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Could Craniometric Measurements Explain the Growth of the Superior Sagittal Sinus?

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Key Words
Superior sagittal sinus · Skull · Craniometry · Cephalometry

Abstract
Objective: The objective of this study was to relate demographic variables and craniometric measures with measurements of the superior sagittal sinus (SSS) at different points along the path of the SSS. The findings were then discussed with regards to theories of skull growth. ***Methods:*** We studied 33 skulls with known demographic characteristics and measured various craniometric parameters and distances related to the specific dimensions of the SSS. These data were statistically analyzed, and the results are presented. ***Results:*** Of the 33 cadaver samples, 16 were female and 17 were male, aged between 28 and 87 years at the time of death. The cross-sectional area of the SSS measured at the coronary suture was positively correlated with the biauricular length. In addition, when measured 1.5 cm above the torcula, the cross-sectional area of the SSS was negatively correlated with the distance between the medial epicanthi. ***Conclusions:*** The relationships found may indicate that the growth of the SSS is proportional to the activity of each segment of the SSS that occurs along its path.

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Introduction

Surface drainage of the brain is carried out by four groups of veins: the superior sagittal, sphenoidal, tentorial and falcine veins. The superior sagittal sinus (SSS) is responsible for draining the veins of the superior sagittal group, which consists of veins from the upper surfaces of the medial and lateral frontal lobe, the parietal and occipital lobes, and the anterior part of the orbital surface of the frontal lobe [1].

The SSS progresses along the midline, lateralized to the right relative to the sagittal suture [2]. It starts behind the frontal sinus and becomes larger as it traverses from anterior to posterior along the inner table of the skull. It then drains into the transverse sinus at the confluence of sinuses [1] which connects the SSS, transverse sinuses, straight sinus and occipital sinus.

The SSS is closely related to the dura mater (DM), sagittal suture and skull; however, little is known about the correlation between the growths of these structures. The aim of this paper was to utilize cadavers to relate craniometric measures with measures of the SSS at different points in its path and to discuss the findings with respect to theories of skull growth.

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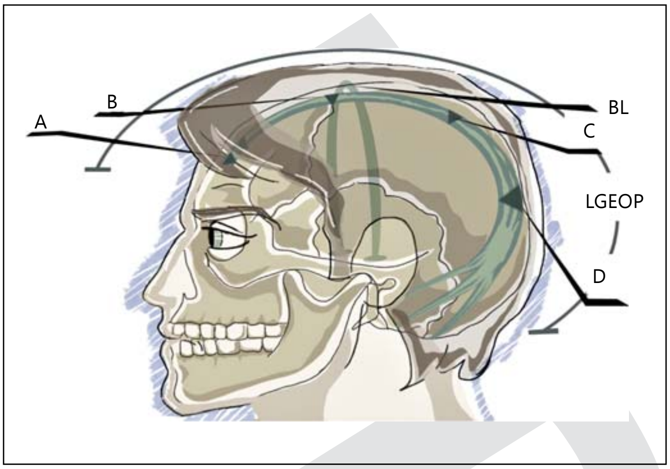

Fig. 1. Illustration representing the points of section of the SSS: near its beginning, at the crest of Galli (area A); in the coronary suture (area B); 7.5 cm above the torcula (area C); and 1.5 cm above the torcula (area D). We also measured the BL and the length between the glabella and the occipital protuberance (LGEOP).

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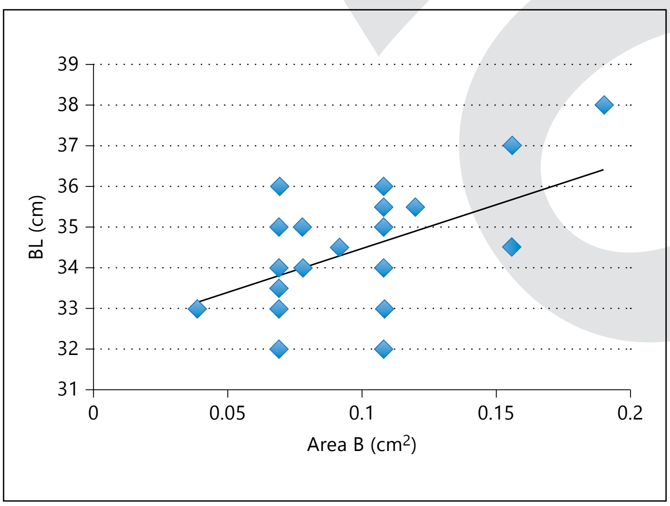

Fig. 2. Positive correlation between the BL and the cross-sectional area of the SSS at the level of the coronary suture (area B).

