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ORIGINAL ARTICLE

A cadaveric study of anatomical variation of sphenoparietal sinus and superficial sylvian draining veins

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ABSTRACT

BACKGROUND: The sphenoparietal sinus (SPS) is a dural venous sinus. It was coined and gained interest in 19th century. However, controversies exist in the drainage of superficial sylvian veins (SSV). One of the key steps in the trans-sylvian and subtemporal approach is to identify SPS and bridging veins from SSV to create a wide surgical corridor. Hence, the aim of this study was to delineate the microsurgical anatomy and variation of the sylvian draining veins.
METHODS: Thirty fresh cadavers were examined in Forensic Department, Queen Elizabeth Hospital between October 2020 to October 2021 and were anatomically analyzed. The cadaveric data collected through a data collection sheet were analyzed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA).
RESULTS: The studied cadavers were 76.7% male and 23.3% female with a median age of 52.5 years old. All cadavers had SPS on both sides and drain to the ipsilateral cavernous sinus. The number of SSV drainage (SSVD) varied from 0 to 4 veins on both hemispheres. About 40% of cadavers had three veins on the left hemisphere, 36.7% had two and three veins on the right hemisphere, and 3.3% had no draining veins on either side. Based on cadaveric data, a new classification for the SSVD-SPS was formulated to describe the number (from 4 to 0) of SSVD veins: Type A to type E.
CONCLUSIONS: We have consolidated our hypothesis on the presence of SPS and variance in the number of draining veins to SPS. This new classification provides a new microsurgical nomenclature that facilitates future use in neuroanatomy and neurosurgery.

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Key words: Cerebral veins; Paranasal sinuses; Cadaver; Drainage.

