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Review Article

# A cadaveric study of superior sagittal sinus and its draining veins among population in Sabah, Malaysia

**Ananda Arumugam[1,2*], Vicnesh Thillynathan[2], Dewaraj Velayudhan[2], Jessie Hiu[3], Emad. M.N Abdelwahab[1]**

[1] *Faculty of Medicine, Lincoln University College, Malaysia*
[2] *Dept. of Neurosurgery, Hospital Queen Elizabeth, Sabah, Malaysia*
[3] *Dept. of Forensic, Hospital Queen Elizabeth, Subah, Malaysia*

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A B S T R A C T

**Background:** The superior sagittal sinus and its draining veins are important venous structures that pose a formidable obstacle to surgical management. It is crucial and essential for the surgeon to acquire the knowledge of the normal course and variations of the sinus and its draining veins. This helps in pre-operative planning and execution of pre-operative measures or manoeuvres needed to minimize blood loss or intra-operative injuries to the sinus.

This study was conducted to delineate the microsurgical anatomy of the superior sagittal sinus to look for any variations among Sabah people as compared to the general studies available. This study was based on dissection of fresh cadavers.

**Materials and Methods:** Thirty fresh cadavers were examined in Forensic Department, Hospital Queen Elizabeth, Sabah between August 2020 to June 2021. They were anatomically analysed and studied through a data collection sheet. All data were analysed using Statistical Package for the Social Science (SPSS).

**Results:** The study revealed that male was predominantly significant and forty-three percent were of Bajau race. Fifty percent of cadavers were around the 50-60 years old age group. The position of superior sagittal sinus (SSS) was variable and within 1cm distance from the midline. The origin of SSS varied from at the foramen caecum to posterior from the foramen caecum. The total length of SSS averages around 321-351mm.

The number of draining veins on the right and left side of SSS were divided into anterior, middle and posterior components with an average of three to six veins respectively on each side. The number of venous lacunae on the right and left side of SSS were divided as well into anterior, middle and posterior components with an average of one to two venous lacunae on each side respectively.

The central sulcus was located 48.87mm posterior to coronal suture and 131.1mm anterior to the lambdoid suture. The Trolard vein was located 53.56mm posterior to coronal suture and 127.36mm anterior to the lambdoid suture. The Trolard vein was situated in average 3.68mm posterior to central sulcus and predominantly drains into the venous lacuna. Ninety percent of SSS terminate on the right of the transverse sinus. The position of torcula varies from the location on the external occipital protuberance to slightly on the right side of the external occipital protuberance.

**Conclusion:** This study shows that anatomical landmarks among the local population did not differ significantly from that reported by other studies throughout the world. Therefore, the basic neurosurgical principles and craniometric points outlined universally is applicable to this population without the need for any modifications.



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## 1. Introduction

Superior sagittal sinus (SSS) is the largest dural venous sinus. Originating usually at the foramen caecum, the SSS runs from anterior to posterior, grooving the inner surface of frontal, parietal and occipital lobes terminating in the confluence of sinuses.

The SSS is an important component of the venous system that has numerous anatomical and structural variations including the draining veins which are of clinical and neurosurgical significance.

The extensive length of the superior sagittal sinus makes it the largest dural sinus, rendering it most susceptible to injury. In many literatures, the SSS varies between 1mm-12mm on either side of the superior sagittal suture.[1–4] Hence it is essential to identify the superior sagittal suture before placing a burr hole. Burr hole location should be at least 1cm lateral on either side to minimize injury towards the sagittal sinus and avoid torrential bleeding.

Draining veins and lacunae confluent into the SSS either directly or indirectly. Their anatomical location and mode of drainage are important especially superior anastomotic vein of Trolard, as it plays a major role in the venous drainage of the cerebral cortex. Injury to the lacunae or superior anastomotic vein of Trolard can lead to cortical venous infarct especially over pre-central, central and post central gyrus.

It is crucial for the surgeon to acquire the knowledge of the normal course and variations of the sinus and draining veins for pre-operative planning to enable the correct execution of pre-operative measures or manoeuvres needed to minimize risk of intra-operative sinus injury, thus reducing blood loss. An in-depth comprehension and diligent avoidance of the veins and tributaries will aid in obtaining a good functional outcome and avoiding complications such as venous thrombosis. This is crucial in the surgical management of parasagittal or falx meningioma as well as use of transcallosal approach.

Various authors have studied the SSS,[1–4] veins of the brain and their variations in cadaveric studies, as well as radiologically studies.[5,6] Up to date, no such study has been conducted among the population in Sabah. Hence this study was conducted to in order to delineate the microsurgical anatomy of the superior sagittal sinus for better planning and a more focused surgery. This study was based on dissection of fresh cadavers.

## 2. Literature Review

Various authors have studied the superior sagittal sinus, venous drainage of the brain and their variations in cadavers and as well as radiologically.

Historically, many neurosurgeons and anatomists have described the sagittal suture as overlying the middle portion of the SSS. In Bruno et al,[1] the position of superior sagittal sinus was found to lie anywhere within 1cm on either side. In contrast to Samadian et al.[2] and Tubbs et al.,[3] the superior sagittal sinus deviated mostly to the right side, with some cases up to 11mm from the midline or the sagittal suture.

The origin of SSS was consistent in most of the studies done previously with a variable distance of 1mm to 12mm posterior to the foramen of caecum.[1,7–9]

The length of the SSS has been extensively studied anatomically, radiologically and angiographically. In Bruno et al,[1] the average length of sinus varied from 321mm to 357mm done on 60 cadavers. This finding was in conformity with other published studies.[2,4,9–13]

In a study by Vignes et al.,[14] the precise anatomical description of the SSS–cortical vein junction was conducted in order to gain knowledge about cerebral venous autoregulation. In their study, the draining veins were mostly located over the anterior compartment (5-6 veins) compared to middle and posterior compartments (3-4 veins). Brockmann et al.[13] used computed tomography venography to analyze deviations of the SSS and bridging veins. They found that among 30 brains, 120 were found, and the majority of them drained distal to the coronary suture yet near the SSS.[13] Lately Bruno et al.[1] described the number of draining veins varied from 13 to 19 with predominantly over the anterior frontal region (6.5 draining veins in average).