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Methods

We studied the skulls of 33 corpses submitted to the Death Verification Service of the University of Sao Paulo over a period of 2 months. No more than 24 h elapsed between the time of death and measurement of the skull. All local laws were adhered to regarding the inclusion of cadavers in the study; accordingly, only adult cadavers were used.

We first cataloged some general demographic information about the cadavers, including gender, age, ethnicity and weight. We then measured the following skull parameters: head circumference, length from the glabella to the external occipital protuberance, biauricular length (BL), length of a straight line connecting the medial epicanthi (LME), length of the SSS (measured after opening the skull) and diameter of the SSS at different locations.

The diameter of the SSS was measured at four well-defined craniometric points, as illustrated in figure 1. The first, called area A, was at the level of the crista galli. The second, area B, was at the level of the coronary suture. The third, area C, was located 7.5 cm above the torcular herophili, and the fourth, area D, was 1.5 cm above the torcular herophili. The SSS was sectioned at each point, creating a triangle in cross-section. The dimensions of each side of the triangle were measured.

Our analysis sought to characterize the study population to identify potential relationships between sociodemographic variables (weight, height, gender and age) and measurements of the SSS (perimeter, length and diameter) taken at different points along its trajectory.

To analyze the relationship between the cross-sectional area and length of the SSS, head circumference and sociodemographic variables, we employed the Spearman correlation coefficient and simple and multiple linear regressions. The significance level was set at 5%. For linear regression, variables that were not normally distributed were transformed (log x) for analysis and then reconverted for presentation of the results (e^x).

The statistical power of the sample was calculated based on the correlation coefficient of the sample under H0 (0.100) and H1 (0.600), using a type I error of 5%, a type 2 error of 20% and a sample size of 33 individuals. The resulting power was 0.95 (95%).

Results

The sample was composed of the cadavers of 16 females and 17 males, aged between 28 and 87 years at the time of death, with a mean age of 60.9 years.

For the cross-section taken at area A, at the level of the crista galli, the 3 sides of the sectioned triangle were equal (0.20 cm). We did not find statistically significant relationships between the cross-sectional area of the SSS at area A and any of demographic variables or other skull parameters.

At the level of the cross-section at area B (at the level of the coronary suture), the SSS showed an average thickness of 0.46 cm along the side of the cranium, with a range from 0.3 to 0.6 cm. At this plane of section, the correlation between the SSS cross-sectional area and the BL (which ranged from 32 to 38 cm) was statistically significant (two-tailed test, $r = 0.488$, $p = 0.004$), as shown in fig. 2.

At the level of the cross-section taken at area C, the average thickness of the SSS along the side of the cranium was 0.55 cm, with a range from 0.40 to 0.90 cm. At this

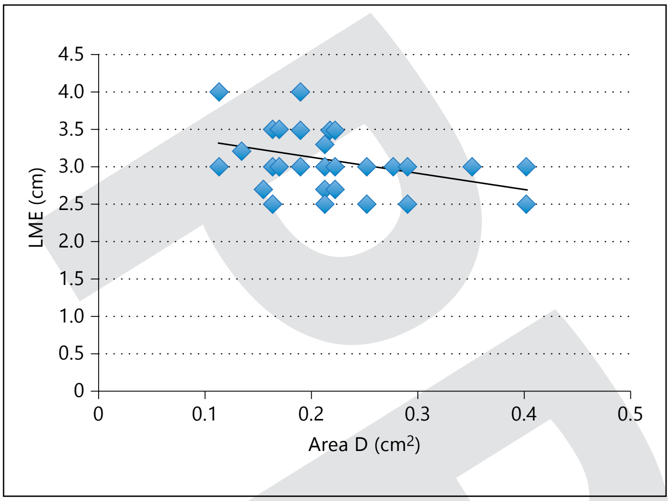

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Fig. 3. Negative correlation between the LME and the cross-sectional area of the SSS 1.5 cm above the torcula (area D).

level, we found no statistically significant relationships with other measures.

