

The Anatomical Relationship Between the Transverse–Sigmoid Complex and Skull Landmarks in a 3D CTV Imaging Study

Siriwut Pokanan¹, Arnupap Puchaisang¹, Chonnawee Chaisawasthomrong²

Woottinun Phondet¹, Atthaporn Boongird^{1,*}

¹Division of Neurosurgery, Department of Surgery, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

²Division of Neurosurgery, Department of Surgery, Faculty of Medicine, Praboromarajchanok Institute, Ratchaburi Medical Education Center, Ministry of PublicHealth, Ratchaburi, Thailand

ABSTRACT

Background: The retrosigmoid craniotomy is one of the most common approaches in neurosurgery. The bony landmarks related to the transverse-sigmoid sinus are important for performing surgery safely and effectively. This study investigated the relationship between the transverse-sigmoid sinus complex and external skull landmarks, focusing on the asterion–digastric point line as a reference for the vertical sigmoid sinus and related anatomy.

Method: Radiographic study was conducted using 51 three-dimensional computed tomography venography scans obtained from patients older than 15 years at Ramathibodi Hospital between 2021 and 2023. Volume-rendering techniques were applied to identify the asterion, the digastric point, the transverse-sigmoid sinus junction, and the vertical segment of the sigmoid sinus. Measurements were taken at the proximal, mid, and distal portions relative to the asterion-digastric point line, with the angles in the x (coronal), y (sagittal), and z (rotational) axes set at 12°, 15°, and 120°, respectively.

Results: The line connecting the asterion and the digastric point serves as the most reliable landmark (100%) for locating the vertical segment of the sigmoid sinus on both sides. The mean distances from this line to the medial border of the vertical part of the sigmoid sinus were 4.16 ± 2.45 mm, 7.90 ± 2.33 mm, and 3.24 ± 1.64 mm from proximal to distal, respectively. The mastoid emissary foramen is more commonly found on the right side than on the left and is mostly located medial to this line. The occipitomastoid suture was found to be medial to the asterion–digastric point line in all cases. The mean distance from the digastric point to the occipitomastoid suture is 9.36 ± 1.30 mm on the right side and 9.48 ± 1.22 mm on the left side. Additionally, the right sigmoid sinus was significantly larger (7.50 ± 1.22 mm, $P < 0.001$) than the left in most cases.

Conclusion: Recognizing the asterion-digastric point line and the occipitomastoid suture as the most reliable landmark for the vertical part of sigmoid sinus helps surgeons avoid inadvertent injury to the transverse-sigmoid venous sinus during routine craniotomy in this area.

Keywords: Transverse-sigmoid complex, Asterion, Digastric point, Volume-rendering 3D imaging, Retrosigmoid craniotomy, Skull bony landmarks

Introduction

The retrosigmoid craniotomy is a widely used neurosurgical approach for accessing lesions in the cerebellopontine angle and adjacent areas¹. Surface landmarks on the occipital bone and the petrous part of the temporal bone guide the surgeon in performing this procedure accurately. Defining these bony landmarks and understanding their anatomical relationship to underlying intracranial structures are essential for safe and effective surgical planning. Particular care must be taken to avoid injury to the transverse and sigmoid venous sinuses, as damage to these structures can lead to serious complications, including significant blood loss, air embolism, and venous infarction².

The asterion, defined as the intersection of the lambdoid, parietomastoid, and occipitomastoid sutures, has been widely reported and used as a superficial landmark for identifying the transverse–sigmoid sinus junction. However, many studies have shown that this landmark is unreliable due to variations in bony anatomy. Recommendations for the location of the safe strategic burr hole have been described differently in the literature³⁻⁶.

The digastric point (DP) is a consistently identifiable landmark, both in dry skulls and during retrosigmoid surgical approaches. In anatomical specimens, it corresponds to the upper margin of the mastoid notch, which is occupied by the posterior belly of the digastric muscle. During surgery, the DP is defined as the point immediately superior to the posterior belly of the digastric muscle. This landmark may serve as a reliable reference for locating and exposing the inferior vertical segment of the sigmoid sinus⁷⁻⁹.

In this study, the imaginary reference line extending from the asterion to the digastric point, in combination with the occipitomastoid suture,

may serve as a practical landmark for locating the vertical segment of the sigmoid sinus.

Methods

Following approval from the Human Research Ethics Committee of the Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Thailand, we conducted a retrospective radiological study of patients who underwent computed tomography venography (CTV) of the brain between January 2021 and December 2023.

A total of 51 CTV brain images were included in the analysis. The inclusion criteria were patients aged >15 years who had undergone CTV at Ramathibodi Hospital for various clinical indications. Exclusion criteria included a history of posterior cranial fossa surgery, known vascular malformations, or intracranial pathologies involving the transverse–sigmoid sinus, such as cerebral venous sinus thrombosis, tumors, or mass lesions that could distort normal anatomical landmarks.

All 51 CTV brain images were acquired by 128 sliced CT machine, 1mm no gap (Iconspectral, Philips, Medical system Nederland B.V.) and analyzed using a volume-rendering technique (Intellispaceportal, image and information management software version 9.0). The locations of the asterion, digastric point (DP), transverse–sigmoid sinus junction, and other relevant skull landmarks were identified. Image orientation was adjusted to approximate the surgical view in the park bench position, with a coronal angle of 12°, a sagittal angle of 15°, and a rotational angle of 120°.