Enlarged venous spaces contained within the parasagittal dura mater and adjoining the SSS are called venous lacunae. In Rhoton AL,[11] most lacunae are large and most constantly found in the parietal and posterior frontal region with small lacunae found in occipital and anterior frontal regions, which is consistent with the findings in other studies done.[5]

It is essential to localize the central sulcus in patients with lesions within or nearby the sensorial and/or motor cortex. The coronal suture is a valuable bony landmark in neurosurgical practice; it could be used to localize the central sulcus. In Bruno et al.,[1] the central sulcus was found at the average of 49.93mm posterior to coronal suture and 130.78mm anterior to the lambdoid suture. Previous studies have shown some variations, with Sarmento et al[15], found the average distance of central sulcus to coronal suture around 59mm, Gusmo et al.[16,17] around 45mm and Vigo et al.[18] averaging 45mm respectively. However other studies such as Ribas et al[19] and Rivet et al,[20] was compatible with Bruno et al[1] study, with mean distance of central sulcus to coronal suture of 50mm and 50.3mm respectively.

The largest draining vein is the superior anastomotic vein (Vein of Trolard) and it corresponds to central sulcus. In Rhoton AL,[11] vein of Trolard was mostly precentral, central or post central in location. The largest draining vein was

* *Corresponding author*.
*E-mail address*: mrananda18@gmail.com (A. Arumugam).

found at an average of 58.83mm posterior to the coronal suture and 126.83mm anterior to the lambdoid suture on the right side and 54.27mm posterior to the coronal suture and 126.4mm anterior to the lamdoid suture on the left side in Bruno et al. study.[1]

The right transverse sinus is usually a continuation of the superior sagittal sinus, draining blood from the superficial structures of the brain and is typically larger than the left transverse sinus, and the left is usually continuous with the straight sinus. Goyal et al.[21] noticed the transverse sinus to be symmetrical in 66.9% of their patients with the left transverse sinus was hypoplastic in 21.3% and aplastic in 4.1%, while the right side was hypoplastic in 5.5% of patients and aplastic in the remaining 0.7%. However, in another study, the mean diameter of the transverse sinus was 6.21 mm and 6.30 mm on right and left sides, respectively thus confirming it's variability.[22]

The torcula which is the confluence of sinuses is believed to be located below or on the external occipital protuberance. However recent studies have shown that the torcula lies slightly superior or on the right side of the external occipital protuberance.[1,23,24]

## 3. Rationale of Study

Superior sagittal sinus is an important venous structure that is implicated in many diseases affecting the intracranial cavity. Surgical approaches and treatment options must take into account this structure in a way that protects the integrity of this venous space.

This study is done to determine normal course of superior sagittal sinus and the draining veins. This study focuses on the following:

1. To determine location of superior sagittal sinus in relation to sagittal suture.
2. Origin of superior sagittal sinus.
3. Length of superior sagittal sinus.
4. Number of draining veins into superior sagittal sinus in relation to coronal suture and lambdoid suture.
5. Number of venous lacunae into superior sagittal sinus in relation to coronal suture and lambdoid suture.
6. Relationship of central sulcus to coronal suture and lambdoid suture
7. Relationship of Trolard vein to the central sulcus.
8. Relationship of Trolard vein to coronal suture and lambdoid suture.
9. The course of Trolard vein draining into venous lacuna or superior sagittal sinus.
10. Termination of superior sagittal sinus in relation to the left or right transverse sinus.
11. Location of torcula in relation to the external occipital protuberance.

Various studies/research conducted appears to produce varying results and cranio-metric points. A thorough understanding of the relationship between the cranial surface and intracranial structures is paramount to avoid unnecessary exposure or damage to critical anatomical structures.

These measurements and landmarks have been described, however none of these studies were conducted among the local population. As the authors are aware that the general anatomy of Western population differs significantly from the local population, therefore it can be implied that previous descriptions or measurements may not applied entirely to the local population without modifications done to suit the local population.

As this is the first study conducted in Sabah, we hope this study will help understand the anatomical variations in the local population and aid the surgeons in organizing and performing safer surgeries.

## 4. Methodology

### *4.1. Study type and design*

An anatomical study (descriptive study), involving measurements of sinus and venous tributaries. All data are recorded by primary investigator and an independent observer. Images are taken for verification purposes. Images and anatomical landmarks are verified & cross referenced with two qualified anatomist, Prof Dr. Emad Mohamed Nafie Abdel Wahab, Anatomist, Faculty of Medicine, Lincoln University College & Dr. Jessie Hiu @ Jessie Dorey Hiu Chen, Head of Forensic Department, Hospital Queen Elizabeth.

### *4.2. Study center and study duration*

Thirty fresh cadavers were examined in Forensic Department, Queen Elizabeth Hospital between August 2020 to June 2021. They were anatomically analysed and studied through a data collection sheet. This study was approved by the Malaysian Medical Research and Ethics Committee (MREC). [NMRR ID: 19-3953-51499 (IIR)]

### *4.3. Inclusion criteria*

The inclusion criteria were set as all subjects above the age of 18 years.

### *4.4. Exclusion criteria*

On the other hand, the exclusion criteria were subjects that succumb to head injury, subjects that had a craniotomy done previously or subjects diagnosed with severe meningitis or brain infection.

### *4.5. Withdrawal criteria*

Dura was adherent to the skull and sinus got torn during dissection and bridging veins avulsed during dissection are criteria for withdrawal

### 4.6. Study conduct

The dissection and observations performed by the investigators were carried out during routine medicolegal post-mortem examinations done in Forensic Department, Queen Elizabeth Hospital. The equipment required for this study were an electric hand drill, craniotomy perforator and cutter, toothed forceps, non-toothed forceps, scissors, number 11 blade knife, curved mosquito artery forceps, straight mosquito artery forceps, silk sutures, ruler, two 21-gauge needle and a Vernier calliper. Vernier calliper with accuracy of 0.1mm was used for conducting the measurements and both a 16-megapixel digital camera and a DSLR camera were used for taking the photographs.

