Localization of Anterosuperior Point of Transverse-sigmoid Sinus Junction Using a Reference Coordinate System on Lateral Skull Surface

Rui-Chun Li[1], Ji-Feng Liu[2], Kuo Li[1], Lei Qi[1], Si-Yao Yan[1], Mao-De Wang[1], Wan-Fu Xie[1]

[1]Department of Neurosurgery, First Affiliated Hospital of Xi'an Jiaotong University, Xi'an, Shaanxi 710061, China
[2]Xi'an Center for Disease Control and Prevention, Xi'an, Shaanxi 710054, China

Abstract

Background: During craniotomies using the transpetrosal-presigmoid approach, exposure of the sigmoid sinus remains an essential but hazardous step. In such procedures, accurate localization of the anterosuperior point of the transverse-sigmoid sinus junction (ASTS) is very important for reducing surgical morbidity. This study aimed to create an accurate and practical method for identifying the ASTS.
Methods: On the lateral surfaces of 40 adult skulls (19 male skulls and 21 female skulls), a rectangular coordinate system was defined to measure the x and y coordinates of two points: the ASTS and the squamosal-parietomastoid suture junction (SP). With the coordinate system, the distribution characteristics of the ASTS were statistically analyzed and the differences between the ASTS and SP were investigated.
Results: For ASTS-x, significant differences were found in different sides ($P = 0.020$); the ASTS-x in male skulls was significantly higher on the right side ($P = 0.017$); there was no significant difference between the sides in female skulls. There were no significant differences in gender or interaction of gender and side for ASTS-x, and for ASTS-y, there were no significant differences in side, gender, or interaction of gender and side. For both sides combined, the mean ASTS-x was significantly higher than the mean SP-x ($P = 0.003$) and the mean ASTS-y was significantly higher than the mean SP-y ($P = 0.011$).
Conclusions: This reference coordinate system may be an accurate and practical method for identifying the ASTS during presigmoid craniotomy. The SP might be difficult to find during presigmoid craniotomy and, therefore, it is not always a reliable landmark for defining the ASTS.

Key words: Craniotomy; Sigmoid Sinus; Transpetrosal-presigmoid Approach; Transverse Sinus

Introduction

During the transpetrosal-presigmoid approach, accurate determination of the surface projection of the anterosuperior point of the transverse-sigmoid sinus junction (ASTS) is particularly important when trying to expose sigmoid sinus safely.[1-3] Traditionally, neurosurgeons have regarded the squamosal-parietomastoid suture junction (SP) as the classic landmark to determine the ASTS.[4-6] However, the cranial sutures of some patients, especially the elderly, have been reported to be not obviously recognizable and palpable in craniotomy.[7,8] These variations make it difficult to confirm the SP during operations. Therefore, a more reliable as well as practical method for locating the ASTS precisely is needed.

Recently, we proposed a reference coordinate system that was established on the lateral skull surface based on several conspicuous osseous landmarks. Using this coordinate system, we statistically analyzed the coordinates of the inferomedial point of the transverse-sigmoid sinus junction (IMTS) of forty adult skull samples. The results can be used to correctly locate the IMTS during the retrosigmoid approach.[9]

This study aimed to use our coordinate system to analyze the distribution characteristics of the ASTS to explore whether

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Address for correspondence: Dr. Wan-Fu Xie, Department of Neurosurgery, First Affiliated Hospital of Xi'an Jiaotong University, 277 West Yanta Road, Xi'an, Shaanxi 710061, China
E-Mail: lrckhz@126.com

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the location of the ASTS can be estimated accurately using this system. Another aim was to compare the location of the ASTS with that of the SP to learn more about the differences in location between these two points.

Methods

Skull samples and measurements

This study was approved by the Internal Review Board of Xi'an Jiaotong University (No. 2014-127). Forty dried human adult skulls, which had clearly identifiable osseous grooves of the transverse and sigmoid sinuses and the point of the SP, were provided by the Department of Anatomy of Medical College of Xi'an Jiaotong University. Of the skulls, 19 were male skulls and 21 were female skulls. A flexible rule was used to measure the skull circumference, which circles the outer surface of the skull through the intercilium anteriorly and the external occipital protuberance posteriorly.