The asterion is the anatomical point where the parietal, occipital, and temporal bones converge, corresponding to the intersection of the lambdoid, parietomastoid, and occipitomastoid sutures¹. The DP is defined as the insertion point of the digastric

muscle's posterior belly at the top of the mastoid notch on the temporal bone⁵.

Differences in 3D reconstruction images were observed at three rotational angles: 90°, 120°, and 150° (Figure 1). At 90°, the mastoid notch was not visible, making identification of the digastric point impossible. At 150°, the asterion–DP line overlapped with the sigmoid sinus, preventing accurate distance measurements. Therefore, 120° was selected, as it

provided a clear separation between the asterion–DP line and the sigmoid sinus while most closely resembling the actual surgical view.

In the inferior view of the 3D reconstruction image (Figure 1), the image was oriented so that the sigmoid sinus appeared parallel to the skull base. In this configuration, Y represents the measured distance used in this study, while Z (or line *ab*) corresponds to the true distance from the asterion–

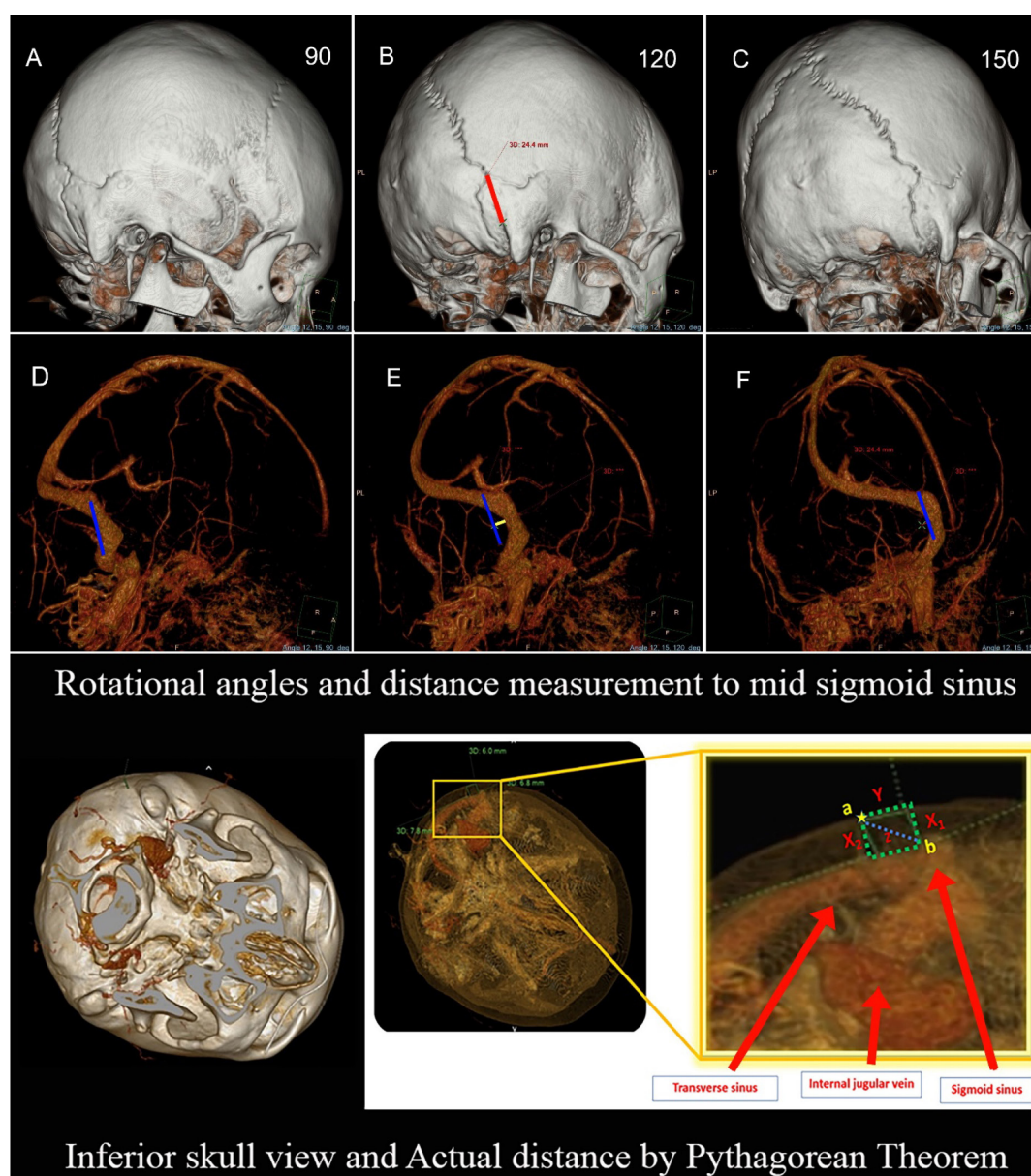


Figure 1: The 3D reconstruction images with and without bone window at rotational angles of 90° (A,D), 120° (B,E), and 150° (C,F), respectively and the inferior skull view for measurement distance (E) from the asterion-digastric point line (Red line in Panel B) to the medial border of the sigmoid sinus (Blue and Yellow line in Panel E).