Venous anatomy is generally more variable than arterial anatomy, and this is especially true for superficial cortical veins. The superficial middle cerebral vein (SMCV), also known as the superficial sylvian vein (SSV), drains into the sphenoparietal sinus (SPS) before emptying into the cavernous sinus (CS).[1, 2] The SMCV is the main component of the sphenoidal group of superficial bridging veins. The SMCV receives cortical venous drainage from the opercula and areas adjacent to the Sylvian fissure as it runs along the course of the Sylvian fissure. The curvilinear path of SMCV is ideal for confocal imaging of the lateral surface of the cerebral hemisphere.[3] In general, the sine is also supported by orbital, medial anterior, temporal (uncal) and lower frontal veins. In an atlas of the venous system in the early nineteenth century, Breschet introduced the phrase sine sphenoparietal sinus (sinus alae Parvae) as it was found within a uniformly oriented gutter, which flows in the cavernous sinus, inside this anterior and media segments of the base of the skull.[4] Cruveilhier later referred to Breschet's description of the SPS as a "sinus found within the limits of the anterior and medial portions of the base of the skull, occupying a transversally oriented gutter that runs inward into the cavernous sinus."[5] Several venous branches from the skull bones, the dura mater, and the diploic vein of the temporal bone enter this sinus.[6] Breschet's drawings correspond to the sphenoid portion of the SPS, located beneath the lesser sphenoid wing and actively engaged in diploic and meningeal venous drainage. The SPS is best visualized by removing the dura mater from the anterior part of the middle cranial fossa and viewing it from the front. Tubbs and colleagues examined 15 adult cadavers, all of which had both left and right sphenoparietal sinuses. The sinuses measured 2.5 and 3 mm on average for the left and right sides, respectively.[7] The SPS is a transversely oriented venous network within the dura mater situated immediately beneath the lesser sphenoid wing. It joins the anterior branch of the middle meningeal vein, which runs from the foramen spinosum along the vascular groove in the floor of the middle cranial fossa, near the pterion.[8] Laterally, it connects to the branches of the middle meningeal vein, and medially, it terminates at the anterior aspect of the cavernous sinus. The SPS receives venous drainage from the nearby skull base, specifically from the orbital roof diploic vein, the greater sphenoid wing diploic vein, and, on rare occasions, an orbital vein.[6, 7, 9] In some cases, the superior ophthalmic vein communicates with the SPS rather than the cavernous sinus.[8, 10] The venous drainage of the brain can be divided into deep and superficial venous systems. The superficial system consists of cortical veins that run along the surfaces of the brain, which are drained venously from the cortex and the subcortical white matter. Cortical venous veins connect to the bridging veins, eventually leading to the venous dural sinuses.[11-13] One of the superficial cerebral veins is the SMCV. It usually runs cranially along Sylvian fissure and drains numerous small tributaries from the opercular areas around the lateral sulcus. It drains into the SPS or directly into the CS after curving anteriorly around the tip of the temporal lobe. However, there is significant variation. It may have anastomotic spine connections to other dura mater venous sinuses, the superior sagittal sinus *via* the superior anastomotic vein, and the transverse sinus *via* the inferior anastomotic vein.[14] SMCV usually runs downward and forward along the Sylvian fissure before entering the SPS or CS.[15] The anatomic relationship between the SPS and the SMCV is debatable. San Millán Ruíz *et al.*[6] studied the venous anatomy of this region in 15 nonfixed cadavers and discovered no link between the SMCV and the SPS in any specimens. Similarly, Nagata *et al.*[8] discovered that the SMCV was not connected with the SPS during contrast-enhanced 3D fast spoiled gradient-echo T1-weighted MR imaging in any of 24 patients. On the other hand, other researchers have discovered a high incidence of a link between the SPS and the SMCV.[1, 7, 16] When the SPS receives a prominent frontobasal bridging vein, the sinus can be skeletonized and mobilized to allow elevation of the frontal lobe and preservation of the vein.[17] The SMCV was not found to enter SPS. Both SPS and SMCV appear to be separate entities. These venous structures can be evaluated using magnetic resonance imaging (MRI) or spoiled gradient-recalled (SPGR) sequence with fat suppression. Ikushima *et al.*[18] reported that the SMCV entered the SPS in 57.5% of patients diagnosed in an MRI study using 3D contrast-enhanced magnetization-prepared rapid gradient-echo (MP-RAGE). Hacker classified drainage of the SMCV to include SPS, sphenobasal vein, sphenopetrosal vein, or cortical veins. Suzuki *et al.* reclassified SMCV drainage into seven patterns using a three-dimensional computed tomography venogram (3D-CTV).[19] These reclassified forms are useful for understanding venous drainage in the context of surgery, as preserving these veins is thought to be necessary to avoid injury. The great anastomotic vein of Trolard connects the SMCV to the superior sagittal sinus, and the posterior anastomotic vein of Labbé connects it to the transverse sinus. Deep cerebral vein and SMCV in 53% of cases are connected, which is a major collateral way whenever a tumor occludes the proximal position of SMCV. The SMCV drainage pattern influences the decision to use a microsurgical skull base approach with a middle cranial fossa dura incision.[20] Frigeri *et al.* explained that one of the three sinuses, superior sagittal, transverse and sphenoparietal sinuses, drains directly from the central lobe.[21] The lower one-third of the lateral surface drains to the superficial sylvian veins, which then drain to the transverse sinus *via* the vein of Labbé or anteriorly to the SPS *via* the SSV. In 50% of their specimens, the inferior one-third of the precentral gyrus drained to the SPS, 40% to the transverse sinus, and 10% to the superior sagittal sinus. Finally, in 35% of the specimens, the lower part of the postcentral drilled to the SPS, in 45%, the transverse sinus, and in the final Trolard vein of the upper sagittal sinus. One of the key steps in the trans-sylvian approach is the dissection of the SSV to create a wide surgical corridor without interfering with the normal venous flow.[22] The size and linkage of the SSV vary frequently. According to previous research mostly on sylvian veins, the discovery of outflow points was performed using angiography, 3D computed tomography, and cadaveric study. According to the gold standard for surgery in this area, the arachnoid of the Sylvian fissure should be opened on the frontal side of the veins, so that they will not cross the Sylvian fissure when the frontal lobe is retracted. To complete the dissection, two or three fronto-orbital venous tributaries that cross the Sylvian fissure and enter the middle cerebral vein must be sacrificed.[23] Drainage of SSV has been reported in many literatures with controversies exist. One of the key steps in the trans-sylvian and subtemporal approach is to identify this sinus and bridging veins from SSV to create a wide surgical corridor. Hence, this study aims to delineate the microsurgical anatomy and variation of the sinus and sylvian draining veins.