Anterosuperior point of the transverse-sigmoid sinus junction and squamosal-parietomastoid suture junction

The transverse-sigmoid sinus junction was defined as the transitional zone where the transverse sinus ended by the vertical descending segment of the sigmoid sinus viewed from the inside of the cranium.[8] Thus, the ASTS was identified as the anterosuperior point of the junction. To project the ASTS to the outer surface of the skull precisely, a vernier caliper was modified by extending the outer measuring claws to form two L-shaped arms. The two tips of the arms correspond with each other and can remain aligned when one arm is moved away from the other arm [Figure 1]. When the tip of one arm was located at the ASTS on the inner side of the cranium, the other arm could be moved to touch the outer surface of the skull and thereby point out the corresponding site of the ASTS on the outer skull surface correctly [Figures 2 and 3].

Some parietomastoid sutures bifurcate into two branches before they join the squamosal sutures. Therefore, we defined the junction of the squamosal suture with the extension line of the main stem of the parietomastoid suture as the SP [Figure 4].

Coordinate system establishment

On the lateral surface of the skull, a rectangular coordinate system was established by a horizontal line (X-axis) and a vertical line (Y-axis). The X-axis was defined by points A and B. Point A was located where the upper edge of the zygomatic arch (UEZA) joins anteriorly to the frontal process of the zygomatic bone (FPZ), and point B was located where the UEZA blends posteriorly into the supramastoid crest (SMC). The Y-axis was defined by a line through the tip of the mastoid and perpendicular to the X-axis. Where the axes crossed, the origin was noted by "O" [Figure 5]. On the X-axis, the anterior side (frontal side) of the origin was defined as negative while the posterior side (occipital side) was defined as positive. On the Y-axis, the upper side (rostral side) of the origin was defined as positive and the lower side (caudal side) was defined as negative. Therefore, the X and Y coordinates of the ASTS, which represented the distances from the points to the Y and X axes, respectively, could be measured by a vernier caliper in this coordinate system.

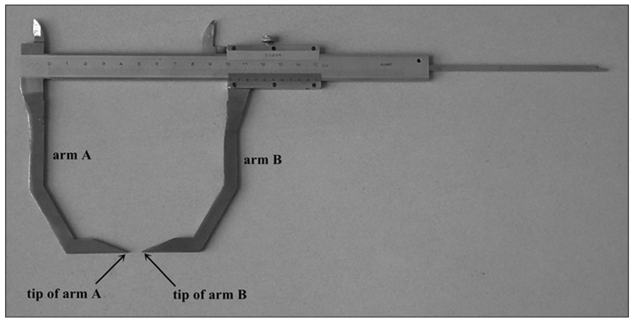

Figure 1: The vernier caliper measuring claws were modified into two L-shaped arms. The two tips of the arms correspond with each other and can continue working in a line when one is moved away from the other.

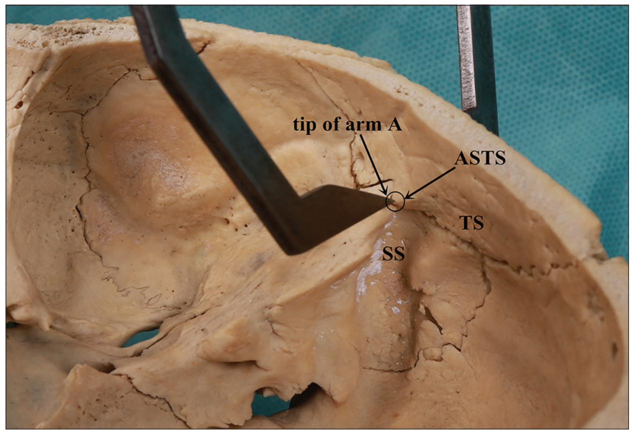

Figure 2: Inner side of the cranium. The tip of arm A is placed at the ASTS (open circle). TS: Transverse sinus; SS: Sigmoid sinus; ASTS: Anterosuperior point of the transverse-sigmoid sinus junction.

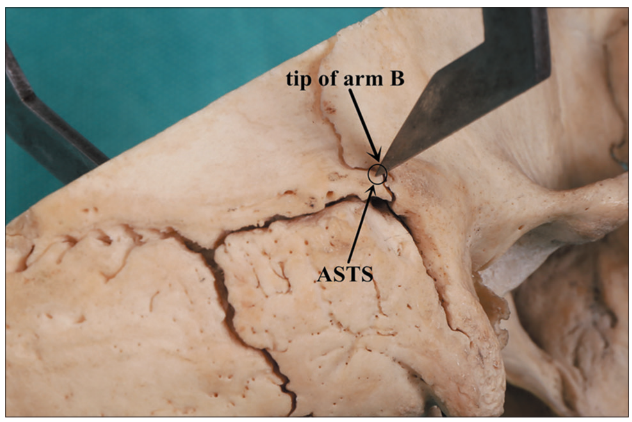

Figure 3: After the tip of arm A was pointed at the ASTS on the inner side of the cranium, the tip of arm B was moved in an orthogonal direction and touched to the outer surface of the skull. The tip of arm B pointed out the corresponding site (open circle) of the ASTS on the outer surface precisely. ASTS: Anterosuperior point of the transverse-sigmoid sinus junction.