DP line to the sigmoid sinus. The Y value was considered appropriate for analysis because X_1 and X_2 were nearly equal, allowing the application of the Pythagorean theorem ($Z^2 = X_1^2 + Y^2$, where $X_2 \approx X_1$). Given that the sigmoid sinus runs perpendicular to the skull surface and that the craniotomy involves a vertical bone cut, Y provides a practical and relevant measurement, whereas the oblique distance (Z) is less applicable for surgical planning.

The mean distances from the asterion–DP line to the medial border of the vertical portion of the sigmoid sinus at the proximal, middle, and distal segments were independently measured by two senior neurosurgical residents and an experienced radiology staff member.

A cadaveric skull was used to demonstrate the external and internal landmarks relevant to this study.

Data collections

Data were collected as descriptive measures, including mean and standard deviation (SD), for the following parameters: (1) the distance from the DP–asterion line to the vertical segment of the sigmoid sinus at the proximal, middle, and distal portions; (2) the identification of the asterion as a landmark for localizing the transverse-sigmoid junction; (3) the identification of the mastoid emissary foramen and occipitomastoid suture, and their relationships with the sigmoid sinus and the asterion–DP line; and (4) the determination of the size of the sigmoid sinus on both sides.

Statistical analysis

Descriptive data are presented as means and standard deviations for continuous variables. For statistical analysis, repeated-measures one-way analysis of variance (ANOVA) with Bonferroni cor-

rection was used for pairwise comparisons among the proximal, middle, and distal segments. Paired t-tests were applied to compare measurements between the right and left sides for normally distributed numerical data. For categorical variables, McNemar's test was used to assess differences between paired proportions. All statistical analyses were performed using Stata version 13 (StataCorp, College Station, TX, USA), and a p-value of less than 0.05 was considered statistically significant.

Results

A total of 51 patients over the age of 15 from Ramathibodi Hospital were included in the study between 2021 and 2023. The mean age was 47 years, and the majority were female ($n = 37$, 72.6%). The asterion–DP line had a mean distance of 29.39 ± 4.03 mm on the right side and 29.15 ± 3.90 mm on the left.

The right sigmoid sinus was significantly larger (7.50 ± 1.22 mm, $p < 0.001$) than the left (5.95 ± 1.53 mm) in most cases. The asterion was most commonly located medial to the transverse-sigmoid (TS) junction, with a mean distance from the proximal point of the asterion–DP line to the TS junction of 4.16 ± 2.45 mm. The mastoid emissary foramen was more frequently observed on the right side (49.0%) than on the left (35.3%) and, in most cases, was situated medial to the asterion–DP line.

The occipitomastoid suture was consistently located medial to the asterion–digastric point (DP) line. The mean distance between the occipitomastoid suture and the digastric point was 9.36 ± 1.30 mm on the right side and 9.48 ± 1.22 mm on the left. (Table1)

Table 1 Comparison table of the Digastric point - Asterion line in relation of the vertical part sigmoid sinus, the size of vertical part of sigmoid sinus, asterion location, mastoid emissary foramen and occipito-mastoid suture on both sides of the skull

Parameters	Right sided	Left sided	P-value
Asterion-DP line, mean $\pm$ SD (mm)	29.39 $\pm$ 4.03	29.15 $\pm$ 3.90	0.587
Medial to vertical part of sigmoid sinus, n(%)	51(100)	51(100)	1
Sigmoid sinus diameter, mean $\pm$ SD (mm)	7.50 $\pm$ 1.22	5.95 $\pm$ 1.53	<0.001
Asterion location, n(%)			
Medial to TS junction	46 (90.20)	46(90.20)	1.00
Midpoint of TS junction	5 (9.80)	5 (9.80)	
Mastoid Emissary Foramen, n(%)			
Absent	26 (50.98)	33 (64.71)	0.108
Medial to asterion-DP line	24 (47.06)	17 (33.33)	
Midpoint to asterion-DP line	1 (1.96)	1 (1.96)	
Occipitomastoid suture, n(%)			
Medial to asterion-DP line	51(100)	51(100)	1
Distance to DP, mean $\pm$ SD (mm)	9.36 $\pm$ 1.30	9.48 $\pm$ 1.22	0.163

TS - Transverse-Sigmoid junction

The mean distances from the asterion–DP line to the vertical portion of the sigmoid sinus at different segments were as follows: proximal, 4.16 ± 2.45 mm; middle, 7.90 ± 2.33 mm; and distal, 3.24 ± 1.64 mm. A statistically significant difference was observed among these segments ($p < 0.001$). Pairwise comparisons revealed that the middle segment differed significantly from both the proximal and distal segments, indicating that the distance between the asterion–DP line and the vertical portion of the sigmoid sinus is greatest at the middle portion (7.90 ± 2.33 mm, $p < 0.001$), consistent with the sigmoid sinus curving laterally toward the mastoid bone rather than running vertically toward the internal jugular vein. (Table 2)

These consistent distances between each portion of the asterion–DP line and the vertical segment of the sigmoid sinus suggest that the two structures do not overlap, with the asterion–DP

line located medial to the vertical portion of the sigmoid sinus.

