Original Article

Surface Anatomy for Surgery Around Transverse Sinus, Torcular Herophili in Relation to Lambdoid Suture, Inion, and Superior Nuchal Line

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Background: Dural venous sinuses around the torcular herophili area must be preserved during routine craniotomy such as suboccipital approach, supracerebellar approach. Localization of these venous sinuses is usually guided by surgical landmarks such as inion, superior nuchal line and asterion.

Objective: The present study aimed to demonstrate the accuracy of routine surface landmarks in estimating the exact location of these dural venous structures in the Thai population.

Materials and Methods: Fifty-one formalin-fixed skulls were studied in their bony landmarks around the torcular area. Surgical landmarks included lambdoid sutures, inion, and superior nuchal lines within 3.5 cm lateral from the inion bilaterally. The transverse sinuses were measured in relation to the surface landmarks by using vernier calipers.

Results: Inion is located at the torcular herophili area 68.6%, inferior to the torcular herophili 19.6% and superior to the torcular herophili 11.8%. The right superior nuchal line located at the transverse sinus 68.6%, inferior to the sinus 13.7%, and superior to the sinus 17.7%. The left superior nuchal line located at the transverse sinus 66.7%, inferior to the sinus 9.8%, and superior to the sinus 23.5%. Lambdoid sutures located superior to the sinuses 3.5 cm on the right and 3.8 cm on the left. The width of the right transverse sinus was greater than the left transverse sinus significantly. ($p<0.05$).

Conclusion: Inion and superior nuchal lines were roughly useful landmarks for torcular herophili and transverse sinuses. Right transverse sinus is larger than the left transverse sinus. Lambdoid suture is not a good landmark for these venous sinuses. Without availability of the neuro-navigator, burr holes of adult craniotomy should be placed inferior to the superior nuchal line at least 15 mm to avoid transverse sinuses and cut the bone at least 8 mm below inion to avoid torcular herophili for routine midline posterior fossa surgery.

Keywords: Torcular herophili; Transverse sinus; Inion; Superior nuchal line

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Craniotomy around the occipital, suboccipital area is commonly performed in neurosurgical operation such as posterior fossa lesion or pineal region tumor. Dural venous sinuses are important vascular structures usually encountered during placing burr holes and opening of the bone flap. Generally, injury to major venous sinuses may cause significant morbidity such as massive blood loss, delayed sinus thrombosis and also mortality[1-3]. Nowadays, surgical navigation is helpful to confirm these vital structures, but it may not be available in every operative theatre. The surface landmarks of the skull are still important and can be used to approximate the location of dural venous sinuses.

In occipital and suboccipital osteology, superior nuchal line, muscle insertion of semispinalis capitis, and inion are used to delineate the trajectory of the transverse sinus and torcular herophili[4,5]. Carefully studying preoperative MRI in sagittal view of muscle insertion and venous sinus is practically recommended for craniotomy around this area[6]. The purpose of this study is to clarify the accuracy, anatomical variation by using the superior nuchal line, inion, and lambdoid sutures to estimate the position of the torcular herophili and transverse sinuses establishing the proper site for burr hole/craniotomy in order to perform optimal midline posterior fossa craniotomy safely.

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Materials and Methods

This is a cadaveric study of 51 heads fixed with formalin which was carried out between October 2015 and 2016 in the Department of Anatomy, Mahidol University, Thailand. The study was approved by Ramathibodi hospital ethics committee (No. MURA2015/246).

Inion is defined as the tip of largest prominence, the external occipital protuberance. It is palpated easily in

the midline of the squamous portion of the occipital bone. Superior nuchal line is an elevated ridge of bone that arches from the external occipital protuberance laterally on both sides. Superior nuchal line is attached by an investing layer of the deep cervical fascia, trapezius, sternocleidomastoid, and semispinalis capitis. Uncovering of these muscle layers lead to better identification of the superior nuchal line. The lambda corresponds with the point where the lambdoid sutures and sagittal suture join in the midline. The lambdoid sutures begin at the lambda and course oblique laterally to the asterion.