Materials and methods

Study design

This is a single-center cadaveric dissection and a 1-year prospective study conducted from October 1, 2020, to October 1, 2021, at the Forensic Department of Hospital Queen Elizabeth (QEH) in Sabah, Malaysia. The study was approved by the Malaysian Medical Research and Ethics Committee (MREC) (NMRR ID: NMRR-19-4104-50949[IIR]).

Cadaveric dissection approach to examine the anatomical variation of sphenoparietal sinus and superficial sylvian draining veins

Thirty fresh cadavers of the Sabah population (Sabahan) above 18 years old of both genders were recruited for this neuroanatomical study. Equipment and tools used included an electric hand drill craniotomy perforator and cutter (Midas Rex; Medtronic, Dublin, Ireland), toothed forceps, non-toothed forceps, scissors, number 11 blade knife, curved mosquito artery forceps, straight mosquito artery forceps (SMS Instruments, Kuala Lumpur, Malaysia), and silk sutures size 2/0 (Silkam; B. Braun Melsungen AG, Melsungen, Germany). A digital camera with 16 megapixels (Canon EOS 5D Mark IV 30MP sensor Dual Pixel CMOS AF; Canon Inc., Tokyo, Japan) was used for photography. The dissections were performed during routine medico-legal investigations. The skin incision was made through the scalp from behind one ear to the other over the vertex while standing at the top end of the table with the body supine and the head elevated on a supporting block. The technique for cranial and neck dissection is done by the forensic team using the standard Knight forensic autopsy method. Skin incisions began about 1 cm behind one of the ear lobes and proceeded to a coronal plane to a point 1 cm behind the other ear. A sharp scalpel blade was used to cut through the whole thickness of the scalp. The initial incision took place when the scalpel was inserted into the skin down to the bone. Then the scalpel was turned over toward the periosteum with its back to continue with the incision superior to that point. The overlying hair was divided into pieces instead of cut. The anterior and posterior halves of the scalp was reflected forward and backwards to expose the upper skull surface. The anterior flap was retracted forward using a retractor, while the scalpel swept gently toward the calvary, extending it 1cm just above the supraorbital ridge. The posterior flap was retracted to the occipital protuberance, followed by a similar procedure. On either side, the temporal muscles were retracted, and burr holes was made using a perforator drill around the cranium, and then an electric cutter to cut the skull around the periphery to produce several interconnection cuts (Figure 1A). The temporalis muscles on both sides were cut along the lines of the subsequent saw cuts prior to sifting. When using the cuts, the dura and leptomeninges needed not to be cut too deep, if possible, intact with the brain, and not attached to the skull. That was started on the mid-timer zone on one side and runs forward to the forehead, followed by an angle that ends just above and behind the reverse ear that intersects the previously constructed burr holes. According to the standard incision during autopsy, the inner skull table was cracked by using a mallet, chisel, or skull key. With blunt dissection, the inner surface of the skull's vault and the skull cap was carefully removed. Blue saline dye injection was used for proper visualization of the vein. The internal jugular veins were dissected cautiously in the neck and sampled. A saline solution had been completely scrubbed on the venous system (Fig-