Discussion

During retrosigmoid craniotomy, accurate identification of the vertical portion of the sigmoid sinus is essential to avoid injury and unnecessary exposure. Injury to the sigmoid sinus can result in serious complications and significant blood loss, and surgical repair is mandatory to preserve the sinus lumen for long-term safety¹⁰. Prior studies utilizing cadaveric specimens and dry crania demonstrated substantial variability in traditional bony landmarks such as the asterion or digastric point⁵; radiographic assessment using defined surface reference lines resolves these identification challenges to optimize initial burr-hole localization¹¹. This study utilized CTV to demonstrate multiple bony landmarks and to measure distances from a

Table 2 A comparison table of the distance between the asterion- digastric point line and the sigmoid sinus at proximal, middle, and distal points, as well as a comparison between these points.

Distance (mm)	Mean±SD	P-value	Pairwise P-value
Overall (n=102)			
Proximal	4.16±2.45	<0.001	Proximal VS Middle $p < 0.001$
Middle	7.90±2.33		Middle VS Distal $p < 0.001$
Distal	3.24±1.64		Proximal VS Distal $p = 0.102$
Right sided (n=51)			
Proximal	4.16±2.45	<0.001	Proximal VS Middle $p < 0.001$
Middle	7.82±2.56		Middle VS Distal $p < 0.001$
Distal	3.32±2.25		Proximal VS Distal $p = 0.243$
Left sided (n=51)			
Proximal	4.10±2.44	<0.001	Proximal VS Middle $p < 0.001$
Middle	7.99±2.59		Middle VS Distal $p < 0.001$
Distal	3.17±1.76		Proximal VS Distal = 0.126

reference line to the sigmoid sinus, with a consistent viewing angle applied by multiple researchers.

Based on this study, the asterion is predominantly located medial to the transverse–sigmoid junction, with a mean distance of 4.16 ± 2.45 mm from the proximal point of the asterion–DP line. This consistent anatomical relationship suggests that the asterion can serve as a reliable surface landmark for the proximal sigmoid sinus during retrosigmoid craniotomy. Placing a burr hole or performing drilling slightly inferior and medial to the asterion provides a practical approach for exposing the transverse–sigmoid junction and posterior fossa dura; however, anatomical variations exist, and meticulous exposure is recommended^{3,6}. The use of preoperative imaging or 3D reconstruction to confirm the locations of the asterion and sigmoid sinus can further enhance surgical precision, although such resources may not be universally available, particularly in developing countries¹². Incorporating the asterion as a key reference

point in the initial steps of craniotomy planning can improve surgical accuracy and outcomes in procedures involving the cerebellopontine angle or posterior fossa¹¹. Additionally, performing the craniotomy slightly medial to the asterion–DP line allows for a safe cut relative to the vertical segment of the sigmoid sinus, with mean distances of 7.90 ± 2.33 mm at the middle portion and 3.24 ± 1.64 mm at the distal portion. A study by Jair Leopoldo Raso reported that the digastric point, or top of the mastoid notch, lies approximately 3.11 mm from the sigmoid sinus, closely aligning with the present findings and further supporting the digastric point as a reliable distal vertical sigmoid sinus landmark⁵.

Our study confirmed that two anatomical lines—the asterion–digastric point (DP) line and the occipitomastoid suture—are located medial to the vertical portion of the sigmoid sinus and can be readily identified in the operative field. Furthermore, the vertical segment of the sigmoid

sinus consistently curves laterally away from the asterion–DP line (Figure 2). Based on the anatomical relationship between the occipitomastoid suture and the digastric point, our findings indicate that the occipitomastoid suture is consistently medial to the digastric point. The mean distance from the digastric point to the sigmoid sinus was 3.24 ± 1.64 mm, consistent with previous anatomical and surgical studies⁵.

To minimize the risk of sigmoid sinus injury during craniotomy, it is advisable to perform the bone opening at the midpoint between the occipitomastoid suture and the digastric point or to drill in this area to expose the posterior fossa dura and delineate the vertical sigmoid segment. Nevertheless,

caution is warranted, and preparation for hemostasis should be made in case of injury to the mastoid emissary vein. The mastoid emissary foramen was more commonly observed on the right side than the left and, in most cases, is located medial to the asterion–DP line. However, significant anatomical variability of the mastoid emissary foramen—frequently located directly on or adjacent to the occipitomastoid suture—limits its standalone reliability, underscoring the value of high-resolution CT mapping alongside established cranial landmarks to safely navigate the transverse-sigmoid transition^{12,13}. Preoperative CT evaluation, particularly of the size, number, and location of emissary veins, is recommended before retrosigmoid craniotomy¹⁴.