After soft tissue was dissected out of occipital and suboccipital bone, the surface anatomy of superior nuchal line, semispinalis capitis insertion, inion, and the lambdoid sutures were identified in an area located within 3.5 cm from inion. Small holes using 2 mm drill were created on inion, superior nuchal line lateral to the inion 3.5 cm both sides, and lambdoid suture in the midline and lateral to the midline 3.5 cm, and then needles were inserted on these landmarks' holes. The distances were measured with vernier caliper recording the lambda-torcular herophili, both sides of lambdoid-transverse sinus, superior nuchal line-transverse sinus, inion-torcular herophili, and width of the transverse sinus. Statistical analysis consists of range, mean, median, standard deviation, and 95% confidence interval. The statistic paired t-test for 2 dependent means was used to compare the width of the right and left transverse sinuses and significant if p-value less than 0.05 (PASW Statistics 18)

Results

Fifty-one cadaveric heads consisted of 19 females and 32 males. Age of the cadavers ranged from 48 to 97 years and cause of deaths were not related to intracranial diseases. Superior nuchal line, semispinalis capitis muscle insertion, and inion were found in all cadavers, but there were 2 skulls that lambdoid sutures fused and disappeared. The size of the right transverse sinus was larger than the left transverse sinus, 0.74 cm (95% CI; 0.68 to 0.79) and 0.59 cm (95% CI; 0.52 to 0.66) respectively. Its difference was statistically significant with the p-value=0.00072. When the distances between the transverse sinuses and lambdoid sutures were measured, they were 3.51$\pm$0.78 cm on the right side and 3.80$\pm$0.77 cm on the left side. The lambda was 6.41$\pm$1.01 cm superior to the torcular herophili in the midline.

Right superior nuchal line located at the level of the right transverse sinus in 35 from 51 specimens (68.6%). It was superior to the upper edge of the transverse sinus in 9 specimens (17.7%) with the mean 0.60$\pm$0.25 cm, while 7 (13.7%) specimens were inferior to the lower edge of the sinus 0.70$\pm$0.30 cm. Superior nuchal line on the left side located at the transverse sinus 34 in 51 specimens (66.7%), 12 specimens (23.5%) situated superior to the upper border of the transverse sinus with mean distance 0.94$\pm$0.51 cm, and 5 specimens (9.8%) were inferior to the lower border of the left transverse sinus and its mean length was 0.98$\pm$0.44 cm. Inion located exactly to the torcular herophili in 35 of 51 specimens, which was 68.6%. It was 6 specimens (11.8%) that were superior to the torcular herophili for 0.80$\pm$0.38 cm, in contrast to 10 specimens (19.6%) of inion which were inferior to the torcular 0.75$\pm$0.49 cm (Figure 1).

Discussion

Dural venous sinuses in the posterior fossa such as torcular herophili, transverse sinuses, occipital sinus are important vascular structures. During occipital and suboccipital craniotomy, preservation of these venous sinuses decreased surgical complications. With different pathology and optimal corridor, exposure close to the sinus or over sinus can increase the angle of operative view through the microscope. Knowing the anatomical surgical landmarks and its variation helps optimize the surgical planning and workflow.

In the present study of Tubbs et al[4], insertion of the semispinalis capitis situated between superior and inferior nuchal line was the most reliable external landmark locating the transverse sinuses, not the superior nuchal line and inion. This landmark is easily identified under the trapezius and splenius capitis and does not change regarding the posterior fossa pathology. The study recommended that transverse sinuses were safe if the burr hole was placed 5 mm below the semispinalis capitis insertion with average 2.8 cm lateral from the midline.

Suslu et al[5] reported that inferior nuchal line reliably determined the proximal transverse sinuses in a dry skull osteology especially for infratentorial supra-cerebellar approach in pineal tumor and the burr hole could be safely created at 1 cm inferior to the inferior nuchal line in order to prevent injury to transverse sinus. Inferior nuchal line is palpable before operation and visible on the occipital bone after muscle dissection. This line is always just superior to the superior border of the sulcus that leads to the transverse sinus[7].

