

Anatomic Position of the Asterion and Implication for Neurosurgical Procedure

Posición Anatómica del Asterion y sus Implicancias en el Procedimiento Neuroquirúrgico

Wimon Wirakiat¹; Anukoon Kaewborisutsakul² & Wilairat Kankuan Kaewborisutsakul¹

WIRAKIAT, W.; KAEWBORISUTSAKUL, A. & KANKUAN, K. W. Anatomic position of the asterion and implication for neurosurgical procedure. *Int. J. Morphol.*, 39(5):1429-1435, 2021.

SUMMARY: The asterion is the joining of the lambdoid, parietomastoid, and occipitomastoid sutures. It is classified into two types, type I shows small bones or woven bones, while in type II, woven bones are non-existent. In this study, forty cadavers were conducted and observed the asterion on both sides of skulls showing the approximate ratio of type II and type I was 3:2. The asterion was located by measuring the distances from the asterion to skull landmarks, including inion, the root of zygoma, and mastoid tip. The mean distance between asterion and inion was 62.9 ± 6.0 mm. The mean distance between asterion and the root of zygomatic arch was 58.3 ± 6.1 mm, whereas the mean distance between asterion and mastoid tip was 51.1 ± 5.3 mm. The most common location related to the asterion was the dural venous sinuses on 65 % of tested sides, followed by infratentorial dura and supratentorial dura (25 % and 10 %, respectively). However, the authors found no differences between sexes, sides, and types in any underlying structures.

KEY WORDS: Asterion; Skull; Dural venous sinus; Cadave; Thais.

INTRODUCTION

The knowledge of the superficial anatomy is crucial for the surgeon on the initial success of the neurosurgical approach. The asterion is the joining of the lambdoid, parietomastoid, and occipitomastoid sutures (Standing, 2016). It is a superficial anatomical landmark that has not been believed to be related to the underlying posterior fossa dura but indicated the location of the intracranial venous sinuses (Day & Tschabitscher, 1998). Surgeons must consider the appropriate placement of burr holes for craniotomy at the retrosigmoid approach to avoid venous sinus injury and consequent bleeding (Raabe, 2019). As the location of the asterion varies, in the present study, the type of asterion, its relation to the underlying structure, and the distance from skull landmarks were observed from skulls of Thai male and female cadavers. Our findings could be helpful for surgeons in planning to approach posterolateral intracranial.

MATERIAL AND METHOD

After the institutional ethics committee approval (REC.64-031-19-2), forty adult human formalin-fixed cadaveric heads were collected from the Anatomy Program,

Division of Health and Applied Sciences, Faculty of Science. The scalp and soft tissue were removed to expose the lateral and posterior cranial areas, from the root of zygoma (ROZ) to inion, foramen magnum, and laterally to the mastoid tip on both sides. The heads presenting congenital anomalies of cranial or previous skull procedures were excluded. Cadaveric information, including age, sex, type of asterion, and the distance of surface anatomical landmarks to the position of asterion, was recorded and statistically analyzed. In addition, the relationship between asterion and the internal surface of the bone, especially the venous sinus in the posterior cranial fossa, was observed.

Type of asterion. The sutures, including lambdoid, occipitomastoid, parietomastoid, and squamosal in each specimen, were examined to identify the asterion type. The junction of all these sutures at the asterion area was classified into two types (Singh, 2012). Type I presented small bone or woven bone (Fig. 1A), and type II by absent woven bone (Fig. 1B).

Position of asterion. The distance between the critical surface anatomical landmarks, including the root of the zygomatic arch (ROZ), the tip of mastoid process (MT), and the inion

¹ Anatomy Program, Division of Health and Applied Sciences, Faculty of Science, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand.

² Neurological Surgery Unit, Department of Surgery, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand.

(IN) to asterion were measured (Fig. 2) using stainless steel sliding calipers (Mitutoyo®, Japan) with an accuracy of 0.01 mm. All measurements were taken four times by two authors and then averaged to minimize bias errors. Then the authors drilled a small hole of 2 mm in diameter at asterion to evaluate the relationship between asterion and inner surface structures. The cranial vault above the hole was removed. In contrast, the underlying structure, the venous sinus in the posterior cranial fossa, was observed and classified into three groups, namely supratentorial dura, dural venous sinus, and infratentorial dura groups.