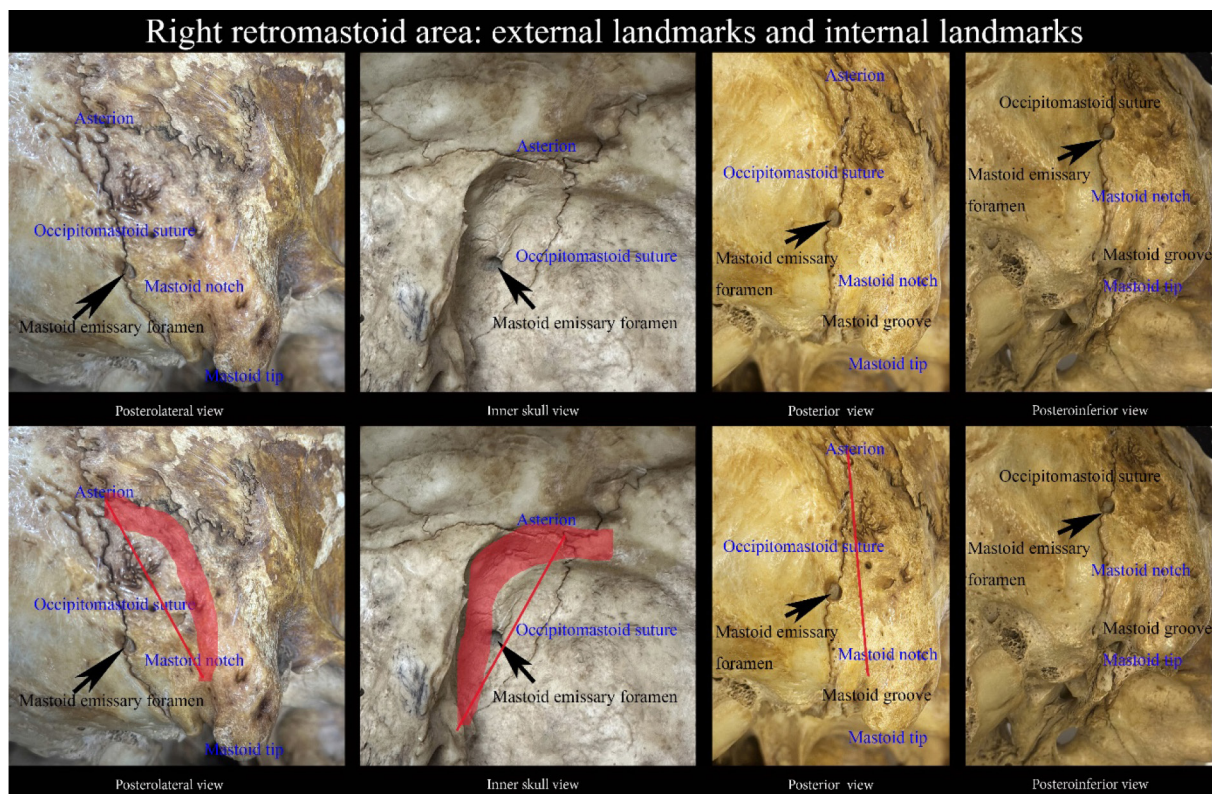


Figure 2: Cadaveric skull landmarks from the neurosurgery lab and reference lines are demonstrated in different views to highlight surgical landmarks. The inner skull view reveals the transverse-sigmoid sinus groove. The occipitomastoid suture is clearly visible running parallel to the vertical part of the sigmoid sinus. The mastoid emissary foramen is located medially from an external landmark and in close proximity to the sigmoid sinus from an internal landmark

Several anatomical landmarks have been explored to improve localization of the transverse-sigmoid sinus junction (TSSJ), which is crucial for posterior cranial fossa surgery. Traditional reliance on the asterion is limited by high variability, as reported by Tubbs et al. (7) and Mwachaka et al.¹⁵. The digastric point, described by Raso et al.⁵, or the top of the mastoid notch (TMN)^{16,17} are useful surgical landmarks for aligning with the vertical portion of the sigmoid sinus. The digastric-condyle (DC) line also provides a reliable trajectory for estimating the position of the horizontal segment of

the sigmoid sinus¹⁸. Superficial landmarks, such as the occipitalis muscle¹⁹ and posterior auricle²⁰, offer practical alternatives when imaging is limited. These findings support the use of composite or line-based landmarks to enhance surgical accuracy. Our study further contributes by defining the relationship between the asterion-digastric point line and the occipitomastoid suture, demonstrating that this line typically lies medial to the TSSJ and lateral to the suture, thereby providing a potentially reliable trajectory for landmark-based navigation during lateral suboccipital approaches (Table 3).

Table 3 The anatomical landmarks relationship with transverse sigmoid complex in various studies

No.	Study (Authors, Year)	Sample/Method	Landmarks Studied	Key Findings
Skin and Soft tissue landmarks				
1.	Broekx S et al. ²⁰ (2024)	one-hundred patients who underwent brain MRI	Most posterior part of auricula	The most-posterior-part-of-the-auricula can be seen as a fast and practical superficial anatomical landmark for identification of the transverse-sigmoid-sinus-transition
2.	Gilkes A et al. ¹⁹ (2023)	18 adult cadaveric heads	Occipitalis Muscle, Mastoid notch	Occipitalis Muscle can be useful when this technology is not available or is not working properly.
Bony landmarks				
3.	Mwachaka PM et al. ¹⁵ (2010)	90 human skulls (both sides examined)	Asterion, root of the zygoma and tip of the mastoid process	The safest surgical approach is posteroinferior to the asterion to avoid lacerating the transverse-sigmoid sinus complex
4.	Raso JL et al. ⁵ (2011)	Cadaveric dissection 127 adult skulls	Digastric point	The mean distance between the digastric point and the sigmoid sulcus was 3.10 mm, and it was located over the sulcus of the sigmoid sinus in 49.6% of cases.