Standing at the top end of the table with the body supine and the head raised on a supporting block, a skin incision was made through the scalp from behind one ear to the other over the vertex. This was about 1 cm behind one of the ear lobes, proceeding in a coronal plane to a corresponding point behind the other ear. A scalpel with a fresh sharp blade was used. The initial incision was made by inserting the scalpel through the skin down to bone and then turning the scalpel over with its back toward the periosteum and continuing the incision superiorly with the point of the blade travelling toward the vertex. This should part the overlying hair rather than cutting it. The skin anteriorly and posteriorly was reflected to expose the superior surface of the skull. The anterior flap was stripped by forceful retraction of the scalp forward over the face while gentle sweeping strokes of the scalpel were made toward the calvarium, extending this to a level just above the orbits.

A similar procedure was followed for the posterior flap, continuing to the occipital protuberance (Figure 1). The temporalis muscles on each side will be retracted towards the side. Prior to opening the skull bone, bilateral anterior neck was dissected to allow visualization of the carotid sheath. The internal carotid artery, internal jugular vein and Vagus nerve with sympathetic plexus is visualized. The internal jugular vein was dissected open, and a size 14F bladder catheter was inserted. Around 50cc of blue ink dye diluted with Normal Saline was injected to allow the cortical veins and sinuses to be dilated and facilitate better visualization (Figure 2). The contralateral internal jugular vein was clamped with an artery to prevent back flow. Using an electrical perforator, a small hole on the bregma was drilled (the junction between coronal and sagittal sutures) and lambda (the junction between lambdoid and sagittal sutures) penetrating the outer cortical and cancellous bone (Figure 3). Using a needle 21G, inner cortical was penetrated to mark the location of bregma and lambda on the superior sagittal sinus/dura (Figure 4). This was followed by an electrical cutter to make a series of interconnecting cuts through the skull around the periphery.

When using the cutter, precaution was taken not to cut too deeply because the dura and leptomeninges should be removed intact with the brain if possible and not left attached to the skull. It begun at the mid-temporal zone of one side with the line of the cut running anteriorly toward the forehead and then continued backwards at an angle ending just above and behind the contralateral ear intersecting the burr holes made earlier. Two further cuts were done at these end points angled backward toward the occipital protuberance, where they should meet at an angle of about 160°. The mallet and chisel or skull key were used to crack the inner part of the table of the skull. By using blunt dissection, the inner surface of skull vault from the dura was removed and the skull cap was carefully separated. The quality of bone was inspected and observe the impact of the needles over the dura/sinus made earlier (Figure 5). The site of impact of the needles was marked for further references. If the dura was very adherent to the skull and got torn in the process thereby avulsing the sinus along with the bridging veins from the cortex, the specimen was not taken into consideration.

Dura was opened on the right side followed by the left side in a C-shaped manner using a sharp scalpel with the base flapped towards the superior sagittal sinus and 3cm lateral from the sagittal sinus.

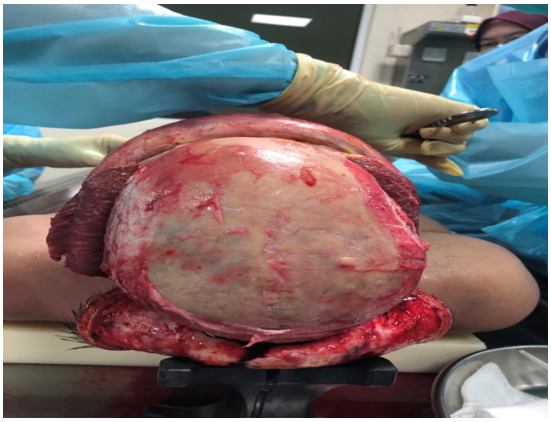


**Figure 1:** Standard opening of skin 1cm behind ear lobe proceeding above the vertex and end at the opposite side 1cm behind the ear lobe

The measurements collected using a data collection sheet during routine post-mortem examination were as the following:

### 4.7. Position of superior sagittal sinus (SSS)

The position of SSS from the coronal suture to the lambdoid suture was noted. The sagittal suture was taken as the reference point, and if the sinus was found directly underneath the suture, it was recorded zero. If the sinus was located on the left or right, the measurements were recorded in units of millimetres using a Vernier calliper.

**Figure 2:** 50cc blue dye diluted with normal saline injected via internal jugular vein with a size 14F Foley's catheter