Statistical analysis. All data were analyzed based on sex and skull sides using the R Foundation for Statistical Computing (version 3.6.3). The differences in the type of asterion were statistically analyzed with the Exact probability test, whereas the distances of the position of asterion between sexes and each side were determined by the two-sample Wilcoxon rank-sum (Mann-Whitney) test. A probability value among groups less than 0.05 ($P < 0.05$) indicated a significant difference.

The two authors (WK and WW) individually evaluated all aspects of the study. The authors decided upon the asterion type and its underlying structures in agreement. The distance between asterion to skull landmarks, as continuous data, was tested inter-rater reliability with Bland-Altman plots. Measurements exceeding the upper- or lower limit of the agreement were remeasured. This study used the mean distances for further statistical analysis.

RESULTS

The forty cadavers in the study consisted of seventeen females and twenty-three males. The mean age of corpses was 78.2 ± 13.0 years, ranging from 41 to 102 years. Asterion was observed on both sides of skulls (80 sides) with a higher proportion of type II than type I asterion. The approximate ratio of asterion type II and type I was 3:2 (61.2 % and 38.8 %, respectively). By sex, the incidence of asterion type II was 73.5 % in females and 52.2 % in males, whereas type I was 26.5 % in females and 47.8 % in males (Table I). To compare the asterion type between sides, the prevalence of bilaterally asterion type II was more common than bilateral asterion type I (40.0 % vs. 17.5 %). However, there was no significant difference between sex and sides (Table I).

The location of the asterion was measured by the distances from the asterion to skull landmarks, including the root of zygoma, mastoid tip, and inion, which have been shown in Table II. The longest distance was found in the line between asterion and inion, 62.9 ± 6.0 mm. The mean

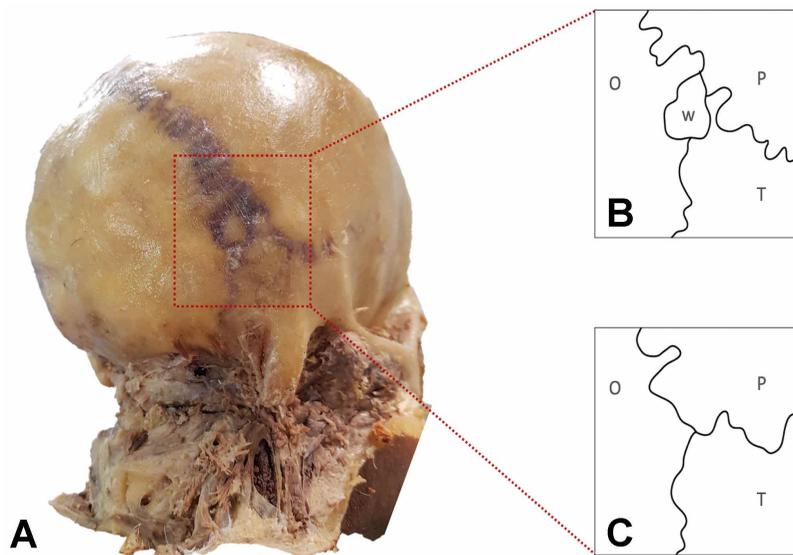


Fig. 1. Type of the asterion. (A) The right posterolateral view of cadaveric head after scalp and soft tissue removal. (B) Asterion type I. (C) Asterion type II. O: occipital bone, P: parietal bone, T: temporal bone, W: woven bone.

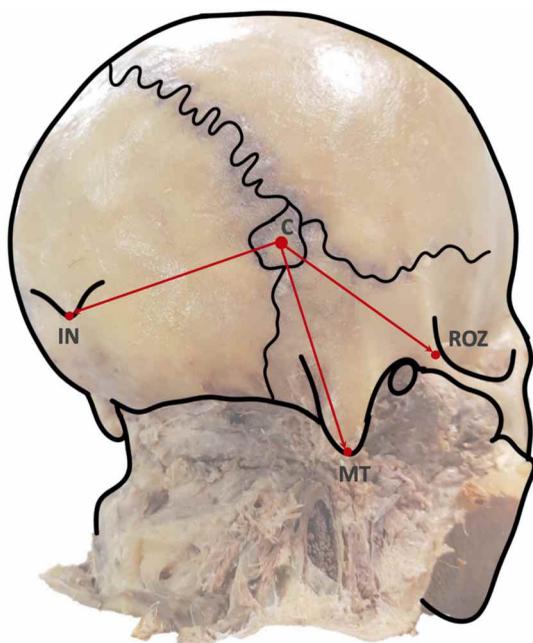


Fig. 2. The distance from the asterion to skull landmarks (on the right side). C: center of asterion, IN: inion, MT: mastoid tip, ROZ: root of zygoma.