Table 3 The anatomical landmarks relationship with transverse sigmoid complex in various studies (Cont.)

No.	Study (Authors, Year)	Sample/Method	Landmarks Studied	Key Findings
5.	Jurgaitis J et al. ¹⁶ (2024)	Cadaveric dissection on 10 adult skulls	Top of mastoid notch (TMN),inion, Frankfurt plane to define TSSJ	TMN is a reliable external landmark for identifying the transverse-sigmoid sinus junction (TSSJ); TS exits rostrally above the Frankfurt plane; right TS is larger than left ($p = 0.048$).
6.	Li R et al. ¹⁷ (2020)	Cadaveric dissection on 43 adult skulls	Top of Mastoid notch	useful landmark for accurately locating the anterosuperior and inferomedial points of the transverse-sigmoid sinus junction.

Imaginary line

7.	Tubbs RS et al. ⁷ (2009)	100 skulls (200 sides)	Mastoid process, zygomatic arch, mastoid notch, squamosal suture, zygomatic line, mastoid line	Burr hole should be placed inferior and medial to TSSJ using zygomatic and mastoid lines; asterion is unreliable.
8.	Matsuo S et al. ¹⁸ (2018)	Three dimensional CTA images of adults (56sides)	The line between the digastric point and posterior edge of the occipital condyle	The DC line can be used as a new surface landmark for estimating the position of the horizontal part of the sigmoid sinus.
9.	Kubo M et al. ²⁵ (2021)	Case series 33 patients with trigeminal neuralgia	The groove line (GL) was also defined as the extension of the digastric groove and was drawn on the surface of the occipital bone.	The key point for burr hole is 20mm from groove point and adjacent to groove line (DP)
10.	Our Study	51 subjects were enrolled, with CTV imaging	Asterion- digastric point line, occipitomastoid suture	The asterion–DP line lies medially to the vertical part of sigmoid. Occipitomastoid suture lies medially to the asterion-DP line.

Limitations

A limitation of this study is that measurement inaccuracies may occur if the sigmoid sinus is not parallel to the inner table of the skull (**Figure 3**). For example, the presence of large mastoid air cells can increase the depth of the sigmoid sinus, causing it to deviate from a parallel alignment with the bone. Additionally, in children younger than 15 years, bony landmarks may be less well defined due to ongoing skull base development and mastoid air cell formation, which represents another limitation.

Despite slight discrepancies compared with cadaveric specimens, 3D radiographic reconstruction may assist preoperative planning by improving visualization of relevant skull-base and venous anatomy. When combined with skull surface landmarks, these imaging data may support localization of the retrosigmoid keyhole and surgical planning for cerebellopontine angle exposure^{12,21}. Additionally, the ability to store and retrieve digital data facilitates longitudinal analysis and further research without the limitations associated with specimen degradation or availability.