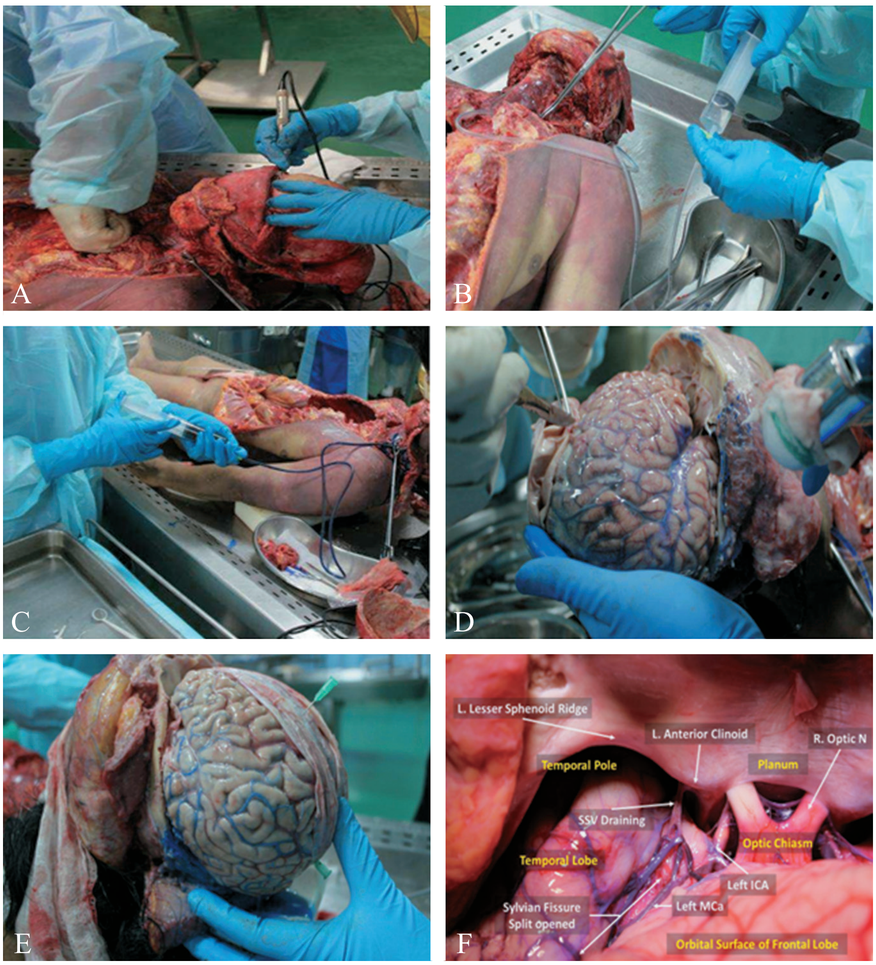

Figure 1.—Cadaveric dissection approach to examine the anatomical variation of sphenoparietal sinus and superficial sylvian draining veins.

ure 1B). Sites of leakage and ligatures had been recognized. A blue dye combination was injected into each jugular vein until it was dilated with the angular veins (Figure 1C). The dura on the right side was cut open in C-shaped manner to expose the Sylvian fissure (Figure 1D). Followed by the left side of the brain, the dura was opened with a sharp scalpel with a base flat to the upper sagittal sinus that exposes the center and lower temporal gyrus to the temporal pole (Figure 1E). The draining veins and sinus were slightly elevated and temporal pole was exposed. Then, SPS final drainage was identified. The sinus variation and its draining veins were observed and recorded (Figure 1F). The other side of the cranium was dissected by using a similar method.

Data collection

Demographic and age of the cadavers were recorded in a data collection sheet. Two separate data were collected to avoid inter-observed variability. A picture of anatomical structure was taken to be verified by an anatomist.

Statistical analysis

Analysis was conducted using statistical software, IBM SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Only descriptive analysis was used in this study. Continuous variables were presented in mean (standard deviation, SD) or median (interquartile range, IQR) depending on the normality of data. Categorical data was presented as frequency and percentage. Cohen's Kappa will be used to assess the inter-rater agreement if any discrepancies are noted between two data given by two observers during data cleaning. Fisher's Exact Test, McNemar Test and Mann-Whitney U Test were applied accordingly in the analyses. A P value of less than 0.05 was considered statistically significant.