Table I. Type of the asterion

Type	By sex				p-value ¹	By side				p-value ¹	Total (n=80)	
	Male (n=46)		Female (n=34)			Right (n=40)		Left (n=40)			n	%
	n	%	n	%		n	%	n	%			
I	22	47.8	9	26.5	0.065	16	51.6	15	48.4	1.000	31	38.8
II	24	52.2	25	73.5		24	49.0	25	51.0		49	61.2

¹Exact probability test

distance between asterion and root of the zygomatic arch was 58.3 ± 6.1 mm. The shortest distance was found in the line between asterion and mastoid tip, 51.1 ± 5.3 mm. In addition, the authors collected and analyzed the database on sexes, sides, and types of asterion as followed.

By the sex, the locations of the asterion from each bony landmark were similar in female and male. The mean distance between asterion and inion was 62.2 ± 5.3 mm in female and 63.5 ± 6.5 mm in male, the mean distance between asterion and root of the zygomatic arch was 58.0 ± 4.9 mm in female and 58.6 ± 6.9 mm in male, and the mean distance between asterion and mastoid tip was 49.8 ± 4.4 mm in female and 52.1 ± 5.8 mm in male (Table II).

By the side, the distances from the asterion to inion, the root of the zygomatic arch, and the mastoid tip were similar. The mean distance between asterion and inion was 63.9 ± 6.4 mm on the right side and 62.0 ± 5.6 mm on the left side. In contrast, the mean distance between asterion and root of the zygomatic arch was 57.8 ± 6.6 mm on the right side and 58.9 ± 5.7 mm on the left side, and the mean distance between asterion and mastoid tip was 51.2 ± 5.6 mm on the right side and 51.0 ± 5.1 mm in the left side (Table II).

The mean distances between asterion and inion were 64.5 ± 7.9 mm and 61.9 ± 4.3 mm (type I and II, respectively)

by type of asterion. The mean distances between asterion and root of the zygomatic arch were 56.6 ± 7.7 mm in the type I asterion and 59.5 ± 4.7 mm in the type II asterion. The latter distances were 50.4 ± 5.0 mm and 51.6 ± 5.5 mm in type I and II, respectively (Table II).

After the asterion types and locations were identified, the authors found that the most common location related to the asterion was the dural venous sinus on 65 % of tested sides, followed by the infratentorial dura and supratentorial dura (25 % and 10 %, respectively). The type I asterion was rather associated with the venous sinus than infratentorial and supratentorial dura (71 %, 12.9 %, and 16.1 %, respectively). Similarly, the type II asterion was located at the venous sinus in 61.2 %, followed by infratentorial dura and supratentorial dura (32.7 % and 6.1 %, respectively) (Table III). Significantly, the location of asterion overlaid the dural venous sinus; it was typically in the transverse-sigmoid sinus junction (51.2 %), only fifteen asterions (18.8 %) were located at posterior fossa dura that just inferiorly to the transverse-sigmoid sinus junction, and four asterion (5 %) were superior to the transverse-sigmoid sinus junction. At the transverse sinus area, eleven asterions (13.8 %) were located, and five asterions (6.2 %) were inferior to the transverse sinus, while the lastly four asterions (5 %) were superior to the transverse sinus (Fig. 3). However, the authors found no differences between sexes, sides, and types in any underlying structures.

Table II. Distance from asterion to anatomical landmarks (mm).