Statistical analysis

Continuous variables were presented as mean ± standard deviation (SD). Categorical variables were presented as counts and percentages. One-way analysis of variance for

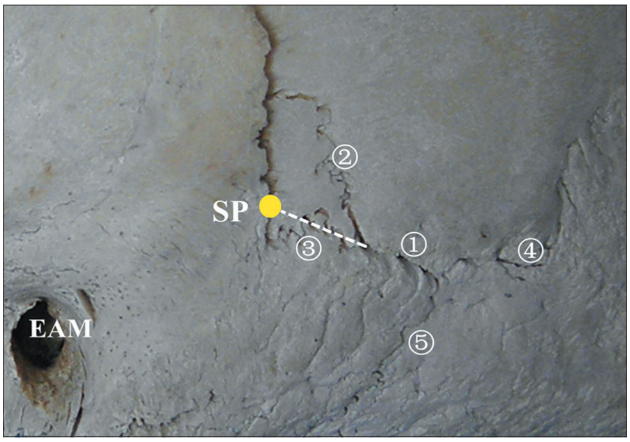

Figure 4: A left lateral side of skull sample. The parietomastoid sutures bifurcate into superior and inferior branches before joining the squamosal sutures. The SP (yellow dot) is defined as the junction of the squamosal suture with the extension line (white broken line) of the main stem of the parietomastoid suture. ① Main stem of the parietomastoid suture; ② Superior branch; ③ Inferior branch; ④ Lambdoid suture; ⑤ Occipitomastoid suture; EAM: External acoustic meatus; SP: Squamosal-parietomastoid suture junction.

repeated measures was used to evaluate the differences between genders and sides. The paired *t*-test was used to compare the differences between ASTS and SP in X and Y. Statistical analyses were performed with SAS software version 9.2 (SAS Institute Inc., Cary, NC, USA). A two-tailed $P < 0.05$ was considered statistically significant.

Results

Baseline characteristics of skulls

The mean age of the skull specimens was 47.8 ± 12.6 years. The mean circumference of male skulls was 49.85 ± 1.29 cm, and the mean circumference of the female skulls was 49.27 ± 1.24 cm.

Comparisons of anterosuperior point of the transverse-sigmoid sinus junction for gender and side

For ASTS-x, a significant difference was found between the left and right sides ($P = 0.020$), but not between males and females ($P = 0.221$), and the interaction of gender and side was not significant ($P = 0.245$). The mean ASTS-x was significantly higher on the right side compared with the left side in males (17.59 ± 3.46 mm vs. 15.33 ± 2.78 mm, $t = -2.49$, $P = 0.017$), but there was no significant difference between right and left sides in females. For ASTS-y, there were no significant differences between males and females ($P = 0.763$) and left and right sides ($P = 0.932$) and the interaction of gender and side was not significant ($P = 0.522$) [Table 1].

Comparisons for anterosuperior point of the transverse-sigmoid sinus junction and squamosal-parietomastoid suture junction

On the 80 skull sides, 11 (13.8%) parietomastoid sutures bifurcated into two branches before they joined to the squamosal sutures.