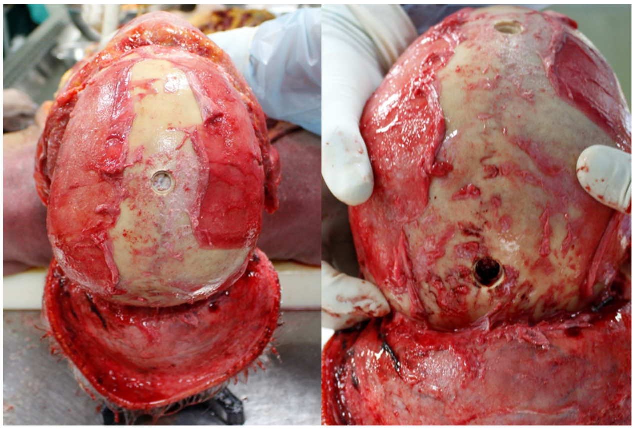


**Figure 3:** Burr hole done over bregma and lambda respectively

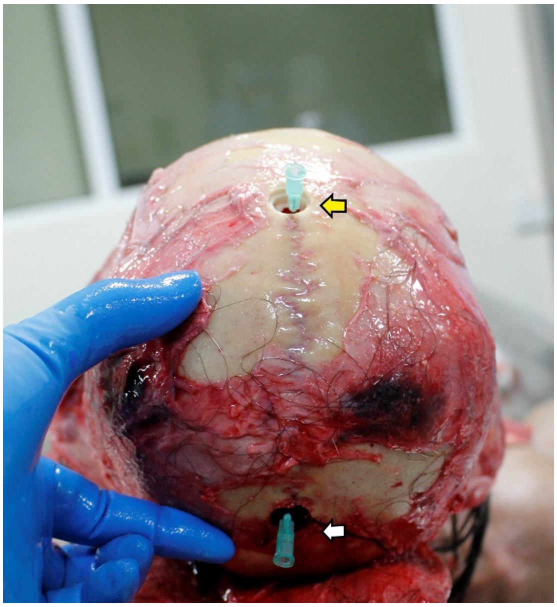


**Figure 4:** Needle placed over bregma (yellow) and lambda (white) post burr hole

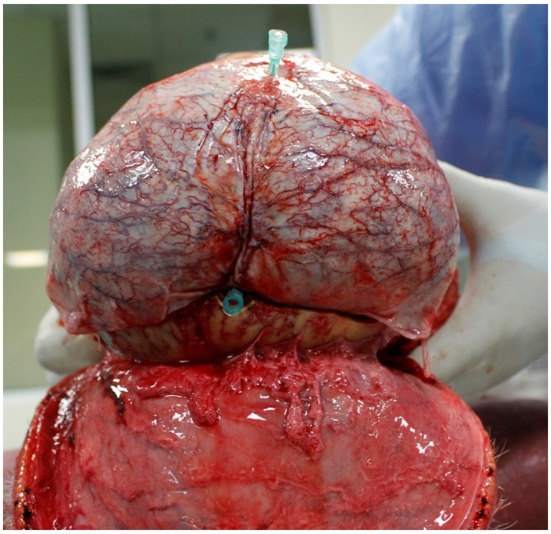


**Figure 5:** Both needles carefully preserved post craniotomy / bone opening

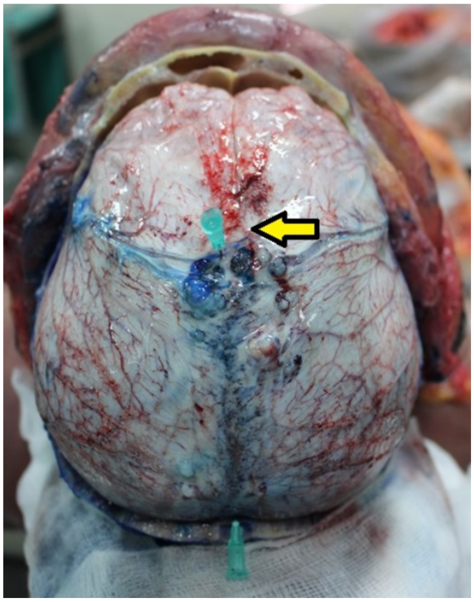


**Figure 6:** Needle demarcates the location of superior sagittal sinus in relation to sagittal suture (yellow arrow)

### 4.8. *Origin of superior sagittal sinus (SSS)*

If the sinus originated from the foramen caecum, it was noted as zero. If the sinus originated anterior or posterior from the foramen caecum, the distance of origin of the SSS for the foramen caecum was measured in millimetres.

### 4.9. *Length of superior sagittal sinus (SSS)*

The length of the sinus was measured from its origin (foramen caecum) to the site of termination (torcula). This was measured using a long silk thread. One end of the

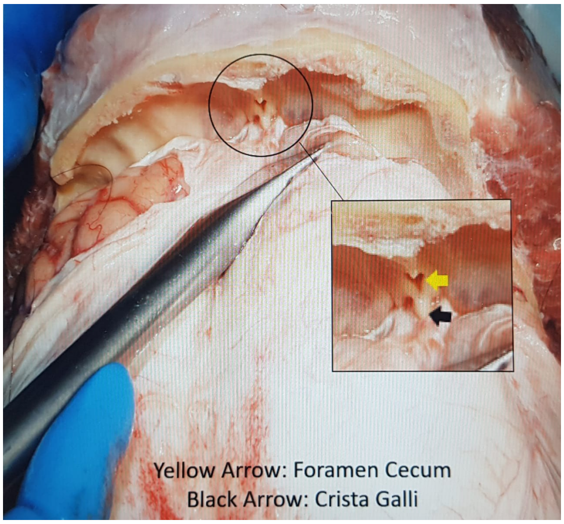



**Figure 7:** Origin of superior sagittal sinus in relation of foramen caecum

thread was placed at the site of origin. The position of the coronal suture and lambdoid suture were noted on the thread. The site of termination was also noted on the thread. The length of the silk thread was then measured with a Vernier calliper and the measurements were noted according to the following landmarks:

1. Anterior one-third of the sinus was regarded as the distance from the glabella to the coronal suture.
2. Middle one-third was regarded as the distance from the coronal suture to the lambdoid suture.
3. Posterior one-third was regarded as the distance from the lambdoid suture to the torcula.

The total length of the sinus was calculated based on these three values.

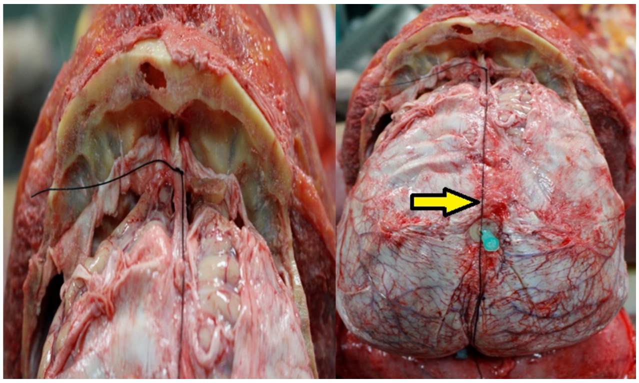


**Figure 8:** Measurement of superior sagittal sinus with Silk 2/0 (yellow arrow)

### *4.10. Number of draining veins in superior sagittal sinus in relation to coronal suture and lambdoid suture*

The dura was opened first on the right side, and then on the left side, in a C-shaped manner, with the base towards the Sylvian fissure and 3 cm lateral from the sagittal sinus and other measurements were made. Draining veins were observed on both sides and grouped in three groups on each side from the glabella to the coronal suture, from the coronal to the lambdoid suture and from the lambdoid suture to the torcula.

