Original Article

Relationship of the sinus anatomy to surface landmarks is a function of the sinus size difference between the right and left side: Anatomical study based on CT angiography

Roy S. Hwang, Ryan C. Turner, Walid Radwan, Rahul Singh, Brandon Lucke-Wold, Abdul Tarabishy, Sanjay Bhatia

Departments of Neurosurgery and Radiology, West Virginia University School of Medicine, Morgantown, West Virginia, USA

E-mail: Roy S. Hwang - rhwang@hsc.wvu.edu; Ryan C. Turner - rcturner@hsc.wvu.edu; Walid Radwan - walid.radwan@hsc.wvu.edu; Rahul Singh - rasingh@hsc.wvu.edu; Brandon Lucke-Wold - bwold@mix.wvu.edu; Abdul Tarabishy - artarabishy@hsc.wvu.edu; *Sanjay Bhatia - sbhatia@hsc.wvu.edu; *Corresponding author

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Abstract

Background: Several cadaveric studies demonstrate reliable localization of the transverse sinus and the transverse sigmoid junction (TSJ). These studies use the line drawn from the inion to the posterior root of the zygoma (IZ) and the asterion, respectively. We investigated how the size difference between the right and left transverse sinuses (TS) and sigmoid sinuses (SS) affected the accuracy of their respective superficial landmarks, particularly with regards to where this relationship may result in unsafe and/or complicated surgical access.

Methods: We utilized Vitrea software to render three-dimensional images based on computed tomographic angiography (CTA). We measured the relationship between the TS and SS to their respective superficial landmarks.

Results: We analyzed 50 patients in this study. The distal TS was found caudal to the inion-to-zygoma (IZ) line on average by 5.0 ± 4.3 mm on the right and 6.4 ± 9.3 mm on the left. The mid TS was found cranial on average 3.5 ± 5.7 mm on the right and 3.2 ± 6.0 mm cranial on the left to the superior nuchal line (SNL). The distance from the asterion to the SS was 11.5 ± 2.4 mm medial on the right and 12.1 ± 4.4 mm medial on the left. The average distance was greater on the left than the right when using the IZ landmark. This was directly proportional to the size difference of the sinuses ($r^2 = 0.15$, $P = 0.03$).

Conclusions: Statistically significant differences between the right and left TS and SS were seen in terms of size. This appeared to correlate nicely to the differences observed between the locations of the TS's and their respective superficial landmarks.

Key Words: Computed tomography angiography, sinus location, surface anatomical landmarks, surgical planning

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INTRODUCTION

The retrosigmoid craniotomy is the most common procedure used for the resection of cerebellopontine angle tumors (CPA). However, the approach is limited by the boundaries of the sigmoid, transverse and transverse–sigmoid junction. These structures are hidden by the calvaria during the initial exposure when the bone is removed. Accurate localization of these structures allows for safe and unrestrained exposure during the craniotomy. Traditionally, superficial landmarks have been used to localize these structures. Some well-known landmarks include the Asterion, the superior nuchal line (SNL), and the plane defined by the line connecting the Inion to the posterior root of the Zygoma (IZ line). These were based on several cadaver studies demonstrating reliable localization of the structures to the superficial anatomy. Different studies disagree on which landmarks are most reliable.

Each superficial landmark is associated with a specific section of the sinus anatomy. For example, the IZ line and the SNL approximates the TS, whereas the asterion approximates the TSJ. Studies disagree, however, on which landmarks are most important clinically. Some authors have tried to bring clarity to this issue by studying volumetric CT imaging to identify the underlying vascular structures. Sheng et al. used CT angiography to study the anatomy in relation to the TS and tested the individual surface landmarks in conjunction to the TS. The key limitation of the study, however, was that they did not study the difference between the right and left TS and how the size difference affects its relationship to the superficial anatomy.