Table 1. The distance from lambda/lambdoid to venous sinuses and width of transverse sinuses

Distance or size	Range (cm)	Mean (cm)	Median (cm)	SD (cm)	95% CI for mean
Right transverse sinus	0.34 to 1.15	0.74	0.75	0.18	0.68 to 0.79
Left transverse sinus	0.20 to 1.50	0.59	0.60	0.24	0.52 to 0.66
Lambda-torcular herophili	3.72 to 8.47	6.41	6.35	1.01	6.12 to 6.70
Right lambdoid-transverse sinus	1.40 to 5.09	3.51	3.72	0.78	3.29 to 3.74
Left lambdoid-transverse sinus	1.10 to 5.00	3.80	3.85	0.77	3.58 to 4.02

Table 2. The superior nuchal line and inion in relation to important venous sinuses

Position	Number (n=51)	Range (cm.)	Mean (cm.)	Median (cm.)	SD (cm.)	95% CI for mean
Inion						
At the level of the torcular	35 (68.6%)	-	-	-	-	
Superior to the torcular	6 (11.8%)	0.24 to 1.20	0.80	0.85	0.38	0.40 to 1.91
Inferior to the torcular	10 (19.6%)	0.15 to 1.50	0.75	0.65	0.49	0.41 to 1.10
Right superior nuchal line						
At the level of the right transverse sinus	35 (68.6%)	-	-	-	-	-
Superior to the upper edge of the transverse sinus	9 (17.7%)	0.20 to 1.00	0.60	0.56	0.25	0.41 to 0.80
Inferior to the lower edge of the transverse sinus	7 (13.7%)	0.45 to 1.00	0.70	0.52	0.30	0.42 to 0.97
Left superior nuchal line						
At the level of the left transverse sinus	34 (66.7%)	-	-	-	-	-
Superior to the upper edge of the transverse sinus	12 (23.5%)	0.10 to 2.10	0.94	0.95	0.51	0.62 to 1.26
Inferior to the lower edge of the transverse sinus	5 (9.8%)	0.40 to 1.45	0.98	0.90	0.44	0.43 to 1.53

In an imaging study utilizing three dimensional image of CTA, Hwang RS et al[8] found that the right transverse sinus was invariably larger and its lower border often inferior to the superior nuchal line which craniotomy would cause sinus injury. Another MRI study from Kivelev et al[6] identified the upper muscle insertion line in the midline and on mid-pupillary line both sides and concluded this landmark was found in every preoperatve MRI sagittal views, which correlated to transverse sinus.

In our osteology, the authors found that the inion and superior nuchal line were roughly reliable anatomical landmarks, which correlated to the torcular herophili and both transverse sinuses in 68.6%, 66.7%, and 68.6% respectively. The right transverse sinus was statistically larger than the left transverse sinus (p-value=0.00072). Asymmetric transverse sinus is common findings in previous anatomical study, which is usually larger on the right side[4]. For the infratentorial supra-cerebellar approach, craniotomy is normally performed superior to the transverse sinuses and torcular herophili in order to retract both structures upward (Figure 2C, 2E). For this craniotomy, burr holes can be placed on the sinus and cut bone away from sinus or alternatively placed close to edge of sinus or not expose sinus initially, then drilled over sinus carefully. Carefully detached slope of sinus and dura because uneven dural fold can easily cut by chance during craniotomy. Once craniotomy done, elevation of bone flap always causes bleeding from emissary vein(s) or arachnoid granulation posterior to torcular herophili, which can be stopped by application of gel foam and surgicel.

From the dissection, there were 9.8% on the left and 13.7% on the right that the superior nuchal lines were inferior to the lower border of transverse sinuses. For midline posterior fossa suboccipital craniotomy, placing of the burr holes inferior to the superior nuchal line at least 7 mm (average width of transverse sinus, 6.6 mm) is generally enough to avoid the sinuses entry. However, the neurosurgeon should be aware that at the level of the superior nuchal line can be located superior to the upper edge of transverse sinus on both sides about 23.5% on the left and 17.7% on the right with the average distance of both sides 7.9 mm. Among these anatomical variations of surgical landmarks, burr holes at about 7 mm below superior nuchal line still have a chance to be on the sinus about 20%. Without navigation, our study in Thai population suggested burr holes at 15 mm (average distance plus average width of transverse sinus) below superior nuchal line are probably safe and practical to avoid sinus injury, this is roughly between the superior nuchal line and inferior nuchal line as mentioned in anatomical study[4] and imaging study for the midline posterior approach[6]. For the pediatric skull, small hole drilling point at mid-distance between superior and inferior nuchal line may be easier to define rather than exact distance from superior nuchal line. For the lateral posterior fossa surgery such as retrosigmoid approach, previous literature recommended at least 3 mm or 10 mm below superior nuchal line to avoid transverse sinus[9,10]. If neuro-navigation is available, the precise anatomical data of individual patients can be very helpful in