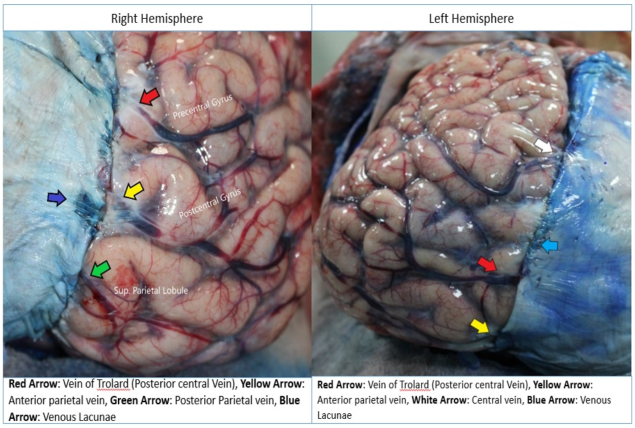



**Figure 9:** Identification of draining veins and venous lacunae on each hemisphere

### *4.11. Number of venous lacunae into superior sagittal sinus in relation to coronal suture and lambdoid suture*

Venous lacuna is defined as a lateral pouch or diverticulum of the SSS of the brain into which protrude arachnoid villi that return cerebrospinal fluid into the venous circulation. The venous lacunae draining from both sides was then noted. It was again grouped into three groups on each side, from the glabella to the coronal suture, from the coronal to the lambdoid suture and from the lambdoid suture to the torcula.

### *4.12. Relationship of central sulcus to coronal suture and lambdoid suture*

The distance of the central sulcus from the coronal suture and lambdoid suture on both sides was measured using a Vernier calliper. This data was of immense clinical significance in locating the motor cortex.

### *4.13. Relationship of Trolard vein to the central sulcus*

The Trolard vein and its location to the central sulcus was noted. If the vein was located on the central sulcus, it was noted as zero. If it was located anterior or posterior to the central sulcus, the distance from central sulcus was

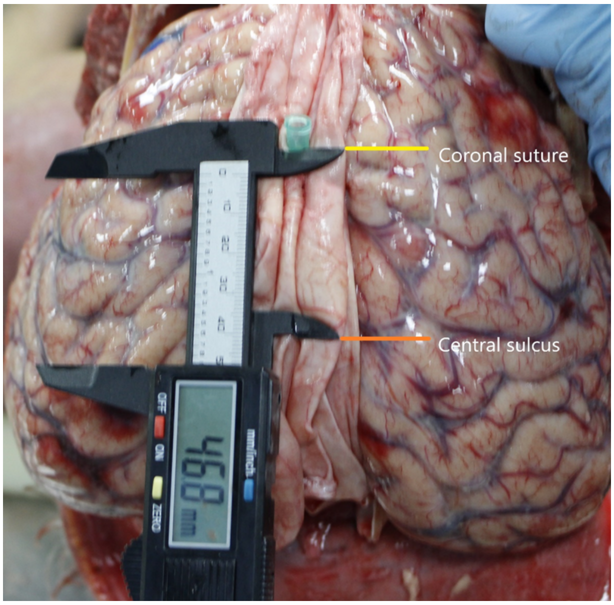



**Figure 10:** The relationship of central sulcus and coronal suture measured with Vernier calliper

measured in millimetres using a Vernier calliper.

### *4.14. Relationship of Trolard vein to coronal suture and lambdoid suture*

The Trolard vein and its location to coronal suture and lambdoid suture was noted. If the vein was located on the coronal suture or lambdoid, it was noted as zero. If it was located anterior or posterior to the sutures, the distance from central sulcus was measured in millimetres using a Vernier calliper.

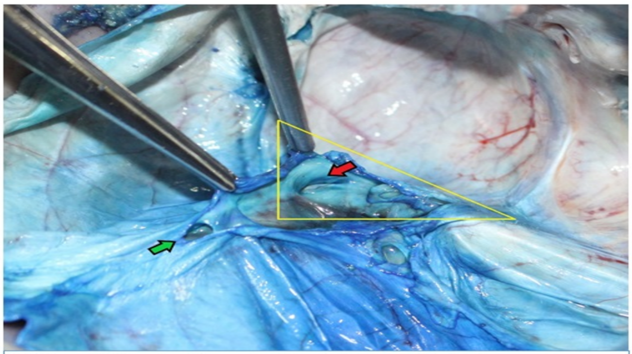
### *4.15. The course of Trolard vein into SSS or venous lacunae*

The Trolard vein drains the superficial middle cerebral vein (sylvian) into the SSS. However, in a certain percentage of population, the Trolard vein drains into the venous lacuna. The course of the Trolard vein draining into the venous lacuna or SSS was observed in this study.

### *4.16. Termination of superior sagittal sinus (SSS) in relation to the left or right transverse sinus*

The torcula was opened in a cruciate manner and the mode of termination of the superior sagittal sinus was noted as follows:

1. Superior sagittal sinus drained only into the right transverse sinus and had no communication with the left transverse sinus
2. Superior sagittal sinus drained predominantly into the right transverse sinus
3. Superior sagittal sinus bifurcated into the right and left transverse sinuses
4. Superior sagittal sinus drained predominantly to the left transverse sinus
5. Superior sagittal sinus drained only into the left transverse sinus and had no communication with the right transverse sinus

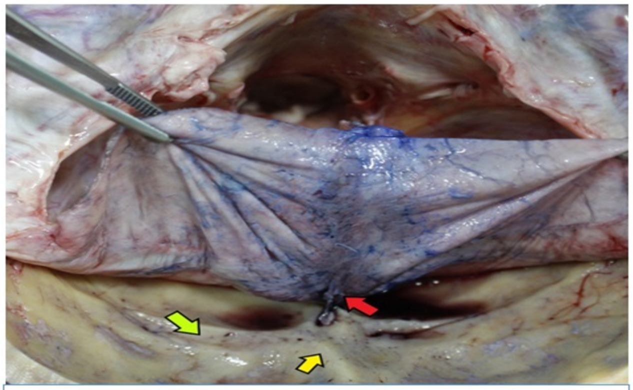


**Yellow Triangle**: Torcula, **Red Arrow**: Right transverse sinus with large lumen, **Green Arrow**: Superior sagittal sinus

**Figure 11:** Termination of superior sagittal sinus in relation to transverse sinus

### *4.17. Location of torcula in relation to the external occipital protuberance*

The location of the torcula in relation to the external occipital protuberance (EOP) was also noted. The position of the torcula was either above the level of the EOP, at the level of the EOP, or below the level of the EOP. Whether the torcula was to the right, at the midline, or to the left of the EOP was also recorded.