At the level of the cross-section taken at area D, the average thickness of the SSS along the side of the cranium was 0.63 cm, with a range from 0.40 to 1.20 cm. At the level of area D, there was a statistically significant negative correlation between the LME (which ranged from 2.50 to 4 cm) and the SSS cross-sectional area (two-tailed test, $r = -0.375$, $p = 0.032$), as shown in figure 3.

There was also a positive correlation between the cross-sectional area of the SSS at areas B and D ($r = 0.365$, $p = 0.037$) and at areas C and D ($r = 0.754$, $p < 0.001$).

No other correlations were statistically significant (two-tailed test).

Discussion

Skull growth follows a pattern that is influenced by the sutures. When a suture remains active, there is bone deposition and subsequent growth of the bone in a direction perpendicular to the orientation of the suture [3]. Considering the close relationship of the SSS with the sagittal suture, one would expect the growth of this venous structure to be related to the activity of the bone suture.

Experimental studies with mice have shown that juvenile DM produces FGF-2 (fibroblast growth factor), which may regulate adjacent osteoblast biology [4]. In addition, calvarial DM is regionally differentiated, resulting in the upregulation of osteogenic cytokines and bone extracellular matrix molecules [5]. It has also been shown that recombinant human FGF-2 can induce the proliferation of dural cells [6]. Therefore, if the growth of bone and DM is proportional, then growth of the SSS is also likely to be related to their growth because the walls of the SSS are draped with DM.

It is also known that the closure of a suture leads to increased activity of the adjacent sutures and, to a lesser extent, increased activity of the more distant sutures [3]. Therefore, it may be possible to infer characteristic measures of the SSS through craniometric measurements, but this has not been attempted previously.

We observed a positive relationship between the BL and the cross-sectional area of the SSS at area B in this study. This relationship may indicate that activity of the sagittal suture, which would lead to further growth of the parietal bones in a direction perpendicular to that of the suture, leads to increased growth of the SSS at this level.

In this study, we observed a negative correlation between the LME and the cross-sectional area of the SSS at area D. Earlier closure of the metopic suture could lead to greater compensatory growth, even in remote areas such as the parietal and occipital bones. As a consequence, the DM under the sagittal suture could also grow, resulting in changes in the size of the SSS.

The proportional increase in the cross-sectional area of the SSS at areas B, C and D is congruent with an increasing extension of the parietal bones in the corresponding coronal planes. This relationship is consistent with a close correlation between the growth of the SSS, DM and sagittal suture.

Assessing these skull parameters in children would be important for measuring the dynamics of the growth process of the structures; however, the standards of the ethics committee of the participating institutions precluded such analysis.

These correlations are also important for neurosurgical practices. The location of the torcula herophili can be identified by the inion, the superior nuchal line, and the insertion of the head of the semispinalis muscle [7]. At the level of section D, 1.5 cm above the torcular herophili, there was a large amount of variation in the thickness of the SSS (0.4 to 1.2 cm). However, because the diameter at this point was negatively correlated with the LME, the easily measured LME could serve as a useful predictor of SSS thickness at this plane of section. Importantly, point D can be used for introducing the proximal catheter during the placement of ventricular sagittal sinus shunts [8]. Thus, a craniometric measure that can be used by neurosurgeons to estimate the cross-sectional area of SSS at this point, such as the LME, may be a useful reference.

These correlations may also be useful in estimating the dimensions of the SSS when planning neurosurgical approaches. For example, estimating the size of the SSS at points B and D using craniometric measures could be helpful when planning interhemispheric approaches [9].

Conclusion

There is a negative correlation between the LME and the cross-sectional area of the SSS at area D, and there is a positive correlation between the BL and the cross-sectional area of the SSS at the area B. These associations support the hypothesis that the growth of bones separated by the sagittal suture, the DM under this suture and the SSS are closely related.

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