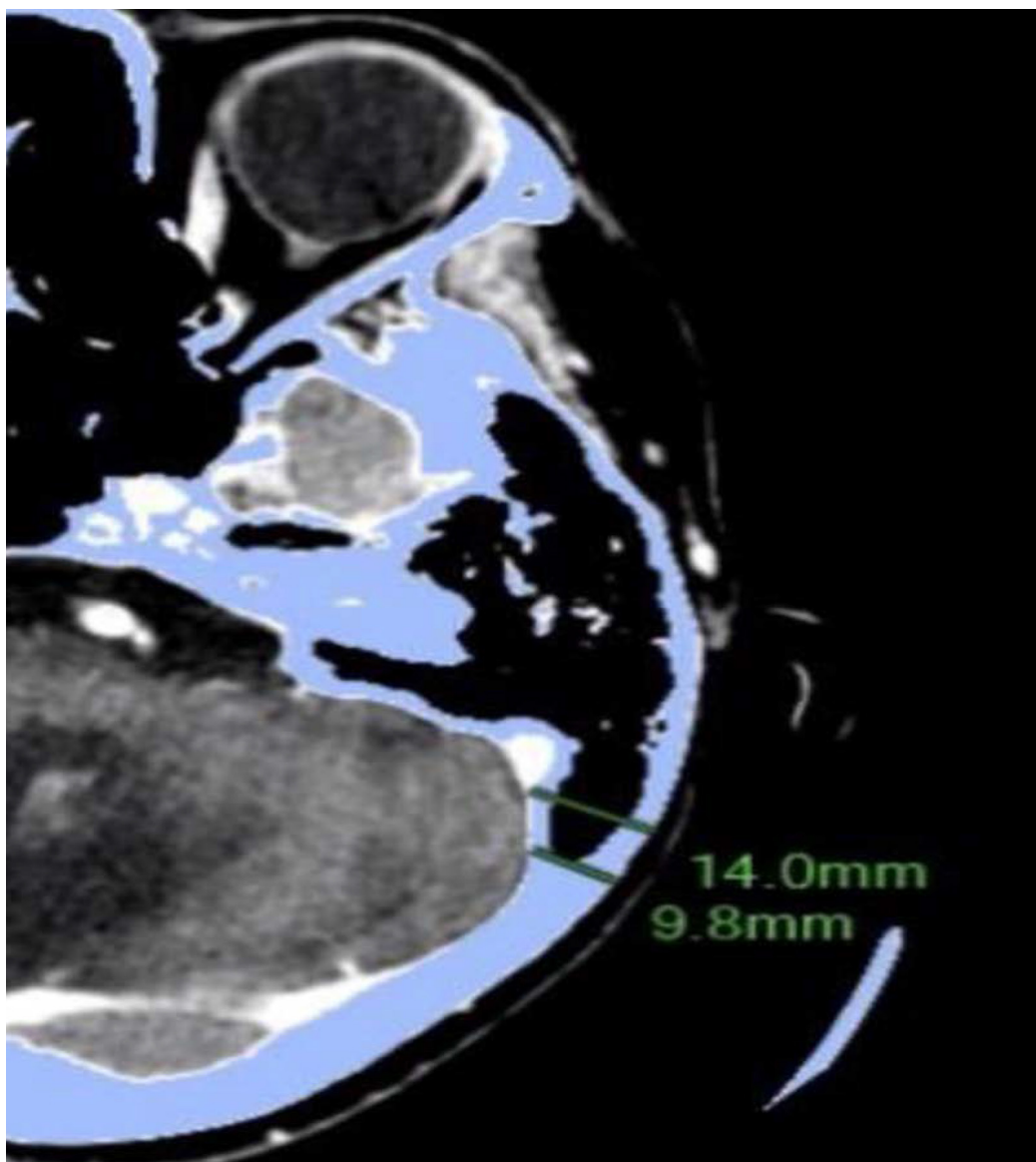


Figure 3: CTV brain showing large mastoid air cells. The measurement from the surface skull area can be shorter than the real distance.

The use of novel 3D anatomical volume rendering techniques has been increasingly reported across various medical subspecialties, particularly in neurosurgery²²⁻²⁴. Its integration into surgical planning and anatomical research represents a shift toward more precise, individualized, and reproducible approaches in both clinical and academic settings. The findings of this study highlight the value of advanced imaging techniques in enhancing anatomical understanding and optimizing surgical outcomes, particularly in regions where traditional landmarks may vary or be difficult to identify. Employing multiple landmarks during routine craniotomy is preferable to relying on a single landmark, as this approach accounts for individual anatomical variation and improves accuracy.

Conclusion

The asterion–digastric point line, together with the occipitomastoid suture, serves as a practical and reliable external landmark for estimating the position of the vertical segment of the sigmoid

sinus. Utilizing multiple skull base landmarks enables surgeons to perform craniotomies safely and efficiently.

Ethics Statement

The materials and methodology for this study were approved by the Human Research Ethics Committee, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Thailand, with code COA. MURA2021/848 Ref. 2674. As this study was an imaging review, the requirement for informed consent was waived by the committee.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Conflict of interest statement

The authors confirmed no conflicts of interest related to the research, authorship, or publication of this article.

References

1. Leuze C, Neves CA, Gomez AM, Navab N, Blevins N, Vaisbuch Y, et al. Augmented reality for retrosigmoid craniotomy planning. *J Neurol Surg B Skull Base*. 2022;83(Suppl 2):e564-e573. doi:10.1055/s-0041-1735509.
2. Teranishi Y, Kohno M, Sora S, Sato H. Determination of the keyhole position in a lateral suboccipital retrosigmoid approach. *Neurol Med Chir (Tokyo)*. 2014;54(4):261-6. doi:10.2176/nmc.0a2013-0020.
3. Rhoton AL Jr. The cerebellopontine angle and posterior fossa cranial nerves by the retrosigmoid approach. *Neurosurgery*. 2000;47(3 Suppl): S93-129. doi:10.1097/00006123-200009001-00013.
4. Yamashita T, Lee JH, Tobias S, Kim CH, Chang JH, Kwon JT. Surgical procedure “simplified retrosigmoid approach” for C-P angle lesions. *J Clin Neurosci*. 2004;11(2):168-71. doi:10.1016/j.jocn.2003.06.004.
5. Raso JL, Silva Gusmão SN. A new landmark for finding the sigmoid sinus in suboccipital craniotomies. *Neurosurgery*. 2011;68 (1 Suppl Operative) : ons1-6; discussion ons6. doi:10.1227/NEU.0b013e3182082afc.