Results

A total of 30 cadaveric examinations were conducted. Inter-rater variability for all the observed data was examined using Cronbach's alpha as well as Kappa's Cohen and obtained a value of 1 for all observed data. Table I summarizes the characteristics of all cadavers. Most cadavers were male (N.=23, 76.7%), with a median age of 52.5 years old (IQR=14 years old). The races of all cadavers were noted to be Native Sabahan where nearly half were reported as Bajau ethnics (N.=13, 43.3%). Both right and left sphenoparietal sinuses were present in all the cadavers (N.=30, 100%) and were draining to the ipsilateral cavernous sinus. SMCV morphological pattern complexity of the left and right hemispheres (N.=30) show no significant difference. For the right hemisphere, a Fisher's Exact Test was run as shown. There was no significant association between gender and complexity of the SMCV venous pattern (P=0.977). Also, there was no significant association between ethnicity and the complexity of the SMCV venous pattern (P=0.711). A Mann-Whitney U Test revealed no significant association between age and complexity of SMCV venous pattern (P=0.142) (data

Table I.—*Characteristics of the cadavers (N.=30).*

Variables	Group	Number (N.)	Percentage (%)
Age (years)	21-30	2	6.7
	31-40	3	10.0
	41-50	7	23.3
	51-60	15	50.0
	61-70	3	10.0
Ethnicity	Sungai	5	16.7
	Bajau	13	43.3
	Dusun	5	16.7
	Kadazan	6	20.0
	Murut	1	3.3
Gender	Male	23	76.7
	Female	7	23.3
Presence of SPS and termination into right/left cavernous sinus	Right	30	100.0
	Left	30	100.0

TABLE II.—*Association between different variables and SMCV morphological pattern complexity for right and left hemisphere (N.=30).*

Variables	Right hemisphere			Left hemisphere		
	Simple	Complex	P value	Simple	Complex	P value
Gender						
Male	13 (76.5%)	10 (76.9%)	0.977*	12 (100.0%)	11 (61.1%)	0.024*
Female	4 (23.5%)	3 (23.1%)		0 (0.0%)	7 (38.9%)	
Ethnicity						
Sungai and bajau	11 (64.7%)	7 (53.8%)		6 (50.0%)	12 (66.7%)	0.458*
Others	6 (35.3%)	6 (46.2%)		6 (50.0%)	6 (33.3%)	

Values are expressed as N. (%).
*Fisher's Exact Test.

TABLE III.—*Number of SSV.*

Number of SSV	Right side (%)	Left side (%)
0	1 (3.3)	1 (3.3)
1	5 (16.7)	3 (10.0)
2	11 (36.7)	8 (26.7)
3	11 (36.7)	12 (40.0)
4	2 (6.7)	6 (20.0)

SSV: superficial sylvian veins.

not shown). For the left hemisphere, a Fisher's Exact Test revealed a significant association between gender and complexity of SMCV venous pattern (P=0.024). The complexity of SMCV patterns is higher in the male group compared to the female group. However, there was no significant association between different ethnicity and complexity of SMCV venous pattern (P=0.582). Comparison of left and right SMCV morphological pattern complexity (N.=30) using McNemar Test revealed no statistically significant difference (Table II). The number of SSV connecting the SMCV to SPS was identified (Table III). Both right and left SMCV drains into sphenoparietal sinus *via* two or three SSV in majority (36.7-40%). On the cadaveric data, we have identified that the SMCV do drain into the SPS *via* superficial sylvian draining veins (aka SSV or bridging veins) before draining into the CS (Figure 2). We have formulated a new classification for the SSV-SPS complex based on the number of bridging veins identified. We classified the SSV-SPS complex into five types as shown in Figure 3.