**Red Arrow**: Torcula, **Green Arrow**: Transverse sinus groove, **Yellow Arrow**: Internal occipital protuberance

**Figure 12:** Location of torcula in relation to the transverse sinus and occipital protuberance

### *4.18. Statistical analysis*

The data analysis will be done using the SPSS version 22. Descriptive will be expressed as mean ± standard deviation (SD) unless otherwise state.

## 5. Results

The number of male patients were 23 compared to 7 female patients. The age varied from 28 years old to 64 years old, with a mean age of 50.57 years old. (Figure 13). The superior sagittal sinus in the study had no side preference. The sinus was found to be up to 10.2mm on the right side and 10.0mm on the left side. (Figure 14). The mean average was 7.19mm on the right side and 7.10mm over the left side (Table 1). The superior sagittal sinus originated at a variable distance from at the foramen of caecum to range of 2.0mm to 10.0mm posterior to the foramen of caecum. The mean site of origin of superior sagittal sinus was 6.02mm posterior to the foramen of caecum. (Figure 15). Length of the superior sagittal sinus varied between the range of 321.5mm to 351.5mm with a mean value of 340.3mm and median value of 342.4mm.

In this study, we found the number of draining veins and venous lacunae varies from anterior to posterior component. The number of draining veins in the anterior component varied from 4-7 draining veins, the middle component and posterior component had around 3-4 draining veins respectively (Table 2). On the other hand, the anterior and middle component had 2 venous lacunae in average while the posterior component mostly had a single venous lacuna (Table 3).

The central sulcus was found at an average distance of 48.84mm posterior to the coronal suture and 131.16mm anterior the lambdoid suture on the right side, whereas on the left side: 48.91mm posterior to the coronal suture and 131.11mm anterior the lambdoid suture. (Table 4). The Trolard vein was identified 53.53mm posterior to the coronal suture and 127.28mm anterior to the lambdoid suture on the right side. On the left side, the Trolard vein was 53.59mm posterior to the coronal suture and 127.36mm anterior to the lambdoid suture. The Trolard vein was found to be posterior to central sulcus ranging from 2.45mm to 5.00mm with a mean distance of 3.67mm. In 25 of the cadavers (83%), the Trolard vein drains into the venous lacunae first before joining the superior sagittal sinus.

Around 27 cadavers (90%) revealed the superior sagittal sinus terminating predominantly to the right side of the transverse sinus. The torcula examined was mostly at the level of external occipital protuberance with six cases were on the right side of the external occipital protuberance.

## 6. Discussion

The cerebral venous system divides into a superficial and deep component with the superior sagittal sinus being the major component of the superficial cerebral venous system. Adequate knowledge of this structure, and its variations are of significant clinical importance to neurosurgeons in the treatment of a number of conditions. A strong anatomical understanding of the superior sagittal sinus is crucial for surgeons, as this dictates the correct surgical approach to avoid injury to veins and sinus.

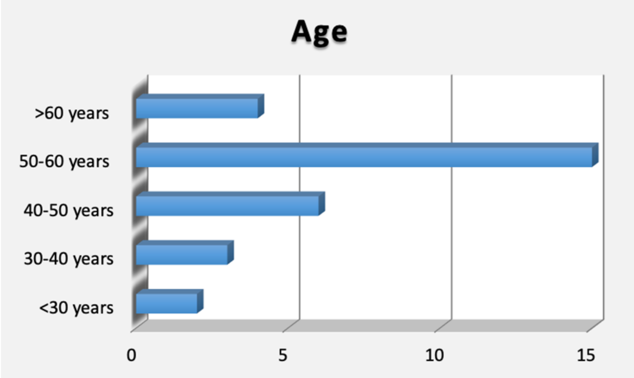



**Figure 13:** Age distribution of patients in the study

This study was done to understand the variations in origin and termination of the superior sagittal sinus, the drainage pattern and important craniometric landmarks for surgery.[1,25] Many studies were done before especially by O'Connell et al. (1934) whom pioneered the research on superior sagittal sinus has led the way to many breakthroughs and better detailed understanding of the cerebral venous structures anatomically and angiographically as well.[1,2,4,9,11–13]

Hence, we have aspired to research and acquire anatomical knowledge of the Sabah population and compare our findings with various other authors and its significance in neurosurgery.

### *6.1. Position of the superior sagittal sinus*

The position of the superior sagittal sinus seems to pose a dilemma to neurosurgeons. Many literatures and publications have recently disputed the findings that the superior sagittal sinus is midline or slightly towards the right side.[1,18,25] In our study the, superior sagittal sinus was found to be 1cm on either side of the sagittal suture, without any predilection for a particular side. In a study done by Reis et al., burr holes should be placed at least 10mm lateral of midline on the left side and 20mm lateral of midline on the right side to avoid injuring the SSS.[26] This was further solidified by Shim et al, that advice operators not to deviate from preoperative plans to create a larger bone flap and to strive to maintain a SSS to a bone flap distance of at least 20 mm intraoperatively.[27]

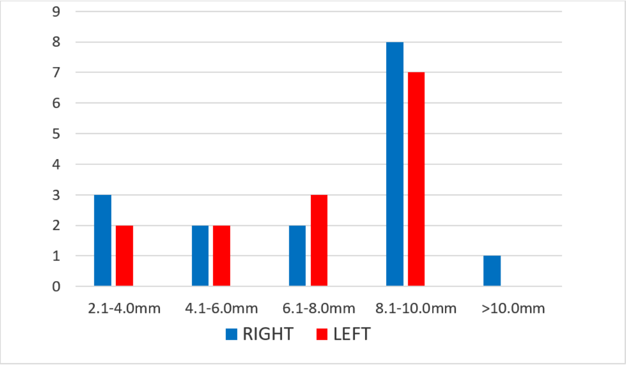



**Figure 14:** Location of superior sagittal sinus in relation to sagittal suture

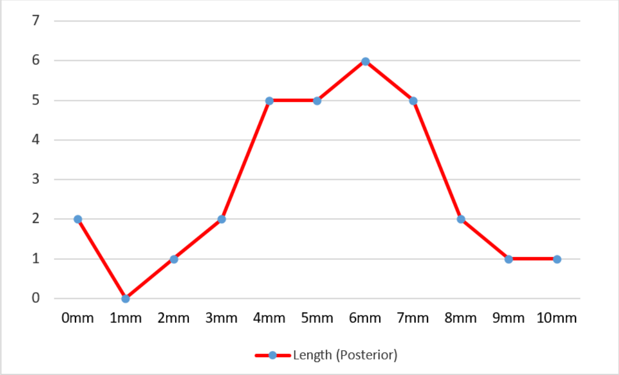



**Figure 15:** Origin of superior sagittal sinus in relation to foramen caecum

**Table 1:** Maximum distance of superior sagittal sinus from the sagittal suture

| Study | Side of Predilection | Maximum distance from the sagittal suture |
|---|---|---|
| Bruno et al.[1] | No side predilection | 10mm |
| Samardian et al.[2] | Right side | 10mm |
| Tubbs et al.[3] | Right side | 11mm |
| This study | No side predilection | 10.2mm |