Distance	By sex			By side			By type			Total
	Male (n=46)	Female (n=34)	p-value ¹	Right (n=40)	Left (n=40)	p-value ¹	I (n=31)	II (n=49)	p-value ¹	
	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD		
AS - ROZ	58.59 ± 6.92	58.01 ± 4.93	0.289	57.82 ± 6.60	58.87 ± 5.66	0.389	56.58 ± 7.66	59.46 ± 4.67	0.1593	58.34 ± 6.13
AS - MT	52.11 ± 5.79	49.83 ± 4.38	0.070	51.24 ± 5.58	51.04 ± 5.13	0.889	50.36 ± 5.00	51.64 ± 5.52	0.435	51.14 ± 5.33
AS - IN	63.50 ± 6.54	62.18 ± 5.29	0.316	63.90 ± 6.42	61.97 ± 5.55	0.084	64.51 ± 7.86	61.94 ± 4.34	0.577	62.94 ± 6.04

¹Two-sample Wilcoxon rank-sum (Mann-Whitney) test. AS: asterion, IN: inion, MT: mastoid tip, ROZ: root of zygoma.

Table III. Association between type of Asterion and its beneath structures.

Type	Structures beneath the Asterion						p-value ¹
	Infratentorial dura		Venous sinus		Supratentorial dura		
	n	(%)	n	(%)	n	(%)	
I (n=31)	4	(12.9)	22	(71.0)	5	(16.1)	0.077
II (n=49)	16	(32.7)	30	(61.2)	3	(6.1)	
Total	20	(25)	52	(65.0)	8	(10)	

¹Exact probability test.

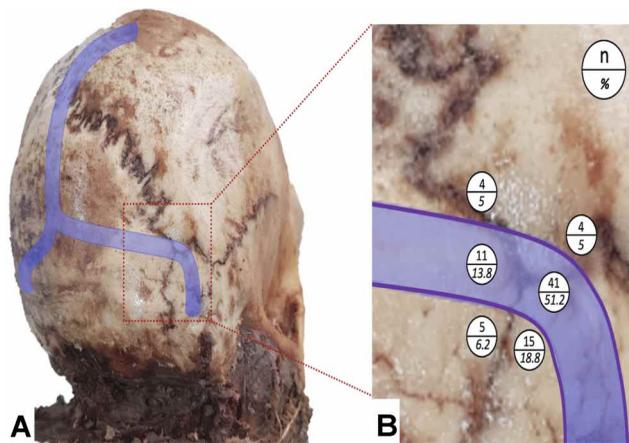


Fig. 3. Position of the asterion in relation to beneath dura and the sinus (purple color). (A) The right posterolateral view of cadaveric head showing the underneath the right transverse and sigmoid sinus. (B) The magnification view, the circle showing the number (n) and percentage (%) of the location of the center of asterion over each area.

DISCUSSION

In brain tumor surgery, the asterion is used as a landmark in the posterolateral region, such as the retrosigmoid approach for tumor resection in the cerebellopontine angle and the suprapetrosal approach for petrous lesions, so the right point at the beginning of craniotomy is desirable to approach into skull cavity (Lang Jr. & Samii, 1991; Ribas *et al.*, 2005; Ribas & Rodrigues, 2007). Asterion is classified as type I and II, where type II commonly occurs. It can be found some small ossicles named Wormian bones (Berry & Berry, 1967; Singh) that derived from the abnormal ossification centers fused into the typical structure during the skull development (Bellary *et al.*, 2013). The appearance of Wormian bones may be related to genetic factors, artificial cranial deformation, an adaptation of skull growth, and metabolic disorders (Manjula & Santosh, 2012; Cirpan *et al.*, 2015; Hardy & Fernandez-Patron, 2020).

In the previous report of Thailand, asterion was easily detected in the dry skull, but it was identified with 60-80 % correctness in fresh cadaver or formalin-fixed heads (Avci *et al.*, 2003; Duangthongpon *et al.*, 2016). However, in this study, the authors ultimately identified both types of asterion in all formalin-fixed cadavers and provided valuable information on asterion types and landmarks in Thai

Table IV. Previous studies of type and location of asterion.