Discussion

Understanding this anatomical architecture is the foundation of many surgical entry zone being formulated.[24] Considerable variations exist in the size, number, and exact location of the bridging veins of the skull base, and knowledge of this anatomic variation is clinically important, particularly from a neurosurgical perspective. In most cases, the surgeon can sacrifice the small veins and dural venous sinuses encountered during surgery without harming the patient. However, serious complications, including venous infarction, have occasionally resulted from seemingly minor injuries to these interconnected veins.[25]

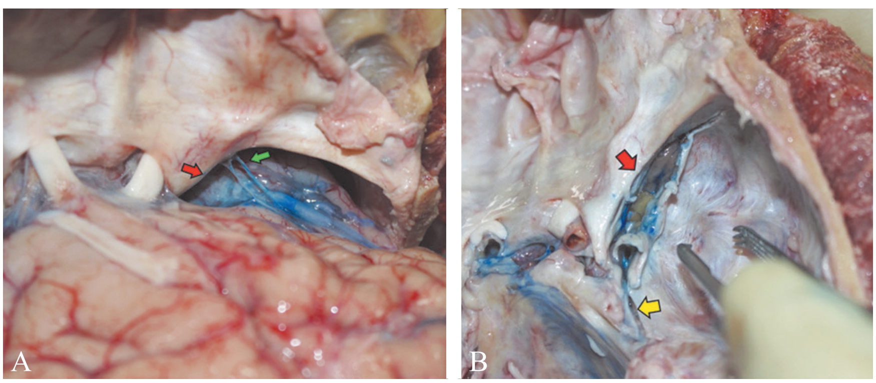

Figure 2.—A) The superior view of the temporal fossa shows SSV (dark gray arrow; green arrow in the online version) and SPS (black arrow; red arrow in the online version). B) SPS is cut open to expose the flow of blue dye into the CS (light gray arrow; yellow arrow in the online version).
SSV: superficial sylvian veins; SPS: sphenoparietal sinus; CS: cavernous sinus.

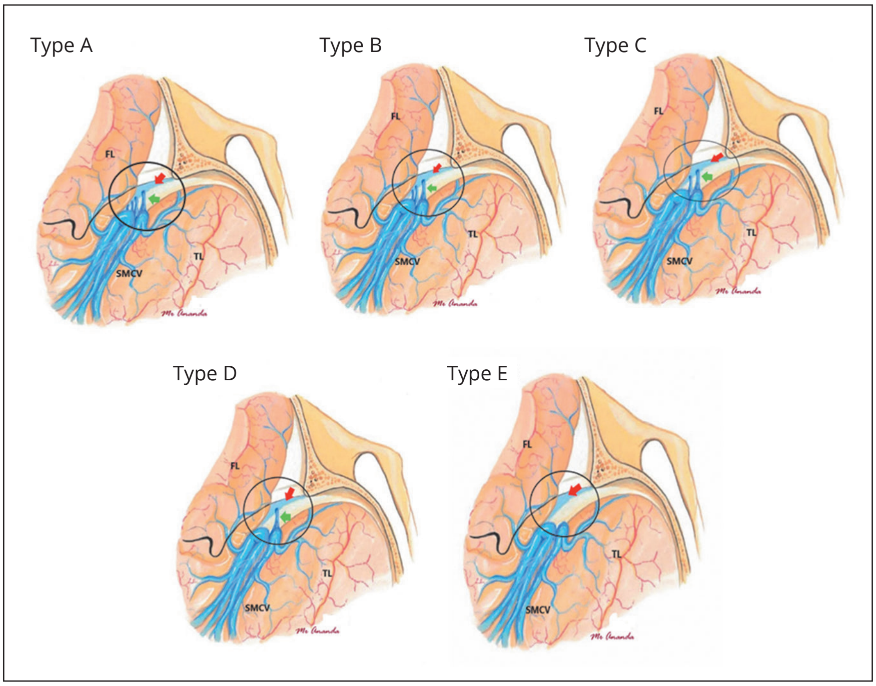

Figure 3.—New classification on the drainage of SMCV based on the presence of SPS and variance in the number of draining veins to SPS. Type A refers to 4 SSV (green arrow) and SPS (red arrow); type B indicates 3 SSV and SPS; type C refers to 2 SSV and SPS; type D includes 1 SSV and SPS; type E represents No SSV.
SSV: superficial sylvian veins; SPS: sphenoparietal sinus; TL: temporal lobe; FL: frontal lobe; SMCV: superficial middle cerebral vein.