### 6.2. *Origin of the superior sagittal sinus – distance from foramen caecum*

In our study, the origin of the superior sagittal sinus was predominantly posterior to foramen of caecum with mostly of a distance from 2.0mm to 10.0mm. The mean site of the origin of the superior sagittal sinus was 6.02mm posterior to foramen of caecum which was consistent with other published studies.[7–9] Kaplan et al. researched extensively on normal cadavers and found no evidence of venous drainage via ethmoid and superior sagittal sinus suggesting it was safe to detach the rostral superior sagittal sinus attachment during bifrontal approach safely.[7] San et al. on the other hand, recently published angiographic evidence of vein of foramen of caecum which terminates into directly into the superior sagittal sinus or via anterior frontal vein, observed in vascular anomaly patients.[28] Therefore, neurosurgeons must be meticulous in understanding the pre-operative angiographic venous drainage especially in anterior frontal approaches.

### 6.3. *Length of superior sagittal sinus*

In this study, the length of superior sagittal sinus varied between the range of 321.5mm to 351.5mm with a mean value of 340.3mm and median value of 342.4mm. This was consistent with previous studies done.[1,2,4,9–11,13] In dealing with superior sagittal sinus bleed or laceration, a small tear can be fixed with gel foam, muscle patch and with the dura flapped with stay sutures.[29] However a larger length of tear or a large tumour invading the length of the superior sagittal sinus may warrant venous sinus reconstruction with silicone tube or pedicle galea flap.[30,31]

### 6.4. *Number of draining veins into the superior sagittal sinus in relation to the coronal suture and lambdoid suture*

In Andrews et al, there were an average 6.5 draining veins in each side of the hemisphere at the anterior frontal region, 3 draining veins in the posterior frontal region, 4 draining veins in parietal region and 1 draining vein in occipital region.[4] In this study however, we have simplified the number of draining veins based on the coronal suture and lambdoid suture, thus dividing them into anterior, middle and posterior components. The number of draining veins in the anterior component varied from 4-7 draining veins, the middle component and posterior component had around 3-4 draining veins respectively (Table 2). The interhemispheric transcallosal approach offers an excellent surgical corridor for the treatment of deep-seated midline lesions however this approach sometimes requires the sacrifice of one or more middle-third superior sagittal sinus draining veins, which introduces the risk of venous infarction and associated neurological injury.[32] Sahoo et al. published a scoring system to determine the dominance of draining veins on the anterior third of superior sagittal sinus based on length of vein, vein calibre, number of tributaries and angulation. Those with dominant drainage are likely to develop venous congestion and complications if sacrificed.[33] Therefore modern neurosurgery warrants preservation of the superior sagittal sinus and it’s draining veins to avoid venous oedema and neurological complications.

**Table 2:** Number of draining veins into superior sagittal sinus

| Number of Draining Veins | Number of Subjects | |
|---|---|---|
| | Right Hemisphere | Left Hemisphere |
| **a) Anterior Component** | | |
| 4 draining veins | 1 | 2 |
| 5 draining veins | 17 | 6 |
| 6 draining veins | 11 | 21 |
| 7 draining veins | 1 | 1 |
| **b) Middle Component** | | |
| 3 draining veins | 5 | 5 |
| 4 draining veins | 25 | 25 |
| **c) Posterior Component** | | |
| 3 draining veins | 16 | 12 |
| 4 draining veins | 14 | 18 |

### *6.5. Number of venous lacunae draining into the superior sagittal sinus in relation to the coronal suture and lambdoid suture*

In this study, the anterior and middle component had two venous lacunae in average with the posterior component mostly a single venous lacuna (Table 3). In Rhoton AL,[11] most lacunae in the parietal and posterior frontal region are the largest and the most constant while small lacunae were found in occipital and anterior frontal regions. In a study done by Tsutsumi et al., venous lacuna with an upward protrusion was commonly found over the frontal region. Therefore, these characteristic findings are important when planning to make a bony window in or involving the parasagittal posterior frontal region to avoid torrential bleeding and venous infarct.[5]

**Table 3:** Number of venous lacunae into superior sagittal sinus

| Number of Venous Lacunae | Number of Subjects | |
|---|---|---|
| | Right Hemisphere | Left Hemisphere |
| **a) Anterior Component** | | |
| 1 venous lacuna | 0 | 0 |
| 2 venous lacunae | 30 | 30 |
| **b) Middle Component** | | |
| 1 venous lacuna | 5 | 5 |
| 2 venous lacunae | 25 | 25 |
| **c) Posterior Component** | | |
| 1 venous lacuna | 30 | 30 |

### *6.6. Relationship of central sulcus to coronal suture and lambdoid suture*

This study concluded that the central sulcus was found at an average distance of 48.84mm posterior to the coronal suture and 131.16mm anterior the lambdoid suture on the right side, where as 48.91mm posterior to the coronal suture and 131.11mm anterior the lambdoid suture on the left side. Various studies have shown different findings in these measurements especially the coronal suture and central sulcus. Sarmento et al. reported the central sulcus to be an average distance of 59mm posteriorly from the coronal suture,[15] with Gusmao et al. reported as 45m.[16,17] Ribas et al as 50mm[19] and Bruno et al as 49.9mm[1] (Table 4). In terms of neurosurgical perspective, the central sulcus plays an important role in identification of motor cortex. Sarmento et al. proposed two lines with line 1 corresponds to the distance between the coronal suture to the beginning of the central sulcus on the midline (60mm) and the line 2 corresponds to the same distance, but just paramedian on the high convexity (52mm).[15] The postcentral gyrus was located 6.5 behind the bregma on the midline and coursed laterally and frontally constituting a 62° angle with the sagittal suture as was reported by Kendir et al.[34] These clearly shows the variation in distance the from coronal suture as the sulcus travels laterally on the cerebral surface. Given that recognition of the pattern of central sulcus awareness of the coordinates and projections of certain gyri according to the craniometric points may considerably contribute to surgical intervention.

