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Original Article

Relationship of superior sagittal sinus with sagittal midline: A surgical application

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ABSTRACT

Background: Interhemispheric approach is widely used to surgical management of midline tumors and vascular lesion in and around the third ventricle. Complete exposure of the superior sagittal sinus to obtain adequate working space of midline lesion is difficult, because of the risk to inadvertent injury to the sinus and bridging veins, which may cause several neurological deficits. Understanding the SSS neuroanatomy and its relationships with external surgical landmarks avoid such complications. The objective of this study is to accurately describe the position of SSS and its displacement in relation with sagittal midline by magnetic resonance imaging.

Methods: A retrospective cross-sectional, observational study was performed. Magnetic resonance image of 76 adult patients with no pathological imaging was analyzed. The position of the halfway between nasion and bregma, bregma, halfway between bregma and lambda, and lambda was performed. The width and the displacement of the superior sagittal sinus accordingly to the sagittal midline were assessed in those landmarks.

Results: The mean width of superior sagittal sinus at halfway between nasion and bregma, bregma, halfway between bregma and lambda, and lambda was 5.62 ± 2.5, 6.5 ± 2.8, 7.4 ± 3.2, and 8.5 ± 2.1 mm, respectively, without gender discrepancy. The mean displacement according to the midline at those landmarks showed a statistically significant difference to the right side among sexes.

Conclusion: In this study, we demonstrate that sagittal midline may approximate external location of the superior sagittal sinus. Our data showed that in the majority of the cases, the superior sagittal sinus is displaced to the right side of sagittal midline as far as 16.3 mm. The data we obtained provide useful information that suggest that neurosurgeons should use safety margin to perform burr holes and drillings at the sagittal midline.

Keywords: Anatomical study, Bregma, Coronal suture, Dural sinus, Superior sagittal sinus

INTRODUCTION

Interhemispheric approach is widely used for surgical management of midline tumors and vascular lesions in and around the third ventricle.[8,9] Superior sagittal sinus (SSS) is often exposed during this neurosurgical approach and its complete exposure substantially increases the working angle view to shallow structures.[1] The need for safe surgical entry points and, tridimensional knowledge with X-ray vision of intracranial structures, has led to searches for surfaces landmarks of the skull to perform safe cranial surgeries.

In general, the superior sagittal suture has been used to approximate the location of SSS, which is considered an external landmark of SSS between the bregma and the lambda, and it is still being used in neurosurgical practices. However, this external anatomical landmark is not useful anteriorly to the bregma, and previous studies, showed that it is not accurate to predict the location of the SSS.[7,20,23]

Complete exposure of the SSS to obtain adequate working space of midline lesion is difficult because of the risk of inadvertent injury to the sinus and bridging veins, which may cause several neurological deficits.[8,14] To guide our neurosurgical planning, understanding the SSS neuroanatomy and its relationships with external surgical landmarks avoid such complications.[6,16]

Although there are some reports about the anatomy of SSS and its relationship with sagittal suture, most of them were performed on cadaveric specimens with relatively low number of cases, and further studies are needed. Our aim is to accurately describe the position of SSS and its displacement in relation with sagittal midline, but unlike the previous reports, to measure them on a wide quantity of samples by magnetic resonance imaging.

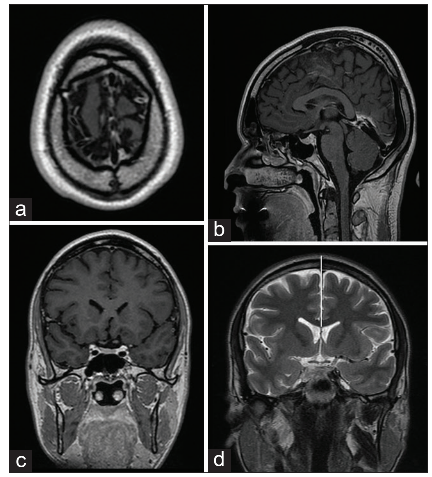

Figure 1: Example of location in (a) axial, sagittal (b), and coronal (c) plane of magnetic resonance image and measurement at bregma in coronal magnetic resonance image in T2 sequence (d). Vertical white line is placed at the sagittal midline. Distance from the sagittal midline to the right and left edge of superior sagittal sinus. This image shows the displacement of the superior sagittal sinus toward the left at bregma. The bregma is the hypointense gap at the top of the head (d).

MATERIALS AND METHODS

Patients

Magnetic resonance imaging (MRI) examinations were retrieved from our electronic medical records. The study included adult patients who consulted the health care of our hospital between March 2018 and February 2020 and who had no pathological imaging findings.

