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Localization of asterion and its relationship to the transverse and sigmoid venous sinuses

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Abstract

Background: Asterion has been recognized as the external skull landmark for localization of the transverse and sigmoid sinus junction (TSJ). This study aimed to localize the asterion using the intersection of the Frankfurt horizontal plane (FHP) line and a vertical line from the mastoid tip, and to determine its relationship with the transverse and sigmoid sinuses.

Materials and methods: Distances from the asterion to the FHP and vertical line were measured on 200 dry skulls (100 males and 100 females). In addition, 48 cadavers (24 males and 24 females) underwent asterion drilling, and the relationship with the transverse and sigmoid sinuses was recorded.

Results: In most skulls, the asterion was superior to the FHP line, with average distances of 0.5 ± 0.3 cm on both sides. Distances to the vertical line were 3.7 ± 0.4 cm and 3.9 ± 0.4 cm for the left and right sides, respectively. These distances were statistically significant different between sides but not between sexes. The location of

asterion was mainly over the TSJ (54%) and transverse sinus (42%). The accuracy of a predictive method was evaluated in additional 10 cadavers. The predicted positions were located with distances ranging from 0 to 1.3 cm in the horizontal plane (0.4 ± 0.4 cm) and 0 to 0.7 cm in the vertical plane (0.3 ± 0.2 cm) from the asterion.

Conclusions: This study confirms the anatomical relationship between the asterion and TSJ including the transverse sinus. Alternative method for localizing the asterion was also introduced.

Keywords: asterion, anatomy, transverse sinus

Introduction

Asterion is an anatomical landmark on the lateral aspect of the skull at the intersection of the lambdoid, occipitomastoid and parietomastoid sutures. Asterion was classified into two types: type I with sutural bone and type II without sutural bone [3, 8, 10, 24]. On the internal surface of skull, the position of asterion is related to the transverse and the junction between the transverse and sigmoid sinuses (TSJ) [1, 2, 4, 5, 7, 8, 16, 17, 19, 20, 22, 24]. Therefore, the asterion was used for burr hole placement during the suboccipital or retrosigmoid approach to avoid dural sinus injury.

However, localization of the asterion using the previously reported methods is relatively complicated in clinical practice. In this study, we aimed to introduce the more applicable method using the Frankfurt horizontal plane (FHP) line and a vertical line passing the mastoid tip. The measurement was performed in dry skulls and the accuracy of this method was verified in the cadavers. Moreover, we examined the relationship between the asterion and the transverse sinus including the TSJ in the cadavers.

Materials and methods

Two hundred adult human dry skulls (100 males and 100 females, undetermined age) collected in the Department of Anatomy, Faculty of Medicine, Chulalongkorn University were used for the external localization of the asterion. Determination of the anatomical relationship between the asterion and the transverse and sigmoid sinuses was done in 48 embalmed cadavers (24 males and 24 females). The age range was 50–115 years (79.6 in average). In addition, 10 more cadavers (5 males and 5 females) with

the age range of 59–94 years (74 in average) were used in the testing for accuracy of the predicted values derived from the localization study. Specimens with damage to the relevant structures were excluded. All these studies have been approved by the institutional ethics committee (050/2022). All measurements were done twice by the same investigator using a digital Vernier caliper (Mitutoyo ®, Japan; resolution 0.01 mm) and the average was calculated.

In the dry skulls, the asterion on each side was identified and classified into 2 types: type I with sutural bone and type II without sutural bone. To localize the asterion, two reference lines were employed: the Frankfurt horizontal plane (FHP) line and a vertical line passing the tip of mastoid process perpendicular to the FHP line (V line) (Fig. 1). The intersection point between these two lines was set as the zero point. The horizontal (X) and vertical (Y) distances from the asterion or the midpoint of sutural bone to the zero point were measured with a measuring tape. The predictive co-ordinate for the location of asterion was then determined.

In the 48 cadavers, the cranial vault or calvarium was opened above the level of transverse sinuses and the brain removed. The scalp covering the asterion was also removed. Then, the asterion was identified and drilled perpendicular to the skull surface using a 2-mm drill. In type I asterion with sutural bone, the hole was made at the center of the sutural bone. The position of the hole was noted on the inner surface of the skull and its relationship to the transverse and sigmoid sinuses were recorded (Fig. 2).

In the accuracy testing, the asterion was located on the 10 cadaveric heads using the predictive co-ordinates from the measurement study. After marking of the predicted asterion, the scalp was removed and the skull cleaned until the asterion was clearly seen. The distances in the x and y axes between the predicted and real positions of the asterion were measured (Fig. 3).