### *6.7. Relationship of Trolard vein to coronal suture and lambdoid suture*

The Trolard vein is the largest draining vein in the cerebral hemisphere, and correspond to the Rolandic vein (vein of the central sulcus). In this study, the Trolard vein was identified 53.53mm posterior to the coronal suture and 127.28mm anterior to the lambdoid suture on the right side. On the left side, the Trolard vein was 53.59mm posterior to the coronal suture and 127.36mm anterior to the lambdoid suture. In Rhoton AL,[11] vein of Trolard was mostly precentral, central or post central in location. The largest draining vein was found at an average of 58.83mm posterior to the coronal suture and 126.83mm anterior to the lambdoid suture on the right side and 54.27mm posterior to the coronal suture and 126.4mm anterior to the lambdoid suture on the left side in Bruno et al. study.[1]

### *6.8. Relationship of Trolard vein to the central sulcus*

In our study the Trolard vein was found to be posterior to central sulcus ranging from 2.45mm to 5.00mm with a mean distance of 3.67mm. Yousry TA et al. studied the relationship between the central sulcus and coronal suture using functional MRI. The study concluded that sulcal veins lying deep within the central sulcus drain activated blood from the adjacent pre- or postcentral cortex during performance of a motor hand task, can be identified easily with functional MR imaging; and, are an anatomical landmark for non-invasive identification of the CS and thus the sensorimotor strip.[6] In the presence of space occupying lesions or brain edema, the central sulcus position might alter in relation to bony landmarks. Therefore, the Trolard vein is feasible as an alternative for neurosurgeons to identify to central sulcus during surgery.

### *6.9. The course of Trolard vein draining into venous lacuna or superior sagittal sinus*

In our study 83% Trolard vein drains into the venous lacunae rather than directly into the superior sagittal sinus. Mathew et al. described a cadaveric dissection of the calvarium of a 90 years old woman, demonstrated a left superior anastomotic vein of Trolard communicating indirectly with the superior sagittal sinus via a left lateral lacuna. As we know, not many publications or research was done in detail regarding superior Trolard vein and it's draining pattern. However from a neurosurgery perspective, occlusion of the lacunae with a large Trolard vein draining into the lacuna could have led to a devastating cortical venous infarct if collateral venous drainage had not been adequate.

### *6.10. Termination of superior sagittal sinus in relation to left or right transverse sinus*

Around 27 cadavers (90% of total cadavers) revealed the superior sagittal sinus terminating predominantly to the right side of the transverse sinus in our study. (Table 5).[14] In Bruno et al, 73.3% of superior sagittal sinus predominantly drain into the right transverse sinus.[1] Hwang et al. studied the drainage patterns of the torcular Herophili via venogram and classified into four types. The study concluded that it was safe to ligate the sinus if the transverse sinus is ligated and cut proximal to the superior petrosal sinus and distal to the vein of Labbé. However, the contralateral sinus must be patent and smaller sinus should be ligated and resected. The patients also were subjected to a preoperative balloon occlusion test or jugular vein compression test as demonstrated by carotid and vertebral artery angiography.[35]

In our study, most cases drained predominantly on the right side suggesting any damage to the right transverse sinus can lead to severe venous infarct and massive bleeding during surgery.

**Table 4:** Termination ofSSS in relation to left and right transverse sinus

| Study | Right Dominance | Left Dominance | Co-Dominance |
|---|---|---|---|
| Bruno et al. [1] | 80% | 11.7% | 8.3% |
| Samadian et al. [2] | 76% | - | - |
| This study | 90% | - | - |

### *6.11. Location of torcula in relation to the external occipital protuberance*

The torcula examined was mostly at the level of external occipital protuberance, 24 cases with 6 cases were on the right side of the external occipital protuberance in our study. This was in contrary to Bruno et al. [1], Tubbs et al.[3] and Ebrahiem et al.[24] which was slightly above and to the right. A study in a Turkish population reported the torcula to range from 11mm to 23mm below the inion.[36] In a supracerebellar infratentorial approach, Suslu et al. recommends the burr hole to be minimum 10mm posterior and lateral to the external occipital protuberance, even suggesting 5mm below the semispinalis capitis muscle attachment to the superior nuchal line as a better landmark.[37] Craniometric localization of the external occipital protuberance and avoidance of the transverse sinus or the torcula enhances the craniotomy size and surgical view for surgery.

## 7. Study Limitation and Recommendation

This present study was done during the COVID pandemic, hence many cadavers had to be screened for Covid prior autopsy performed. Therefore, many patients turned out to be positive which significantly impact our target of number of cadavers. Secondly, this study was done without an operating microscope which might provide better information as well as pictures for the study. We recommend that the future studies to be done with microscope and in a larger scale to solidify previous findings done by previous authors.

## 8. Conclusion

Our study is the first study done focusing on anatomy of the superior sagittal sinus and it's draining veins in Sabah population. In the neurosurgery field, it is essential for surgeons to preserve all cerebral veins if possible. No large important vein should be sacrificed unless preservation of that vein, in the surgeon's judgment in that particular case, results in more danger to the patient by limiting the approach or by making it impossible to deal with the pathology. The study mostly didn't differ much from international publications suggesting a standardised universal approach can be adapted for a better understanding of important veins and craniometric points in management of neurosurgery patients in Asian population.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None.


## 10. Conflict of Interest

None.

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## Author biography


**Ananda Arumugam,** -

**Vicnesh Thillynathan,** -

**Dewaraj Velayudhan,** - https://orcid.org/0000-0003-1695-8769

**Jessie Hiu,** -

**Emad. M.N Abdelwahab,** -



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