Anatomical definitions

The width of the superior sagittal sinus from different sagittal midline convexity craniometric points was performed: (Na-Br) halfway between the nasion and bregma, Br in the bregma, Br-Lamb halfway between the bregma and lambda, and Lamb in the lambda. Subsequently, we measure the displacement of the SSS to the right and to the left accordingly to the sagittal midline in those landmarks. We also evaluated the dominant transverse sinus that primarily drains the SSS [Figure 1].

The anatomical key points were defined as shown below:

- Nasion: Intersection point between frontal and nasal bones, located in a depressed area that connects the nasal bridge and the glabella.
- Bregma: Intersection point between frontal and sagittal sutures. It was first located in the upper axial planes of the skull, to accurately identificate it in the sagittal plane. It appears as a hypointense line that interrupts the full-thickness continuity of the hyperintense bony signal.
- Lambda: Intersection point between lambdoid and sagittal sutures. It was first located in the upper axial planes of the skull, to accurately identificate it in the sagittal plane. It appears as a hypointense line that interrupts the full-thickness continuity of the hyperintense bony signal.

Magnetic resonance imaging data acquisition and image processing

Coronal T2 MRI was acquired using a 1.5-T MR imaging unit (Signa®; General Electric Medical Systems) with a multislice scanning acquisition protocol. Intravenous contrast administration was not required. The images were processed and analyzed by the software OsiriX MD image program, version 11.0 in axial, coronal, and sagittal planes for the following points: Na-Br, Br, Br-Lamb, and Lamb.

Statistical analysis

An observational retrospective cross-sectional study was made. All analyses were performed using the Statistical Software Package (Stata for Macbook version 13.0). The Shapiro–Wilk test was used to test the normality assumption. For the interobserver reproducibility analysis, we used the intraclass correlation coefficient (ICC). Relative frequencies were calculated for categorical data. Continuous data were expressed as mean ± standard deviation (SD). The two-tailed independent sample t-test was performed to compare means between groups. $P < 0.05$ was considered to be statistically significant.

RESULTS

During this period, 76 patients were included in this study. Forty (52.6%) were female and 36 (47.4%) were male [Table 1]. The mean age of the population was 58.7 years (39.6–77.8).

The width of the SSS ranged from 2 to 10.9 mm in the halfway between nasion and bregma (Na-Br) (mean 5.62 ± 2.5 mm), from 1.4 to 13.4 mm in the bregma (Br) (mean 6.5 ± 2.8 mm), from 3.78 to 16.32 mm in the halfway between bregma and lambda (Br-Lamb) (7.4 ± 3.2 mm), and from 4.79 to 13 mm in lambda (Lamb) (mean 8.5 ± 2.1 mm) [Table 2].

There were no significant differences in the mean width of SSS measurements among both sexes [Figure 2]. These results are shown in [Table 3].

Table 1: Descriptive statistics of categorical variables.

Variable	Relative frequency (95% CI)
Sex (*n*=76)	
Female	40 (40–66)
Male	36 (33–59)

CI: Confidence interval

Table 2: Descriptive statistics of continuous variables for total sample (*n*=76).

Variable	Mean±SD
Age	58.7±19.1 (years)
Na-Br	5.62±2.5 (mm)
Br	6.5±2.8 (mm)
Br-Lamb	7.4±3.2 (mm)
Lamb	8.5±2.1 (mm)

Na: Nasion, Br: Bregma, Lamb: Lambda, SD: Standard deviation

We also made observations and measurements concerning the alignment between midline and deviation of the SSS [Figure 3]. The mean lateral displacement was 3.16 ± 1.43, 3.7 ± 1.6, 4.7 ± 1.4, and 8.3 ± 2.1 to the right sided and 2.4 ± 1.2, 2.8 ± 1.3, 3.49 ± 1.72, and 3.7 ± 1.2 to the left sided in the following parameters Na-Br, Br, Br-Lamb, and Lamb, respectively.

The comparison between male and female showed a statistical significant difference when the measurement was related to the displacements of SSS according to the midline in the following measures (Na-Br, Br, and Lamb), but was not when related to Br-Lamb. These results are shown in [Table 4].

Finally, we determined which transverse sinus primarily drained the SSS. A dominant drain was present in 17 (22.36%) patients, of which 12 (70.5%) drained to the right sided.

There was an excellent intraclass correlation coefficient between the two observer measurements of the Na-Br, Br, Br-Lamb, and Lamb with an average k value of 0.82, 0.92, 0.97, and 0.89, respectively.