Our key objective was to measure the relationship between the known surface anatomical landmarks for the transverse sinus and transverse–sigmoid junction on both sides of the skull to determine the amount of variation between the right and left TS and their relationship to surface landmarks. We utilized volumetric 3D reconstruction of CT angiographic imaging to perform these analyses. The ultimate goal was to correlate and define the validity of CTA findings to known surface landmarks in order to guide: (1) Operative planning and (2) how to train neurosurgery residents in the importance of anatomical evaluation prior to entering the operative arena.

MATERIALS AND METHODS

We studied 50 consecutive patients who underwent CT angiographic imaging at our institution for various indications including transient ischemic attack, supratentorial intracranial hemorrhages, headaches, etc. Therefore, 100 anatomical sinuses were acquired for study (50 on the right-side and 50 on the left-side).

Patients with posterior fossa lesions or a history of venous thrombosis were excluded from the study. Patients with imaging that was deemed inadequate for analysis were excluded from the study. General demographics such as age and sex were included for all studied patients.

Image acquisition

All images were obtained via multislice computed tomography (CT) angiography with iodine-based contrast, using an Aquilion CT scanner. Images were acquired under 1 mm thickness cuts. The CTA examinations in our institution were performed using an Aquilion ONE multidetector CT scanner (Toshiba Medical Systems, Japan), equipped with 320 × 0.5 mm detector rows covering 16 cubic cm of volume per rotation. The exam consists of a nomenhanced head CT (Kv 120, MA 240). The scan reformats in the standard three orthogonal planes followed by a CT angiogram with coverage from the skull base to the top of the head. This is done with an IV contrast range of 40 to 60 mL followed by a similar or smaller volume of saline chaser. The contrast is administered through an antecubital 18 to 20g IV at a rate of 4 to 5 mL/S. Images acquired from these acquisitions are automatically sent to PACS and to VITREA (Vitrea, Vital Images). The processed volumetric data is loaded directly into the VITREA system.

Study design and measurements

Two investigators performed VITREA 3D remodeling of the images and performed measurements based on the 3D volumetric model and multiplanar reconstructions. The plane of the inion to the posterior root of the zygoma (IZ) as well as the superior nucal line (SNL) were localized and identified. The asterion was identified as the junction between the lambdoid, occipitomastoid, and parietomastoid sutures. The SNL was identified as the superior bony protuberance in direct continuity with the inion [Figure 1]. Measurements were made based

Figure 1: Identification of the superficial landmarks. Yellow arrows indicate location of key landmarks used: posterior root of zygoma, the inion, the asterion, the superior nucal line (SNL).
on these reference planes and superficial landmarks. The transverse sinus and sigmoid sinus were measured by their largest diameter and the right and left were measured on a fixed slice for both sides [Figure 2]. An emissary vein, if identified, was visualized with the help of bone windowing and documented as present or absent on imaging [Figure 3]. The location of the transverse sigmoid junction was identified as on, above, or below asterion based on their position in the coronal and sagittal planes. All measurements were made to the inferior edge of the TS and the inferior edge of the TSJ because this is the usual limit of the craniotomy.

**Statistical analysis**

All measurements were studied using statistical software GraphPad Prism 7.0 with a *P* value less than 0.05 indicating statistical significance. Student’s *t*-test was used to compare the means, and Chi-square analysis was utilized for proportional analyses. A linear regression analysis was used to compare the relationship between the differences in size of the left and right sinuses and its relative distance to the overlying superficial landmark.

**RESULTS**

Of the 50 patients and 100 half skulls analyzed, the average size of the TS and SS was greater on the right (9.2 vs 8.4 mm) than the left (11.2 vs 10.4 mm). This was statistically significant (*P*-value = 0.04, 0.03, respectively). The plane defined by the IZ line was on average 5.0 mm caudal on the right and 6.4 mm caudal on the left to the lower border of the distal TS just before the TSJ at the location of the asterion for both the right and left sides. The SNL was on average cranial to the lower border of the mid TS on the right and left sides. The sigmoid sinus was lateral to the asterion about 11.2 mm right and 12.1 mm on the left [Table 1]. During our measurements, the SNL was always found to be above the IZ line at the mid TS segment.