preoperative planning of burr holes and craniotomy.

In the midline, the inion located superior to the torcular in 11.8% and the mean distance was 8 mm which again implied that cutting the bone at least 8 mm below the inion can help avoid the torcular herophili. The suboccipital bone in the midline inferior to the inion is thicker as compared to the lateral squamous part of cerebellar fossa of the suboccipital bone because of the underlying internal occipital crest. Burr hole at this area is thicker than usual and carries the higher risk to injure dura (Figure 2F). Craniotomy over the crest from one side to the other can also easily tear dura and occipital sinus, carefully detaching dura away from bone

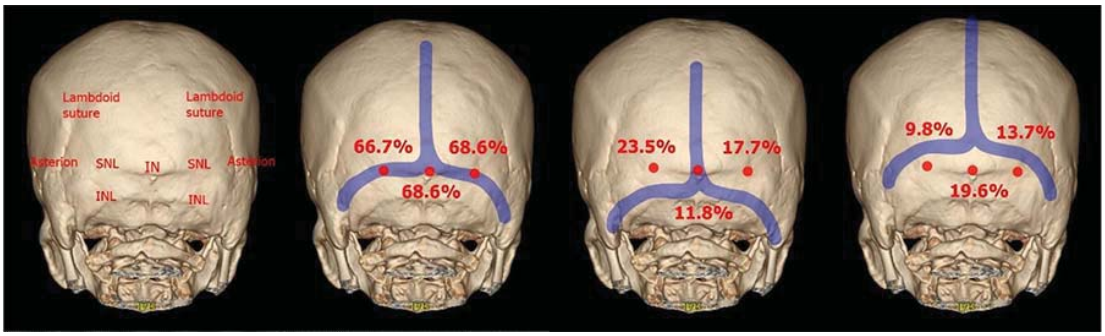

Figure 1. The anatomical variations of transverse sinuses, torcular herophili and outer bony landmarks especially inion and superior nuchal line (IN = inion, SNL = superior nuchal line, INL = inferior nuchal line), dots of both sides were measured at 3.5 cm from inion.