Country	Authors (year)	Number of sides	Type of asterion (%)		Distance from asterion to landmarks (mm)		
			I	II	AS - ROZ	AS - MT	AS - IN
Turkey	Ucerler <i>et al.</i> , 2006.	100	NA	NA	54.6 ± 5.5	49.1 ± 5.4	NA
Kenya	Mwachaka <i>et al.</i> , 2010.	63 Male	NA	NA	59.06 ± 2.72	48.36 ± 2.72*	NA
		38 Female	NA	NA	58.75 ± 2.02	46.62 ± 3.37*	NA
India	Singh, 2012.	56 Male	17.9	82.1	NA	NA	NA
		54 Female	14.8	85.2	NA	NA	NA
	Havaldar <i>et al.</i> , 2015.	296 Male	18.3	81.7	NA	NA	NA
		204 Female	20.6	79.4	NA	NA	NA
	Deepak <i>et al.</i> , 2015.	54 Male	25.9	74.1	NA	NA	NA
		46 Female	28.2	71.7	NA	NA	NA
Iran	Gharehdaghi <i>et al.</i> , 2019.	146 Male	13.7	86.3	NA	45.5 ± 6.7	58.9 ± 7.6
		Right			NA	48.43 ± 2.04	72.87 ± 1.64*
		Left			NA	47.60 ± 2.02*	72.49 ± 1.45
		64 Female	14.7	85.2	NA	45.5 ± 5.5	57.0 ± 7.9
		Right			NA	43.84 ± 1.62	64.46 ± 3.8*
		Left			NA	44.15 ± 2.35*	64.96 ± 4.01
Thailand	Present study.	46 Male	47.8	52.2	58.59 ± 6.92	52.11 ± 5.79	63.50 ± 6.54
		Right			58.41 ± 7.46	51.88 ± 6.26	64.26 ± 6.80
		Left			58.77 ± 6.51	52.35 ± 5.41	62.74 ± 6.32
		34 Female	26.5	73.5	58.01 ± 4.93	49.83 ± 4.38	62.18 ± 5.29
		Right			57.01 ± 5.33	50.38 ± 4.57	63.42 ± 6.03
		Left			59.02 ± 4.43	49.28 ± 4.25	60.93 ± 4.26

AS: asterion, IN: inion, MT: mastoid tip, ROZ: root of zygoma, NA: not available, *statistical significant.

cadavers. The asterion type found in Thai female cadaveric skulls was similar to males, where the occurrence of asterion type II is followed by asterion type I. As well as in Thais, the asterion type II was always the most found in several ethnicities, including Turks (Ucerler & Govsa, 2006), Kenyans (Mwachaka *et al.*, 2010), Indians (Singh; Pavan *et al.*, 2015; Deepak & Dakshayani, 2015), and Iranians (Gharehdaghi *et al.*, 2020) (Table IV). However, the occurrence of asterion type I in the Thai population was significantly higher than those studied in other races. For the asterion type I or asterion presented with sutural bone, the authors observed a connective tissue perched along the suture edge; this tissue could be the cause for unclear asterion identification and asterion type classification in the cadaveric skulls.

The measurements of the asterion location with other pronounced anatomical landmarks related provide information for the clinical, surgical procedures. The authors collected the database in which the mean distance between the asterion and the inion, zygoma root, and mastoid tip were comparable with the earlier studies' results (Table IV).

On the point of the asterion to the inion distance, in Indians, Deepak & Dakshayani, reported 55.8 ± 9.5 mm on the right, 56.9 ± 8.5 mm on the left on male craniums, 58.9 ± 7.6 mm on the right, 57.0 ± 7.9 mm on the left on female craniums. In Iranian, Gharehdaghi *et al.* study found significant differences in distance between the left and right sides in both males and females. They recorded 72.9 ± 1.6 mm on the right, 72.5 ± 1.5 mm on the left on male skulls, 64.5 ± 3.8 mm on the right, 65.0 ± 4 mm on the left on female skulls. We measured 64.3 ± 6.8 mm on the right, 62.7 ± 6.3 mm on the left on male skulls, 63.4 ± 6.0 mm on the right, 60.9 ± 4.3 mm on the left on female skulls in our study (Table IV).

The distance of asterion to the root of zygoma, most of the results were consistent in each race. In Turkish skulls, Ucerler & Govsa measured 54.6 ± 5.5 mm totally. Mwachaka

et al. reported 59.1 ± 2.7 mm in Kenyan males and 58.8 ± 2.0 mm in Kenyan females. In this study, we reported 58.4 ± 7.5 mm on the right and 58.8 ± 6.5 mm on the left of male skulls, 57.0 ± 5.3 mm on the right and 59.0 ± 4.4 mm on left female skulls. There was no significant difference in distance between sides and sexes in our study (Table IV).