Student's *t*-test was employed to detect any significant differences in the measurement data between genders and sides. The test was done using the SPSS for Windows version 23. Differences were considered statistically significant when $p < 0.05$.

Results

Anatomy of the asterion in dry skulls

According to the type of asterion, type II (no sutural bone) was present in most male (187, 93.5%) and female (197, 98.5%) skulls. In the majority of dry skulls, the

asterion was above the FHP line, 194 (96.5%) in male and 198 (99%) in female. The average vertical distances from the asterion to the FHP line were 0.48 cm on the left and 0.46 cm on the right sides of male skulls (Tab. 1). In female, the average distances were 0.55 cm and 0.52 cm on the left and right sides, respectively. Since there were no significant differences between sides or sexes, the predicted vertical distance for both sexes and both sides was 0.51 cm.

As for the relationship to the V line, the asterion was posterior to this line in all skulls. The average horizontal distances in male were 3.72 cm and 3.91 cm on the left and right sides, respectively (Tab. 1). In female, the distances were 3.67 cm on the left and 3.82 cm on the right sides. There were significant differences between sides in both sexes but not between sexes. Therefore, the predicted horizontal distances were 3.70 cm and 3.86 cm for the left and right sides of both sexes, respectively.

Anatomy of the asterion related to the venous sinuses in cadavers

Similar to the results in the dry skulls, type II asterion was observed in most cadavers, in 41 males (85%) and in 45 females (94%). In male, the most common location of asterion hole was at the junction between the transverse and sigmoid sinuses (TSJ) (30, 63%) with lower incidences at the transverse sinus (16, 33%) and inferior to the TSJ (4%, 0.96 and 0.74 cm on the right side of 2 skulls). In comparison, the locations in female were at the transverse sinus (24, 50%), TSJ (22, 46%) and superior to the TSJ (4%, 0.89 and 0.76 cm on the left and right sides of one skull).

Accuracy of asterion localization in cadavers

The accuracy of the predicted location was evaluated in 10 cadavers. The predicted locations tended to be more anterior to the exact asterion (Fig. 4). The distances ranged from 0 to 1.3 cm in the horizontal plane (0.4 ± 0.4 cm) and 0 to 0.7 cm in the vertical plane (0.3 ± 0.2 cm). In the horizontal plane, only 2 of 10 values were greater than 1.0 cm, whereas, in the vertical plane, the approximate range was –0.4 to 0.8 cm. It is worth noting that the predicted positions of one left male and one left female were exactly at the real asterion.

Discussion

Regarding the type of asterion, type I (sutural bone) was present in 6.5% of male and 1.5% of female skulls. In the cadavers, the incidences were 15% for male and

6% for female. These were consistent with those of the previous reports in various ethnic groups (6.5–38.8%) [1, 3, 8, 10, 24]. As a result, this and other studies confirmed that type I asterion is less frequent than type II.

As for the relationship between the asterion and venous sinuses, this study showed that the asterion in most cadavers was on the level of the transverse sinus or TSJ in both sexes (96%). In consistent, the previous studies reported that the asterion was over the transverse sinus or TSJ in the majority of specimens. Day and Tschabitscher, 1998 found the location of asterion at the transverse-sigmoid sinus complex in 66% on the left and 61% on the right sides of cadavers [4]. Sripairojkul and Adultrakoon, 2000 observed that the asterion was overlying the TSJ in 58% and 74% of left and right sides of cadavers, respectively [19]. The incidences of asterion over the TSJ were 80% in Mwachaka et al. 2010 [16], 87% in Ucerler and Govsa, 2006 [22] and 67.5% in Duangthongpon et al. 2016 [5], 60.7% in Muche, 2021 [15]. Using the imaging investigation in the patients, Gharabaghi et al. 2008 found that the location of asterion was on the TSJ in 65% on the left and 75% on the right [7]. CT angiography also showed the asterion overlying the TSJ in 68.75% in Fang et al., 2016 [6] and 74% in Hwang et al., 2017 [11]. Recently, Bojana et al. 2023 found that in 43 skulls, 76.9 % on the right and 72.2 % on the left sides, the asterion was at the level of TSJ [1]. Nevertheless, Jian et al., 2022 found the low percentage of asterion on the TSJ (28%) [12]. Rohilla et al., 2023 observed no TSJ at the asterion position in 16 dried skulls [18]. In some studies, the higher percentage of the asterion over the transverse sinus was reported: 61.3% in Bozbuga et al., 2006 [2], approximately 70% in Teranishi et al., 2014 [20], 63% in Hall and Peter Gan, 2019 [9], 58% in Gharehdaghi et al., 2020 [8]. These data are summarized in Table 2. Despite some discrepancy, the above data suggested the high percentage of asterion over the transverse sinus or TSJ. Therefore, the asterion can be useful as the skull landmark for avoiding venous sinus injury during suboccipital or retrosigmoid approach. The burr hole might be placed posteroinferior to the asterion as suggested by this and another study [5]. However, it is worth noting that other landmarks were suggested for localizing the TSJ: mastoid process and zygomatic arch [21], top of mastoid notch [14], digastric groove [13], 12 mm above the top of mastoid groove from the FHP [12].