6. Day JD, Kellogg JX, Tschabitscher M, Fukushima T. Surface and superficial surgical anatomy of the posterolateral cranial base: significance for surgical planning and approach. *Neurosurgery*. 1996;38(6):1079-83; discussion 1083-4. doi:10.1097/00006123-199606000-00003.
7. Tubbs RS, Loukas M, Shoja MM, Bellew MP, Cohen-Gadol AA. Surface landmarks for the junction between the transverse and sigmoid sinuses: application of the “strategic” burr hole for suboccipital craniotomy. *Neurosurgery*. 2009;65 (6 Suppl) : 37-41; discussion 41. doi: 10.1227/01.NEU.0000341517.65174.63.
8. Kizilkanat E, Boyan N, Ozsahin E, Soames R, Oguz O. Surface landmarks for suboccipital craniotomy. *Neurosurg Q*. 2013;23(2):133-6. doi:10.1097/WNQ.0b013e318266c42d.
9. Avci E, Kocaogullar Y, Fossett D, Caputy A. Lateral posterior fossa venous sinus relationships to surface landmarks. *Surg Neurol*. 2003;59(5):392-7; discussion 397. doi:10.1016/S0090-3019(03)00037-5.
10. Kim YS, Jung SH, Lim DH, Kim TS, Kim JH, Lee JK. Traumatic dural venous sinus injury. *Korean J Neurotrauma*. 2015;11(2):118-23. doi:10.13004/kjnt.2015.11.2.118.
11. Hu W, Zhou J, Liu ZM, Li Y, Cai QF, Hu XM, et al. Computed tomography study of the retrosigmoid craniotomy keyhole approach using surface landmarks. *Int J Clin Pract*. 2023; 2023:5407912. doi:10.1155/2023/5407912.
12. Gharabaghi A, Rosahl SK, Feigl GC, Samii A, Liebig T, Heckl S, et al. Surgical planning for retrosigmoid craniotomies improved by 3D computed tomography venography. *Eur J Surg Oncol*. 2008;34(2):227-31. doi:10.1016/j.ejso. 2007.01.032.
13. Hampl M, Kachlik D, Kikalova K, Riemer R, Halaj M, Novak V, et al. Mastoid foramen, mastoid emissary vein and clinical implications in neurosurgery. *Acta Neurochir (Wien)*. 2018;160(7):1473-82. doi:10.1007/s00701-018-3564-2.
14. Zhou W, Di G, Rong J, Hu Z, Tan M, Duan K, et al. Clinical applications of the mastoid emissary vein. *Surg Radiol Anat*. 2023;45(1):55-63. doi:10.1007/s00276-022-03060-0.
15. Mwachaka PM, Hassanali J, Odula PO. Anatomic position of the asterion in Kenyans for posterolateral surgical approaches to cranial cavity. *Clin Anat*. 2010;23(1):30-3. doi:10.1002/ca.20888.
16. Jurgaitis J, Jukna Š, Terbetas G. Anatomical landmarks for transverse-sigmoid sinus junction: a cadaveric study. *Cureus*. 2024;16(4):e59278. doi:10.7759/cureus.59278.
17. Li R, Qi L, Yu X, Li K, Bao G. Mastoid notch as a landmark for localization of the transverse-sigmoid sinus junction. *BMC Neurol*. 2020; 20(1):111. doi:10.1186/s12883-020-01688-2.
18. Matsuo S, Komune N, Kurogi R, Akagi Y, Iihara K. Relationship between the horizontal part of the sigmoid sinus and the line through the digastric point and posterior edge of the condyle: an anatomic and radiologic study. *World Neurosurg*. 2018;114:e597-e604. doi:10.1016/j.wneu.2018.03.038.
19. Gilkes A, Rajaram-Gilkes M, Cardona JJ, Reina F, Carrera A, Iwanaga J, et al. The occipitalis muscle as an adjunct superficial landmark for the transverse sinus and transverse-sigmoid junction: an anatomical study with application to posterior cranial fossa surgery. *Cureus*. 2023;15(5):e39723. doi:10.7759/cureus.39723.

20. Broekx S, Stevesyns DT, Menovsky T. The auricula as a new surgical landmark for the transverse-sigmoid-sinus-transition. *Brain Spine*. 2024;4:102757. doi:10.1016/j.bas.2024.102757.
21. Jian ZH, Sheng MF, Li JY, Li Y, Weng ZJ, Chen G. Precise localization in craniotomy with a retrosigmoid keyhole approach: microsurgical anatomy and clinical study. *Front Surg*. 2022; 9:809098. doi:10.3389/fsurg.2022.809098.
22. Isikay I, Cekic E, Baylarov B, Tunc O, Hanalioglu S. Narrative review of patient-specific 3D visualization and reality technologies in skull base neurosurgery: enhancements in surgical training, planning, and navigation. *Front Surg*. 2024;11:1427844. doi:10.3389/fsurg.2024.1427844.
23. Jha DK, Khera P, Bhaskar S, Garg M. Three-dimensional volume rendering: an underutilized tool in neurosurgery. *World Neurosurg*. 2019;130:485-92. doi:10.1016/j.wneu.2019.07.065.
24. Zhou B, Li MH, Wang W, Xu HW, Cheng YD, Wang J. Three-dimensional volume-rendering technique in the angiographic follow-up of intracranial aneurysms embolized with coils. *J Neurosurg*. 2010;112(3):674-80. doi:10.3171/2009.7.JNS081718.
25. Kubo M, Mizutani T, Shimizu K, Matsumoto M, Iizuka K. New methods for determination of the keyhole position in the lateral suboccipital approach to avoid transverse-sigmoid sinus injury: proposition of the groove line as a new surgical landmark. *Neurochirurgie*. 2021;67(4):325-9. doi:10.1016/j.neuchi.2020.12.009.