These complications have prompted anatomic and surgical efforts to foster greater understanding and prevention of these events. Predicting the consequences of surgical ligation of the venous structures is challenging because there are no effective measures to guide the surgeon. Unlike the arteries, intraoperative occlusive testing is not feasible with veins, because the onset of venous infarction varies greatly among individuals. Nakase *et al.*[25] encountered symptomatic postoperative venous infarction in approximately 0.3% of cases. In their series, three patients had a severe type of venous complication from the sacrifice due to sphenopetrosal veins. Thus, preoperative assessment of these veins and their anastomoses is important because it allows the surgeon to optimize the surgical approach and anticipate sources of venous bleeding. The SMCV is the main component of the cerebral hemisphere's sphenoidal group of superficial bridging veins. It receives cortical venous drainage from the opercula and areas adjacent to the Sylvian fissure as it runs along the course of the Sylvian fissure.[26] The SSCV has been classified into five types from 45 adult cadaveric dissection. They reported various courses and anastomosis but the connection of SMCV to SPS *via* SSV was not stated. The SPS joins the anterior branch of the middle meningeal vein, which runs from the foramen spinosum along the vascular groove in the floor of the middle cranial fossa, near the pterion.[9] One of the key steps in the trans-sylvian approach is the dissection of the SMCV to create a wide surgical corridor without interfering with the normal venous flow.[22] Previous research mostly on sylvian veins, has discovered outflow points using angiography, 3D computed tomography, and cadaver study. The current study was conducted by dissecting the cranium of cadavers to determine the presence of SPS. The findings reported that the SPS is present on both sides of the hemisphere. The current 30 cadaveric anatomical studies demonstrated the presence of SPS on both left and right hemispheres. The reported findings have shown that the superficial sylvian draining veins varies among the Sabah population. The cadavers between age of 50-60 years have a high number of draining veins into ipsilateral SPS. Our data analysis shows variation among numbers of draining veins that form bridging veins and drain into ipsilateral SPS. However, the variation is relatively consistent among all cadavers. All cadavers have SPS terminating into ipsilateral cavernous sinus. The numbers of SSV in the cadavers ranges from 0 to 4 draining veins with variations between both hemispheres. It is important to create awareness among neurosurgeons regarding the inconsistency of SSV that varies in numbers. The SSV is always hidden beneath the sphenoid ridge and SMCV, hence premature retraction of the temporal lobe may result in torrential venous bleeding. The majority of those examined dictated cadavers has 2 to 3 draining veins in both hemispheres, accounting for 36% in the right hemisphere and 40% in the left hemisphere. Hence, based on this variation in numbers, we have proposed a new nomenclature based on the number of SSV draining into SPS. The proposed classification is called SSV-SPS complex based on the number of draining veins.

Conclusions

Conclusively, we have consolidated our hypothesis on the presence of SPS, drainage pattern of SPS and variant in the numbers of draining veins to SPS. This new classification is aimed to provide new microsurgical nomenclature for future use in neuroanatomy and neurosurgery.

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Conflicts of interest
The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Authors' contributions
Ananda Arumugam has given substantial contributions to the study conception and design; Ananda Arumugam, Harvinth Nagalingam and Hiu Jessie contributed to the performance of the cadaveric dissection; Ananda Arumugam and Harvinth Nagalingam contributed to the data collection and to the manuscript draft; Pike-See Cheah contributed to the data analysis and interpretation; Pike-See Cheah and Emad M. Abdelwahab contributed to the manuscript critical revision for important intellectual content. All authors read and approved the final version of the manuscript.

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History
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