Several measurement parameters using external skull landmarks were previously reported for localization of the asterion in dry skulls and cadavers. Those landmarks were the mastoid tip, inion and root of zygoma [2, 8, 16, 22, 24] including

the suprameatal crest (Henle's spine) and FHP [22]. However, it is difficult to apply the direct distances between the asterion and the above landmarks without angle values for localizing the asterion in the living subjects. This study proposes a new method which can be applied to patients using palpable bony landmarks and two lines. The external auditory meatus and orbit were used to determine the FHP (horizontal line) and the tip of mastoid process to determine the V line (vertical line). Employing this method, we found that the average distance to the FHP line of 0.51 cm was applicable without significant differences between sexes or sides. Ucerler and Govsa, 2006 reported the average distance to the FHP of 1.5 cm which was higher than our value [22]. The reason underlying this discrepancy is unknown but might be due to different ethnicity. In contrast, the horizontal distances to the V line were significantly different between sides in both sexes. Therefore, the average horizontal distances of 3.70 cm for the left and 3.86 cm for the right sides were obtained.

This study also investigated the accuracy of the localization of asterion using the above distances. The results showed that the distances between the real and predicted asterion were within 1.0 cm in the horizontal plane except two values. In the vertical plane, the values were within the range between –0.4 and 0.8 cm. These data suggest the proximity between the positions of real and predicted asterion. As a result, the prediction using the proposed distances was useful for localizing the asterion in the patients.

It is worth noting that these measurement data were derived from the dry skulls. In the cadavers, presence of soft tissue might account for some errors in the localization of the asterion in the accuracy study. Moreover, structural alterations after death and embalming process should be concerned when localizing the asterion in the living subjects. Another limitation is anatomical variations among different subjects. Therefore, future studies are required to provide the clinical applicability of this prediction method.

In conclusion, we found a high incidence of type II asterion and location of asterion over the transverse sinus and TSJ. The distances from the asterion to the vertical line passing the mastoid tip and to the FHP were also presented. The predicted position of the asterion derived from these data was less than 1 cm from the real position in both vertical and horizontal planes in most specimens. These findings provide alternative method for localization of the asterion which is important for

avoiding venous sinus injury during suboccipital craniotomy. Its clinical applications should be confirmed by further investigation.

Article information and declarations

Data availability statement

Original contributions presented in the study are included in the article.

Ethics statement

All these studies have been approved by the institutional ethics committee (050/2022).

Author contributions

Conceptualization: TT, SD, PA, TH, and VC. Data acquisition: all authors. Data analysis or interpretation: SD, PA, TH, SA, and VC. Drafting of the manuscript: SD, SA, and VC. Critical revision of the manuscript: TT, SD, SA, and VC. Approval of the final version of the manuscript: all authors.

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Conflict of interest

None declared.

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Table 1. Measurement data related to the asterion in dry skulls.

	Distance [cm]					
	Male (n = 100)			Female (n = 100)		
	Left	Right	Both sides	Left	Right	Both sides
Frankfurt horizontal plane (Y)	0.48 ± 0.32	0.46 ± 0.33	0.49 ± 0.31	0.55 ± 0.33	0.52 ± 0.35	0.54 ± 0.34
Vertical line passing the tip of mastoid process (X)	3.72 ± 0.37	3.91 ± 0.43*	3.81 ± 0.41	3.67 ± 0.44	3.82 ± 0.46*	3.74 ± 0.45

Data are means ± SD. *p < 0.001 left vs. right.

Table 2. Comparison of the type and location of asterion related to the sigmoid and transverse sinuses among different studies.