Interestingly, the TSJ was below the asterion in 14 patients on the right (28%) and 13 patients on the left (26%). No statistical significance was observed between the right and left sides [Table 2]. The emissary vein was present in 18 sinuses on the right and 11 sinuses on the left although this was not found to be statistically significant [Table 3].

The average distance from the superficial landmarks was greater on the left than the right when using the inion to the zygoma landmark and greater on the right when using the SNL as a landmark. This appeared to be a function of the size of the sinuses. On regression analyses, a relationship between the size of the sinus and its proximity to the superficial landmarks was found. This was statistically significant, although with a modest correlation coefficient ($r^2 = 0.15, P = 0.03$) [Figure 4].

**DISCUSSION**

There have been several studies performed utilizing cadavers to localize the sinus anatomy focusing on a single side of the skull during a lateral suboccipital craniotomy.[1,2,5,6,13,14] Day et al. in 1996 and 1998 described the SNL as being approximated by the line drawn between the inion and the posterior root of the zygoma. He also reported the asterion as being accurate in localizing the TSJ, but then updated his findings in fixed cadavers studies as being unreliable for localizing the TSJ.[4,5] In 2003 Avci et al. studied 12 injected cadavers and 10 dried skulls. He concluded that the SNL was a more accurate anatomical landmark to localize the distal transverse sinus and that the asterion was unreliable to localize the TSJ.[1] This corresponds to several studies that have found the TSJ at the asterion in only 60–80% of patients.[5,6,15] In 2005, Ribas performed measurements on 50 sinuses from 25 dried skulls. He found that the transition between the transverse and sigmoid sinus occurred approximately 1 cm in front of the asterion.[10]
Several other studies have shown close approximation of CT and MR imaging to what is seen intraoperatively on a single side of the skull.\cite{3,6,7} Sheng et al. utilized CT angiography to perform assessments on the location of the TS in relation to the standard surface landmarks used. Sheng found that the TSJ was localized approximately 80% of the time to the asterion and that the SNL and the IZ had a complex relationship with the TS. The mid to distal segments of the TS changed their relationship to the surface anatomy. At the mid segment of the TS the IZ was positioned below the TS while the SNL was positioned above it.\cite{12}

Our main objective for this study was to delineate the difference between the left and right TS position and size as they correlate with bony landmarks. This is an important consideration for neurosurgeons and adds value especially when planning the surgical approach. We found that the right and left TS were invariably different in size and the right TS was more often larger than the left TS. We found a modest but statistically significant correlation between the size difference and the distance to the superficial landmark. As has been delineated in prior studies, no single landmark was completely accurate. The mid and proximal TS were closest to the SNL and its lower margin was often found below it. The SNL did not correspond to the IZ line, and the IZ line was always found below the SNL. Therefore, the TS roughly courses between the SNL and the IZ line as it moves distally from the proximal/mid TS segment to the distal TS. The lower edge of the TS is roughly 5 mm above IZ line at the level of the asterion, and none of the measured sinuses were found to be more than 5 mm below the IZ line just before the asterion. The TSJ is approximated at the asterion in roughly 74% of the patients in our study, and the SS courses inferiorly approximately 1 cm lateral to the asterion. It is important for neurosurgical residents to carefully consider these anatomical correlations and know how they differ between the left and right side as outlined in the following paragraph.