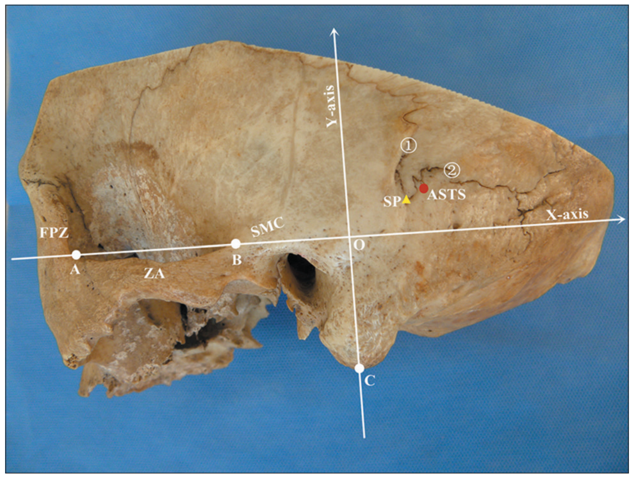

Figure 5: Illustration of the coordinate system on the left side of a skull sample. The X-axis is established by the horizontal line connecting points A and B, which are located where the upper edge of the ZA joins anteriorly to the FPZ and blends posteriorly into the SMC, respectively. The Y-axis is defined by a line through the tip of the mastoid (Point C) and perpendicular to the X-axis. The crossing of the axes, the origin, is noted as "O." FPZ: Frontal process of the zygomatic bone; ZA: Zygomatic arch; SMC: Supramastoid crest; ASTS (red dot): Anterosuperior point of the transverse-sigmoid sinus junction; SP (yellow triangle): Squamosal-parietomastoid suture junction; ① Squamosal suture; ② Parietomastoid suture.

Table 1: Comparisons between genders and sides for the ASTS in this study (mm)

Items	Males ($n = 19$)	Females ($n = 21$)	*P* for gender	*P* for interaction
ASTS-x				0.245
Left	15.33 ± 2.78	15.29 ± 3.06	0.964	
Right	17.59 ± 3.46	16.07 ± 3.62	0.095	
P for side	0.017	0.371		
ASTS-y				0.522
Left	7.52 ± 2.4	7.65 ± 2.47	0.810	
Right	7.80 ± 2.53	7.43 ± 2.66	0.506	
P for side	0.616	0.687		

ASTS: Anterosuperior point of the transverse-sigmoid sinus junction.

For the left and right sides combined, the mean ATST-x and ATST-y were significantly higher than the mean SP-x and SP-y, respectively (x: 16.05 ± 3.32 mm vs. 14.7 ± 3.16 mm, $t = 3.09$ $P = 0.003$; y: 7.6 ± 2.47 mm vs. 6.65 ± 2.53 mm, $t = 2.61$, $P = 0.011$). For the left side, the mean ATST-y was significantly higher than the mean SP-y (7.59 ± 2.41 mm vs. 6.49 ± 2.45 mm, $t = 2.12$, $P = 0.041$), but there was no significant difference between the mean ATST-x and mean SP-x. For the right side, the mean ATST-x was significantly higher than the mean SP-x (16.79 ± 3.59 mm vs. 15 ± 2.76 mm, $t = 2.95$, $P = 0.005$), but there was no significant difference between the mean ATST-y and mean SP-y [Table 2].

Discussion

The transpetrosal-presigmoid approach provides an excellent corridor for neurosurgeons to deal with the petroclival

Table 2: Comparisons between the ASTS and SP in this study (mm)

Items	Numbers	ASTS	SP	Difference	*t*	*P*
Total sides						
x	80	16.05 ± 3.32	14.7 ± 3.16	1.35 ± 3.92	3.09	0.003
y	80	7.6 ± 2.47	6.65 ± 2.53	0.95 ± 3.25	2.61	0.011
Left side						
x	40	15.31 ± 2.89	14.39 ± 3.53	0.91 ± 3.99	1.45	0.155
y	40	7.59 ± 2.41	6.49 ± 2.45	1.1 ± 3.28	2.12	0.041
Right side						
x	40	16.79 ± 3.59	15 ± 2.76	1.79 ± 3.84	2.95	0.005
y	40	7.61 ± 2.57	6.81 ± 2.62	0.8 ± 3.26	1.55	0.129

Difference represented the mean of difference between the ASTS and SP (ASTS−SP). ASTS: Anterosuperior point of the transverse-sigmoid sinus junction; SP: Squamosal-parietomastoid suture junction.

lesions. In such surgical procedure, exposure of the sigmoid sinus from the transverse-sigmoid sinus junction to the jugular bulb remains an essential and hazardous step.[1-3,10,11] Many experts have described their techniques to expose the sigmoid sinus safely without extensive bony defect. In such procedures, accurate localization of the ASTS is very important for the intervention. Goto *et al*.[1] introduced a surgical skill for safely and simply exposing the sigmoid sinus. The authors used four key holes, including the lateral end of the transverse sinus, ASTS, mastoid emissary foramen, and midpoint of the transverse sinus, for guidance to complete the exposure of the sigmoid sinus. Jia *et al*.[3] recommended a two-bone flap craniotomy for the transpetrosal-presigmoid approach to avoid bony defect in the periauricular area, and the first bone flap should distinctly expose the ASTS to facilitate dissection of the sigmoid sinus away from the inner table of the mastoid bone.