Study (ref. no.)	Number of samples	Type of asterion		Position of asterion over the transverse & sigmoid sinuses
		Type I	Type II	
This study	200 skulls	4%	96%	

	48 cadavers	10.4%	89.6%	95.8%: 97.9% (L),93.8% (R)
Day & Tschabitscher, 1998 [4]	100 skulls			66% (L),61% (R)
Sripairojkul & Adultrakoon, 2000 [19]	43 cadavers			58% (L),74% (R)
Ucerler and Govsa, 2006 [22]	56 half-skulls & 44 half-cadaver heads			87%
Gharabaghi et al., 2008 [7]	CT of 100 patients			65% (L),75% (R)
Mwachaka et al., 2010 [16]	50 skulls & 40 cadavers			80%
Teranishi et al., 2014 [20]	88 patients			71.1 % (L),70% (R)
Duangthongpon et al. 2016 [5]	20 cadavers			67.5%
Fang et al., 2016 [6]	CT of 32 patients			68.75%
Hwang et al., 2017 [11]	CT of 50 patients			74%
Hall & Peter Gan, 2019 [9]	CT of 50 patients			63%
Gharehdaghi et al., 2020 [8]	105 skulls	14.7%	85.3%	58.1%
Muche, 2021 [15]	61 skulls	16.4% (L) 13.1% (R)		60.7%
Wirakiat et al., 2021 [24]	40 cadavers	38.8%	61.2%	65%
Jian et al., 2022 [12]	15 skulls & 8 cadavers			28%
Bojana et al. 2023 [1]	39 skulls	34.88%	65.12%	72.2 % (L),76.9 % (R)

CT — computed tomography; L — left side; R — right side.

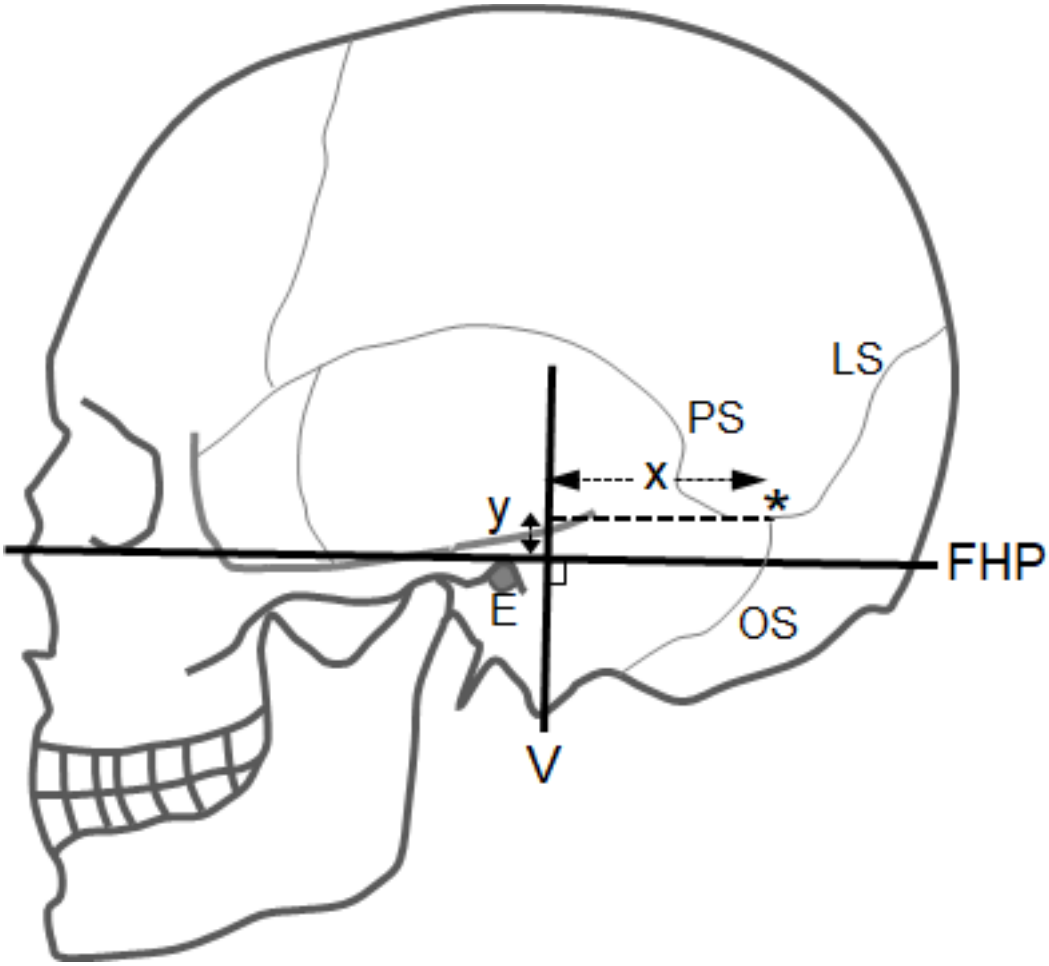

Figure 1. Measurements related to the location of asterion in the dry skulls. *Asterion. x — horizontal distance from the asterion to the V line; y — vertical distance from the asterion to the FHP. E — external auditory meatus; FHP — Frankfurt horizontal plane; LS — lambdoid suture; OS — occipitomastoid suture; PS — parietomastoid suture; V — vertical line passing the mastoid tip and perpendicular to the FHP.