If one is operating on the right side, the sinus tends to be larger, and therefore, the landmark is either more cranial to the SNL or less caudal to the IZ line during bone removal [Figure 5]. For a safe craniotomy, the IZ line is more useful for placing the burr hole because the craniotomy lies a few mm below the lower edge of the TS. After the craniotomy, the remainder of the bone can be drilled to expose the edge of the TS. Using the SNL, the craniotomy is more useful for placing the skull bone as follows: if SNL is used as a landmark on the right side, one has to be more careful to dissect the sinus free prior to using the footplate attachment to complete the craniotomy. Specifically, of 50 sinuses on the right side there were only 3 sinuses that were below the IZ line and none were greater than 5 mm below. The rest were either on the IZ line or above it. On the left side, there were only 5 sinuses that were below the IZ line and only 1 that was 5 mm below the IZ line. In regards to the SNL, 6 of the 50 sinuses on the right were above the TS and therefore supratentorial. On the left, only 3 were completely above and therefore supratentorial. On the right the SNL was
Given the flexibility of this modality for this purpose, we have been able to characterize differences between the different methods used to localize the sinuses. We feel that this type of modeling is an effective method for studying anatomy as well as in creating models for surgical planning in living patients, which supersedes what can be done strictly with cadaveric study. In the near future, we anticipate that volumetric 3D rendering will be utilized more frequently as an effective tool in both research and teaching and can help guide preoperative planning with consideration to burr hole placement on either side of the skull.

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Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Avci E, Kocaoğullar Y, Fossett D, Caputy A. Lateral posterior fossa venous sinus relationships to surface landmarks. Surg Neurol 2003;59:392-7.
2. Bozbuda M, Boran BO, Sahinoglu K. Surface anatomy of the posterolateral cranial rim regarding the localization of the initial burr-hole for a retrosigmoid approach. Neurosurg Rev 2006;29:61-3.
3. da Silva EB, Jr., Leal AG, Milano JB, da Silva LF, Jr., Clemente RS, Ramina R. Image-guided surgical planning using anatomical landmarks in the retrosigmoid approach. Acta Neurochir 2010;152:905-10.
4. Day JD, Kellogg JX, Tschantz M, Suzuki T. Surface and surgical anatomy of the posterolateral cranial base: Significance for surgical planning and approach. Neurosurgery 1996;38:1079-83.
5. Day JD, Tschantz M. Anatomical position of the asterion. Neurosurgery 1998;42:198-9.
6. 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;34:227-31.
7. Han H, Yao Z, Wang H, Deng X, Yu Fong AH, Zhang M. Dural entrance of the bridging vein into the transverse sinus provides a reliable measure for preoperative planning: An anatomic comparison between cadavers and neuroimages. Neurosurgery 2008;62(Suppl 2):ONS289-95.
8. Kivelev J, Kivisaari R, Niemela M, Hernoisieni M. Muscle Insertion Line as a Simple Landmark To Identify the Transverse Sinus When Neuronaivation Is Unavailable. World Neurosurg 2016;94:394-7.
9. Raso J, Giammarino SB, et al. New landmark for finding the sigmoid sinus in suboccipital craniotomies. Neurosurgery 2011;68(Suppl Operative):1-6.
10. Ribas GC, Rhoton AL Jr., Cruz OR, Peace D. Suboccipital burr holes and craniectomies. Neurosurg Focus 2005;19:E1.
11. Samii M, Matthies C. Management of 1000 vestibular schwannomas (acoustic neuromas): The facial nerve–preservation and restitution of function. Neurosurgery 1997;40:684-94.
12. Sheng B, Lv F, Xiao Z, Ouyang Y, Lv F, Deng J, et al. Anatomical relationship between cranial surface landmarks and venous sinus in posterior cranial fossa using CT angiography. Surg Radiol Anat 2012;34:701-8.
13. Tubbs RS, Loukas M, Shoja MM, Bellway MF, 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(Suppl):S37-41.
14. Tubbs RS, Salter G, Oakes WJ. Superficial surgical landmarks for the transverse sinus and torcular herophili. J Neurosurg 2000;93:279-81.
15. Ucerler H, Govsa F. Asterion as a surgical landmark for lateral cranial base approaches. J Craniomaxillofac Surg 2006;34:415-20.