DISCUSSION

The SSS is the longest dural sinus, which courses in the midline along the superior edge of the falx cerebri, beginning just behind the frontal bone and grows larger as it continues posteriorly, as it receives blood from the frontal, parietal, and occipital superior cerebral veins and the diploic veins.[21]

Intracranial venous structures have gained especial neurosurgical interest due to improvements in neuroimaging techniques and clinical applications.[3,4,18] The

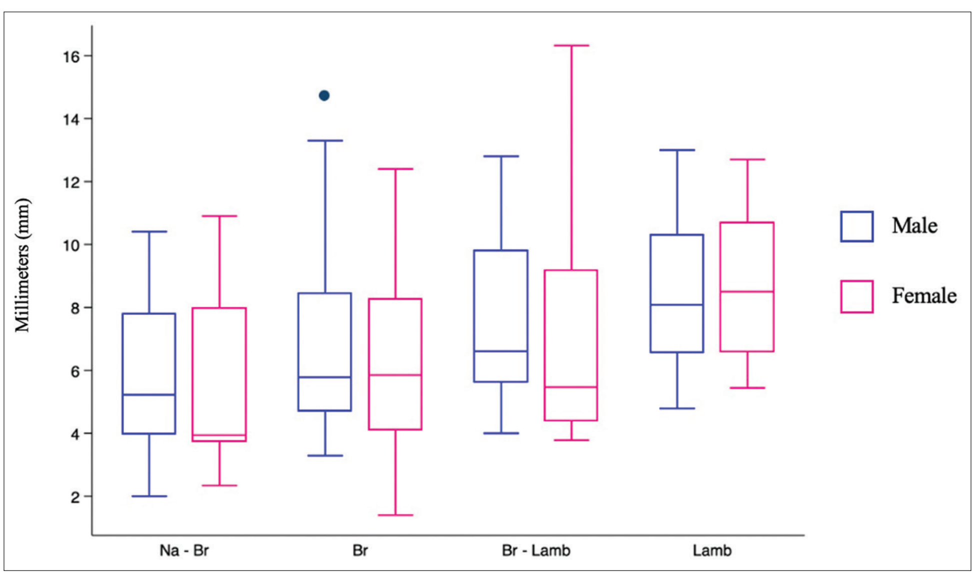

Figure 2: Boxplot graph shows median and interquartile range comparison of width of superior sagittal sinus between male and female group at the four landmarks points. Br: Bregma, Br-Lamb: Midpoint bregma-lambda, Lam: Lambda, N: Nasion, Na-Br: Midpoint nasion-bregma.

Table 3: Univariate analysis. Independent sample *t*-test.

Variable	Sex		*P*-value
	Female (*n*=40)	Male (*n*=36)	
Na-Br	5.7±2.4 (mm)	5.4±2.7 (mm)	NS
Br	6.7±2.9 (mm)	6.3±2.7 (mm)	NS
Br-Lamb	7.5±2.7 (mm)	7.3±3.7 (mm)	NS
Lamb	8.3±2.1 (mm)	8.6±2.3 (mm)	NS

P-value: Two-sided *P* values for *t*-test. NS: Not significant. Na: Nasion, Br: Bregma, Lamb: Lambda

Table 4: Univariate analysis. Independent sample *t*-test.

Variable	Displacement		*P*-value
	Right	Left	
Na-Br	3.16±1.43 (mm)	2.4±1.2 (mm)	<0.006
Br	3.7±1.6 (mm)	2.8±1.3 (mm)	<0.002
Br-Lamb	4.7±1.4 (mm)	3.49±1.72 (mm)	NS
Lamb	8.3±2.1 (mm)	3.7±1.2 (mm)	<0.0003

P-value: Two-sided *P* values for *t*-test. NS: Not significant, Na: Nasion, Br: Bregma, Lamb: Lambda.

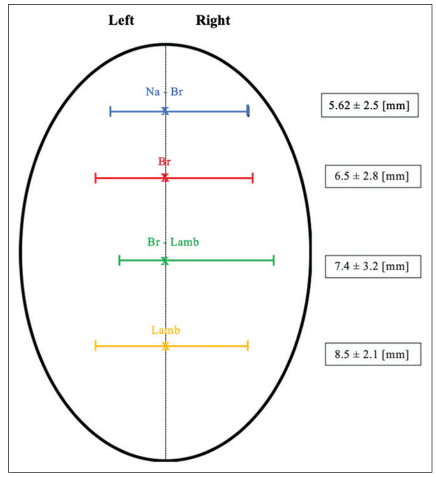

Figure 3: Scheme representing the width of sinus at the four landmark points and the range of its deviation. SSS at halfway between nasion-bregma (blue), bregma (red), bregma-lambda (green), and lambda (orange). Br: Bregma; Br-Lamb: Midpoint bregma-lambda, Lam: Lambda; N: Nasion, Na-Br: Midpoint nasion-bregma, SSS: Superior sagittal sinus.