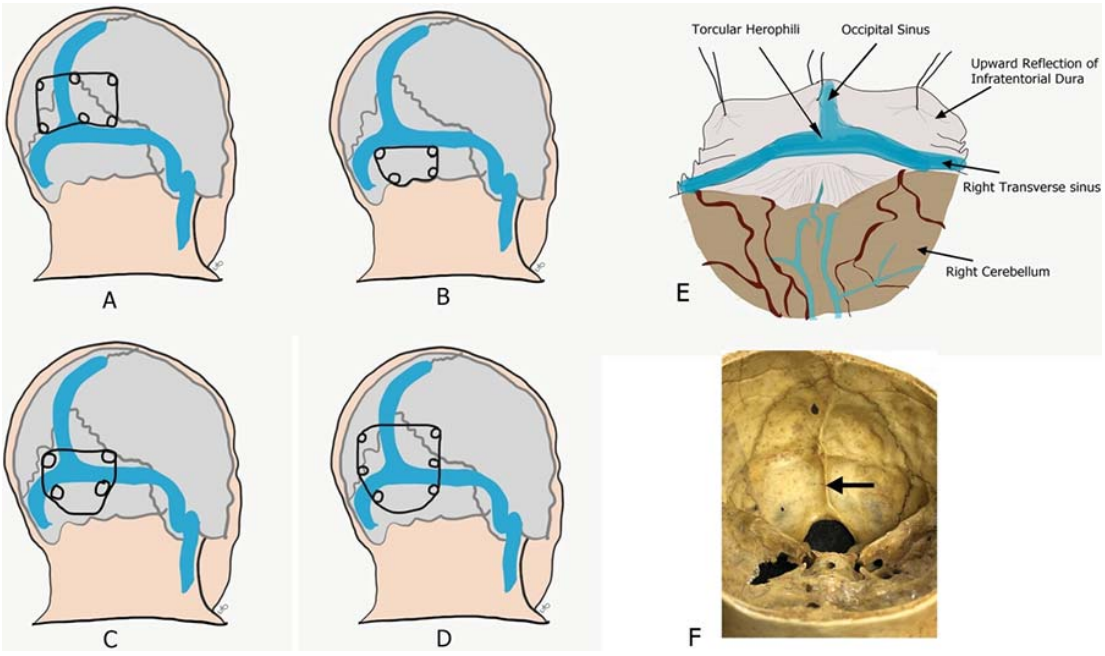

Figure 2. Various surgical operations around the torcular herophili area: A) occipital transtentorial approach, B) suboccipital approach, C) infratentorial supra-cerebellar approach, D) combined supratentorial and infratentorial approach. E) Dural opening and corridor for infratentorial supra-cerebellar approach and F) internal occipital crest (black arrow).

with dissector is recommended before craniotomy. Occipital sinus is commonly found (64.5%) in adult posterior fossa venous drainage[11]. Either single occipital sinus subtype or double occipital sinus subtype involved in the midline posterior fossa craniotomy. Preoperative MRI and MRV is necessary for knowing anatomy of individual patients such as asymmetric transverse sinus both size and location, marginal sinus[12] and occipital sinus.

For the occipital transtentorial approach, bone flap is created superior to the transverse sinuses and extended to the contralateral side of the occipital lobe depending on the preference of tumor location. Superior cuts usually covered the lambda area, which allowed retraction space above calcarine cortex in order to avoid contralateral homonymous hemianopia (Figure 2A). Sometimes the bony corridor can be extended above and below the transverse sinus for combined approach both supratentorial and infratentorial such as very large pineal tumor (Figure 2D). From the present study, it was 13.7% and 9.8% on the right and left sides which superior nuchal lines were inferior to the lower border of the transverse sinuses with the average distance of both sides 8.1 mm. In routine practice of adult craniotomy without navigation, placing burr holes superior to the superior nuchal line at least 15 mm (average distance plus average of transverse sinus), would be generally safe not entry into the sinuses. Certainly, individual anatomy should be studied carefully before tailored craniotomy. Another concerning point is the diploic venous system during midline craniotomy above torcular herophili, which is less commonly found as compared to the posterior temporal diploic vein in the asterional area[13]. The lambdoid suture is not a good landmark for transverse sinus. Because position and morphology of the lambdoid is variable and intricate as its growth has membranous and cartilaginous origin. Our cadaveric results demonstrate a wide range of distance between lambdoid sutures and transverse sinuses and absence of lambdoid suture in 2 specimens. However, lambdoid suture is a good landmark to limit craniotomy anteriorly due to more risks of injury to lateral lacunae[14].

Conclusion

Superior nuchal lines and inion are known to be surgical landmarks for posterior fossa surgery and this study confirms their accuracy to predict the location of the torcular herophili and transverse sinuses. Lambdoid suture is not a reliable landmark for these sinuses. Without availability of the neuro-navigator, burr holes for adult craniotomy should be placed inferior to the superior nuchal line at least 15 mm to avoid transverse sinuses and cutting the bone 8 mm at least below the inion to avoid torcular herophili for routine midline posterior fossa surgery. Among variations of bony landmarks, preoperative imaging of individual patients should be carefully studied before performing safe craniotomy.

What is already known on this topic?

Surface landmarks of transverse sinus in relation to bony anatomy have variations and different recommendations for burr holes location.

What this study adds?

This study provided anatomical variations of location of transverse sinus in Thai population and practical recommendations of safe burr hole for surgery around torcular herophili area especially when performing operation without surgical navigation system.

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Potential conflicts of interest

The authors declare no conflict of interest.

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