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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

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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 TSs' 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).[11] 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).[1,4,5,9,10] 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.[1,4,5]

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.[1,4,5,10] 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.[3,6,7,12] 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 nonenhanced 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 anticubital 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

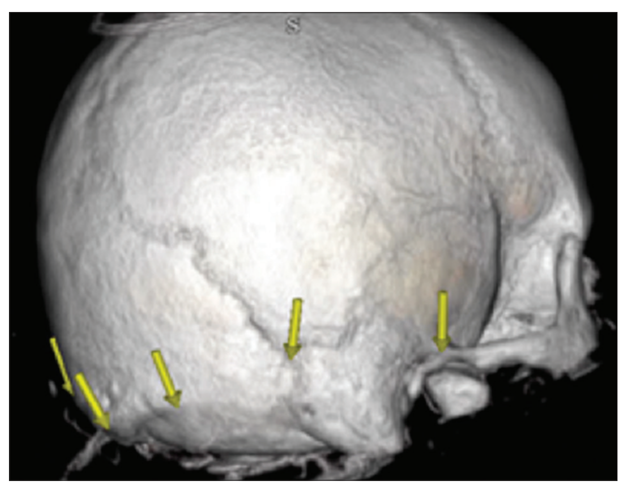

Figure 1: Identification of the superficial landmarks. Yellow arrows indicate location of key landmarks used: posterior root of zygoma, the inion, the asterion, the superior nuchal line (SNL)

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.

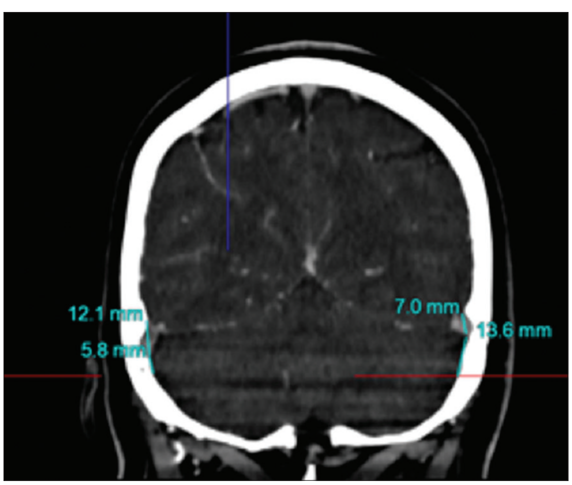

Figure 2: Measurement paradigm of the right and left TS. Red line indicates IZ line, note measurements were performed on a given slice in the coronal plane

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]

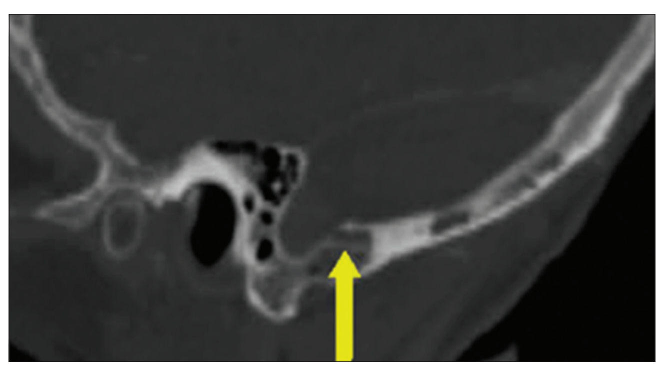

Figure 3: Identification of the emissary vein. Bone windowing was used to identify the entry of the emissary vein to the transverse sigmoid junction

Table 1: Overall measurements of sinus structures compared to the superficial anatomy

Sinus Structure	Right TS	Left TS	Right SS	Left SS
Size (mm)	9.2±2.1	8.4±1.9	11.5±2.4	10.4±2.3
TS distance from IZ line at the Asterion (distal segment) (mm)	5.0±4.3	6.4±9.3	-	-
TS distance from SNL (midsegment) (mm)	−3.5±5.7	−3.2±6.0	-	-
SS distance from Asterion (mm)	-	-	11.2±4.3	12.1±4.4

-: Numbers indicate landmarks that lie above the sinus structure, therefore distances are measured caudally

Table 2: Position of TSJ to the asterion

Sinus Structure	Right Asterion (%)	Left Asterion (%)
Below TSJ	3 (6)	4 (8)
At TSJ	37 (74)	37 (74)
Above TSJ	14 (28)	13 (26)

