in water gives the volume or cubical capacity.

As the casts are porous, they were first dipped into melted paraffin, so that the interspaces might be made impervious to water. After this the cubical capacity was ascertained volumetrically in cubic centimeters, as follows:

Head.	Right. cc.	Left. cc.
VII	6.5	9.9
VIII	3.8	3.0
IX	2.4	2.3
XI	4.0	4.5
XII	0.6	7.5
XIV	6.3	1.0
XXIII	3.0	3.1
XXVI	11.8	1.9
XXVII	4.8	8.2
XXXV	8.3	10.0
Average	5.15	5.14
Average of all the sinuses.....		5.145
The range is from 0.6 to 11.8.		

These figures are greatly in excess of those of Braune and Clasen, with an average of 3.08 cc., and of Brühl, with an average of 2.23 cc. This may be accounted for by the fact that in the former the range was 0.5 cc. (of which there were two) to 6.9 cc., and in the latter from 1.0 cc. to 3 cc. Taking all together, the average for the forty sinuses is 3.73 cc.

The similarity in the averages of the right and the left sphenoid sinuses in the ten heads is most striking. It would be unfair, however, to draw any definite conclusion from this until many more such sinuses are subjected to the same method of measurement.

SUPERFICIAL AREA.

Various experiments were made to discover a suitable method for determining the superficial area of the cavities. It was soon established that a fair estimate could be made by

taking a given quantity of material, cutting it appropriately and fitting the various pieces over the plaster cast so as to cover it completely without any overlapping.

The superficial area equals the known quantity less the amount remaining, which can be easily measured by the use of paper ruled in square millimeters.

Tin foil was first used, but it was discarded because it failed to adhere sufficiently to the casts. Gummed paper was then utilized, but it failed to adhere satisfactorily. However, it was found possible to color the area covered by each slip of paper with pencil marks until no portion of the cast remained free.

Finally, adhesive plaster was found most acceptable. A strip equalling 25 square centimeters was placed with the adhesive part down on a small board without stretching. Pieces were cut with a knife and fitted upon the cast until it was entirely covered, without any overlapping. Though this was somewhat laborious and tedious at first, it soon became less difficult and consumed less time.

It is safe to say that this method is not subject to an error of two per cent; in fact, it is more than likely that there is not more than a half of one per cent of error.

The results in square centimeters are as follows:

Head.	Right. qcm.	Left. qcm.
VII	26.7	27.2
VIII	13.9	12.9
IX	8.9	9.7
XI	13.2	16.5
XII	2.4	22.7
XIV	24.7	4.0
XXIII	10.5	12.2
XXVI	26.4	7.4
XXVII	17.3	21.8
XXXV	25.5	28.2
Average	16.95	16.26
General average		16.65

Here again is found the remarkable similarity in the average of the right and of left sphenoid cavities. A larger number of

observations will be necessary to establish whether or not this is the rule.

Having established the cubical capacity or volume and the superficial area of 20 sinuses, it was thought desirable to determine a formula by which it would be possible to estimate the superficial area from a known cubical capacity. It is not difficult to determine the cubical capacity of a number of sphenoid sinuses, but the superficial area is a much more difficult undertaking. For this reason such a formula is of value.

The data given result in the formula

$$Y = 0.2 X + 4.4.$$

X is the volume and Y is the superficial area divided by the volume. In order to determine the superficial area, the value of Y must be multiplied by the already known volume of the sinus. The curve, figure 31, corresponds very closely to the figures for the sinuses measured.

Dr. Virgil Loeb made the casts for me, Mr. Tom Jones the drawings, and Leo Loeb, M. E., the formula.

CONCLUSION.

The casts prepared according to the method described shows that the cubical capacity in the twenty sphenoid sinuses examined varies from 0.6 to 11.8 ccm., with an average of 5.145 ccm.; and the superficial area from 2.4 to 28.2 qcm., with an average of 16.65 qcm.

The formula for calculating the superficial area from the known cubical capacity is subject to change, depending upon additional data.

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HEAD VII. Anterior view.

HEAD VII. Superior view.

HEAD VII. External view.

HEAD VII. Inferior view.

HEAD VIII. Anterior view.

HEAD VIII. Superior view..

HEAD VIII. External view.

HEAD VIII. Inferior view.

HEAD IX. Anterior view.

HEAD IX. Superior view.

HEAD XI. External view.

HEAD XI. Inferior view.

HEAD XI. Anterior view.

HEAD XI. Superior view.

HEAD XI. External view.

HEAD XI. Inferior view.

HEAD XII. Anterior view.

HEAD XII. Superior view.

HEAD XII. External view.

HEAD XII. Inferior view.

HEAD XIV. Anterior view.

HEAD XIV. Superior view.

HEAD XIV. External view.

HEAD XIV. Inferior view.

HEAD XXIII. Anterior view.

HEAD XXIII. Superior view.

HEAD XXIII. External view.

HEAD XXIII. Inferior view.

HEAD XXVI. Anterior view.

HEAD XXVI. Superior view.

HEAD XXVI. External view.

HEAD XXVI. Inferior view.

HEAD XXVII. Anterior view.

HEAD XXVII. Superior view.

HEAD XXVII. External view.

HEAD XXVII. Inferior view.

HEAD XXXV. Anterior view.

HEAD XXXV. Superior view.

HEAD XXXV. External view.

HEAD XXXV. Inferior view.

HEAD VII. Reduced one-fourth.

HEAD VIII. Reduced one-sixth.

HEAD IX. Reduced one-fifth.

HEAD XI. Reduced one-fourth.

HEAD XII. Reduced one-fourth.

HEAD XIV. Reduced one-fifth.

HEAD XXIII. Reduced one-third.

HEAD XXVI. Reduced one-fourth.

HEAD XXVII. Reduced one-fourth.

HEAD XXXV. Reduced one-fourth.