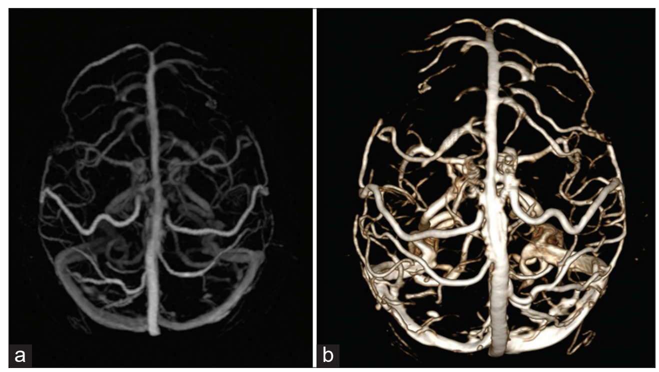

Figure 4: 3-D magnetic resonance venography (MRV) (a) and volume rendering of MRV (b) in a normal individual showing cerebral bridging vein emptying in the superior sagittal sinus.

distribution of cerebral bridging vein (BV) and dural venous lake through the SSS is not irregular as it was generally supposed [Figure 4].[12] Most of BV empty into the SSS at the level of or distal to the coronal suture. They typically drain into dural venous lakes rather than entering directly in the dural sinus.[3,12] These BV and dural venous lakes may represent a significant obstacle to surgical approaches to the parasagittal region and during the opening of the dura mater adjoining to the SSS,[10,22] and they may become inadvertently injured, despite extreme care to preserve it. Cerebral BV damage during neurosurgical procedures could result in various neurological complications, including postoperative brain edema and infarction,[8,15] especially when it is associate with brain retraction and dural sinus occlusion, which could results in more serious venous complication.[2,13,17] Therefore, special attention is needed to these structures.

The SSS is often encountered during neurosurgical procedures for interhemispheric transcallosal approaches, among many other access points into the skull. Exposure of this dural venous sinus is often required in the management of lesions situated in proximity to the falx and tentorium. Although extremely useful, the navigation systems are not available in many countries around the world. Current location of the SSS on the external cranial surface for proper positioning of supratentorial craniotomy and for transoperative orientation is still mostly based in cranial topographic anatomy studies, performed especially in cadaveric specimens. Although the sagittal suture can be used as a rough external landmark to estimate placement of the underlying SSS, it is not an accurate landmark[20,23] and disruption of the SSS can lead to serious complications.[11] Due to this surgical challenge, it is essential that the neurosurgeon estimates the correct location of the SSS.

We found that SSS width in these different landmarks (Na-Br, Br, Br-Lamb, and Lamb) was 5.62 ± 2.5, 6.5 ± 2.8, 7.4 ± 3.2, and 8.5 ± 2.1 mm, respectively. Tubbs *et al* and Samadian[20,23] found similar results, and their studies were performed in cadaveric specimens. This observation reinforces that MRI is a reliable source of data. We found that the majority of our measures revealed that SSS tends to deviate to the right side of the midline, which is in accordance with the previous studies.[19,20,23] In addition, the SSS has a tendency to a dominant drainage to the right transverse sinus.[5,20] In accordance with our findings, we recommend that burr holes placement and drillings should be at least, 1.7 cm away from sagittal midline because of the potential risk for disrupting SSS and other bridging veins.

Reis *et al.*[19] measured the width of the SSS in cadaveric specimens and on *in vivo* patients through MRIs using the midline as a landmark. Although we found similar results with the anatomical specimens, their radiological group found higher results. This may be due to the MRI sequence they used for SSS measure, since T1 is not the best for venous sinus evaluation and measurement, and could overestimate the SSS size and displacement.

CONCLUSION

For neurosurgical approaches to the midline, neurosurgeons should be aware that sagittal midline and sagittal suture are not reliable landmarks for the SSS course. However, it can approximate the external location of the SSS. Our data, in accordance with the previous published study, confirm that SSS is in the majority of the cases displaced to the right side of the sagittal midline, as far as 16.3 mm. Thus, we suggest that neurosurgeons should use 1.7 cm as safety margin to perform burr holes and drillings. Always when possible neurosurgeon should carefully analyze preoperative imaging and consider SSS location and relationship with external landmarks.

Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

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Conflicts of interest

There are no conflicts of interest.

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