Table 3: Emissary vein present or absent

Sinus Structure	Right Emissary (%)	Left Emissary (%)
Present	18 (36)	11 (22)
Absent	32 (64)	39 (78)

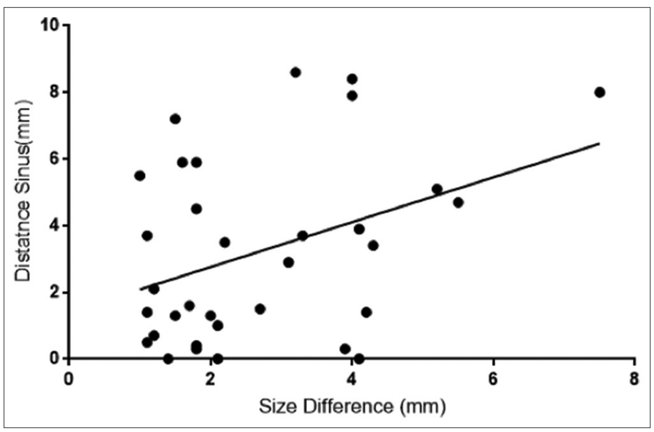

Figure 4: Regression analysis of sinus size difference and distance from IZ line. Regression analysis shows a proportional relationship between the distance from the superficial landmark to the TS and the size difference between the right and left sides. (r^2 = 0.15, P = 0.03)

Several other studies have shown close approximation of CT and MR imaging to what is seen intraoperatively on a single side of the skull.[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.[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 likely to be closer to the sinus potentially creating a disastrous scenario where the burr-holes would be placed over the sinus directly. Thus, 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

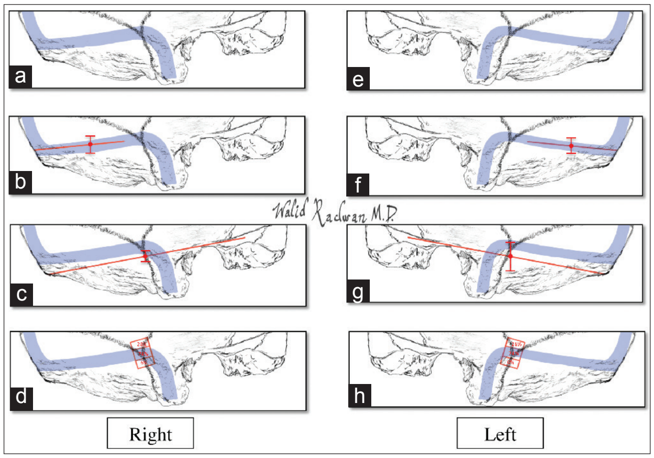

Figure 5: Artist illustration of predicted course of TS and TSJ right and left Both right (a) and left (e) TS and TSJ drawn to scale. Average location of TS in reference to the superior nuchal line with range shown on right (b) and left (f). Average location of TS in reference to the IZ line with range shown on right (c) and left (g). Average location of TSJ in reference to the asterion with range shown on right (d) and left (h). The most common predicted course of the TS was closely related to the SNL at the TS proximal and mid segment. The distal TS prior to the TSJ was most likely found above the IZ line before the asterion. The asterion localized the TSJ approximately 80% of the time. The sigmoid sinus was roughly 1 cm distal to the caudal line drawn below the asterion

below the TS 8 out of 50 and for the left 9 of the 50 SNL's were below the TS.

A limitation of this study is the potential for measurement error given the restriction of measurements within a single plane. In comparison, in a dry or fixed cadaver skull measurements can be made in multiple planes simultaneously, as one takes a ruler that can encircle the skull in three dimensions. The key benefit of this work, however, is that we expanded upon the initial work of Sheng *et al*. by examining the differences between the TSs' on the right and left independently. This is important because it directs the neurosurgeon to a safe placement of the burr hole depending on the side of the skull being operated on. We strongly advocate for further studies to use imaging processing software in studying surgical anatomy. This will not only aid in greater appreciation of anatomical differences but also provide a powerful tool for operative planning.

CONCLUSION

In conclusion, we describe a method that enables us to measure the anatomical relationship between superficial landmarks and their associated underlying vascular structures (sinuses) via volumetric 3D rendering of CT angiographic imaging. This method is proven to have good correlation to prior anatomical studies.[1,3,5,6,10,15] This work is significant in that it evaluated the differences in sinus location and size between the right and left side of the skull further expanding upon the findings proposed by Kivelev *et al*.[8] 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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Nil.

Conflicts of interest

There are no conflicts of interest.

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