In the present study, we found two more factors that would attenuate the accuracy and practicability of using SP to locate the ASTS. First, about 14% of the parietomastoid sutures separated into two branches before concatenating squamosal sutures, leading to an uncertainty of confirming the definite SP. Second, according to the results, there were significant differences between ASTS and SP both in ASTS-x and ASTS-y ($P = 0.003$ and $P = 0.011$, respectively). That means SP cannot represent the location of the ASTS precisely. Hence, it will be difficult to utilize the SP for localization of the ASTS accurately and universally.

Some neurosurgeons preferred to use image-guided surgical planning to complete localization. Those methods, including neuronavigation and others based on three-dimensional volume rendering (3D VR) technique, can yield morphometric data in individual patients and overcome extreme individual variations. However, they are not so practical and convenient. When neuronavigation is used, the patient should undergo high-resolution computed tomography or magnetic resonance imaging scans in combination with sinuses angiography for 3D VR of the cranial bone and the dural vasculature at the same time.[12,13] It is both expensive and time-consuming. Moreover, not all the hospitals can provide neuronavigation service. Hence, it is still worth exploring an easy, quick, practical, and low-cost method for locating the sinuses precisely.

Ugur *et al*.[14] recommended using easily palpable skull landmarks (such as zygomatic root, inion, and mastoid process), not cranial sutures, to identify the locations of the transverse and sigmoid sinuses. The authors measured the distances between the three landmarks and the midpoints, and the shortest distances of the midpoints to the border of the groove for sigmoid and transverse sinuses. Moreover, the authors considered the data of the measurement could be used to avoid venous injury during posterior fossa approaches.

In our previous study, we used a rectangle coordinate system on the lateral surface of the cranium to locate the IMTS. The results showed that the positioning system was a reliable and practical method for identifying the IMTS precisely. Moreover, it had two advantages: first, the coordinate system could be defined easily during the operation because the scalp covering the zygomatic arch, FPZ, SMC, and the mastoid is thin enough to palpate points A, B, and C; second, this positioning system does not need recognition of the cranial sutures (the lambdoidal, squamosal, and parietomastoid sutures) which should be identified for using the traditional method to locate the IMTS.[9]

In the present study, we continued to take the advantages of the coordinate system for localization of the ASTS. According to the results, the SDs of the data were less than 4 mm. The mean distance from the ASTS to the Y-axis (mean ASTS-x measurement) was statistically larger on the right side versus the left side, and there was no significant difference between genders. With regard to the mean distance from the ASTS to the X-axis (mean ASTS-y measurement), there was no significant difference between genders or skull sides. It was noteworthy that there were no interaction effects among gender and skull side for either ASTS-x or ASTS-y which meant that in this system, gender and skull side do not influence each other in localization of the ASTS.

In previous studies, the calibers of the transverse and sigmoid sinuses were slightly larger on the right side than left side.[15,16] The nature of the sinuses may be why the IMTS was located more closely to the Y-axis on the right side.[9]

In the present study, however, the ASTS was closer to the Y-axis on the left side than the right side.

In the application of this coordinate system during the presigmoid approach, we recommended that the X-axis and Y-axis should be outlined and the site of the ASTS should be marked on the scalp according to the data shown in Table 1 before disinfection and draping of the operation area. In males on the left side, the ASTS was located approximately 15.33 mm posterior to Y-axis and 7.52 mm above X-axis while on the right side, it was 17.59 mm posterior to Y-axis and 7.80 mm above X-axis. In females, the ASTS was located approximately 15.29 mm posterior to Y-axis and 7.65 mm above X-axis on the left side, and 16.07 mm posterior to Y-axis and 7.43 mm above X-axis on the right side. After scalp incision, the ASTS should be marked on the bone immediately for drilling the "key" hole. Because the sinuses are occasionally embedded in and adherent to the bony groove, we advised that the center of the strategic burr hole should be placed a little further away in anterosuperior direction from the ASTS to increase the security.

One of the limitations of this study was that since only adult skulls were used, the results may only be applied to adults. Another limitation was that sometimes, there is a high degree of individual variation in the relationship between surface landmarks and the sinuses, which will decrease the accuracy of the locating and increase the risk of sinus injury.[17-19] Therefore, if possible, surgeons should utilize image-guided surgical planning technology, such as neuronavigation and other methods based on the 3D VR technique, to obtain individual morphometric data for overcoming extreme variations.[12,13]

In conclusion, the craniometric measurements and statistical analyses of this study showed that our coordinate system was an accurate and practical method for identifying the ASTS. The SP, which has been classically used to locate the venous junction, might be difficult to find during presigmoid craniotomy and is not always a reliable landmark for defining the ASTS.

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Conflicts of interest

There are no conflicts of interest.

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