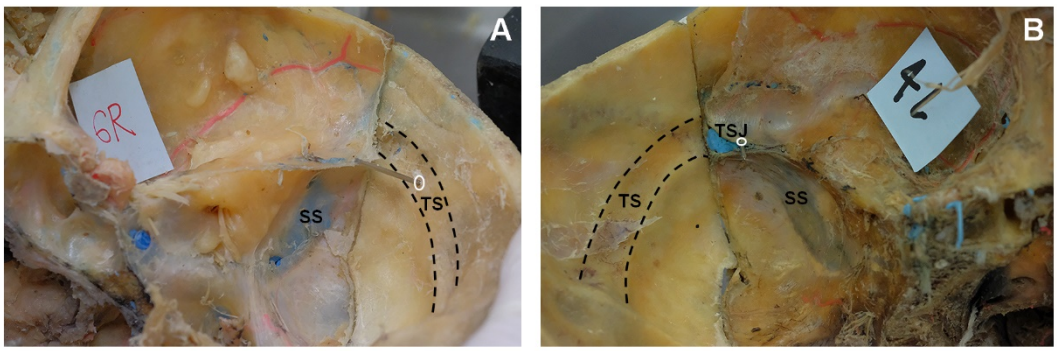

Figure 2. Inner surface of skull showing the transverse (TS) and sigmoid (SS) sinuses. White circles indicate the locations of drill holes from the asterion on the external skull surface. **A.** location of asterion over the TS; **B.** location of asterion over the junction between the TS and SS (TSJ).

Figure 3. Measurements of distances between the real and predicted locations of asterion in the cadavers. Arrow and arrowhead indicate the real and predicted locations of asterion, respectively. x — distance between the two locations along the x axis, y — Distance between the two locations along the y axis. LS — lambdoid suture; OS — occipitomastoid suture; PS — parietomastoid suture.

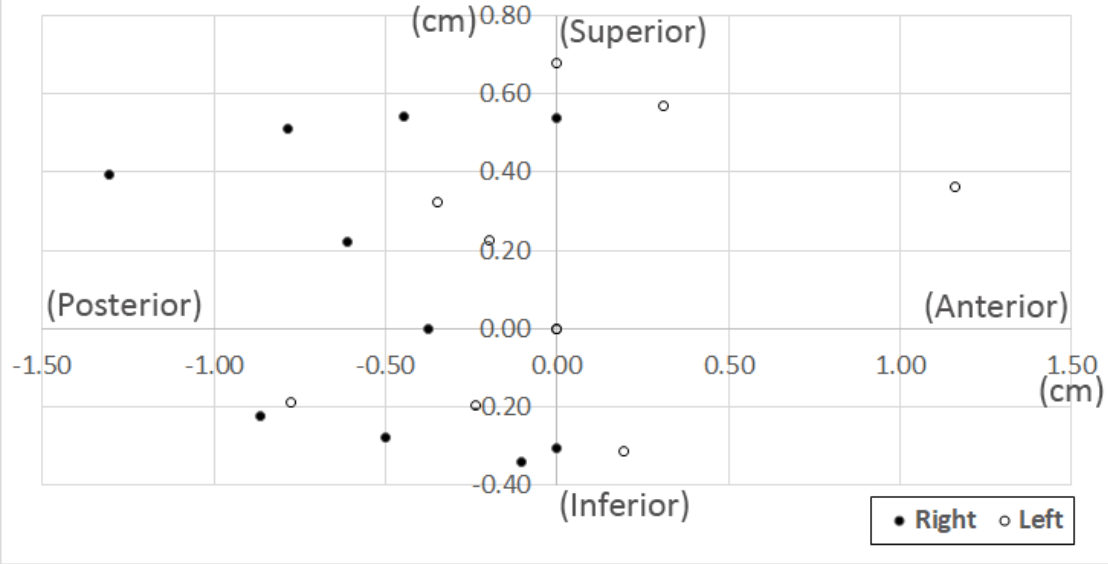

Figure 4. Distribution of the predicted locations of asterion in 10 cadavers. FHP — Frankfurt horizontal plane; V — vertical line passing the mastoid tip and perpendicular to the FHP. 0,0 is the location of real asterion. The positions of one left male and one left female were at the 0,0 point.