The distance between asterion and mastoid tip process, Ucerler & Govsa reported measured 49.1 ± 5.4 mm totally in Turkish skulls. In Indians, Deepak & Dakshayani reported 50.9 ± 4.9 mm on the right, 48.5 ± 8.5 mm on the left on male skulls, 45.5 ± 6.7 mm on the right, 45.5 ± 5.5 mm on the left on female skulls. However, there was a sign of this distance between Kenyans and Iranians. Mwachaka *et al.*, who found differences between distances in males and females, recorded 48.4 ± 2.7 mm in Kenyan males and 46.6 ± 3.8 mm in Kenyan females. In contrast, Gharehdaghi *et al.* reported significant differences in distance between the left and right sides in both males and females. They recorded 48.4 ± 2.0 mm on the right, 47.6 ± 2.0 mm on the left on male skulls, 43.8 ± 1.6 mm on the right, 44.2 ± 2.4 mm on the left on female skulls. In this study, we found no difference in distance between sides and sexes, 51.9 ± 6.3 mm on the right and 52.4 ± 5.4 mm on left of male skulls, 50.4 ± 4.6 mm on the right and 49.3 ± 4.3 mm on left female skulls (Table IV).

Nowadays, a microsurgical innovation technique as the key-hole craniotomy can replace large craniotomies to provide shorter surgery time and avoid severe complications in neurosurgery; the relationship between surface anatomy and underneath structure must be crucially concerned. The venous sinus was the most common location related to the asterion in several studies (Table V). Also, in Thailand, a study led by Sripairojkul & Adultrakoon (2000) observed the asterion in 66.3 % cases above the venous sinuses, 16.3 % infratentorial, and 17.4 % supratentorial. In contrast, in the study by Duangthongpon *et al.* (2016) in 90.9 % cases the asterion was above venous sinuses, in 3 % located at the infratentorial, and in 6.1 % at supratentorial position (Table V).

Table V. Previous studies of the structure beneath the asterion.

Country	Authors (year)	Number of sides	Structures beneath the asterion (%)		
			Infratentorial dura	Venous sinus	Supratentorial dura
Turkey	Ucerler <i>et al.</i> , 2006.	100	11.0	87.0	2.0
Kenya	Mwachaka <i>et al.</i> , 2010.	180	0.6	80.0	19.4
China	Sheng <i>et al.</i> , 2012	200	0.5	78.5	21.0
India	Deepak <i>et al.</i> , 2015.	100	32.0	62.0	6.0
Iran	Gharehdaghi <i>et al.</i> , 2019.	210	30.5	58.1	11.4
Thailand	Sripairojkul <i>et al.</i> , 2000.	86	16.3	66.3	17.4
	Duangthongpon <i>et al.</i> , 2016.	33	3.0	90.9	6.1
	Present study.	80	25.0	65.0	10.0

In the previous studies, Day & Tschabitscher concluded that the asterion is an unreliable landmark for posterolateral craniotomy. However, a more accurate performance of craniotomy, which aims to identify posterior fossa dura and transverse-sigmoid junction, needs other assisting methods, such as the neuronavigational system. However, the system has limited availability or accessibility, especially in countries with low resources (Gnanakumar *et al.*, 2020). Hall & Gan (2019) compared the qualitative and quantitative differences between ten methods to approach the posterior fossa dura at the transverse-sigmoid sinus junction, also called key point. They showed asterion positions away from the key point with an average of 13.9 ± 5.2 mm and proposed a method with the highest accuracy to intraoperative application. In a retrosigmoid approach described by Li *et al.* (2014) as novel coordinate system, the placement of the initial burr hole was 6.3 ± 2.9 mm away from the key point. It is known that each patient's key point position is located differently (Hall & Gan). Therefore, planning the surgery with the information of the patient is probably a suitable method. Xia *et al.* (2012) studied eighteen patients who underwent retrosigmoid craniotomy by surgery planning to place the burr hole at the key point with a preoperative 3D computed tomography comparing the position of asterion and digastric groove. There the burr hole was set at the corrected key point position and led to no venous sinus injury.

Therefore, our findings may help to recognize the variation of asterion type and its location in terms of distance from other skull landmarks and beneath structures. However, this study was limited by the small numbers of cadaveric heads in southern Thailand. Further work, as multi-institutes in different regions, is required to establish the exact information for Thai people.

ACKNOWLEDGMENTS. The authors would like to acknowledge the Anatomy Program, Division of Health and Applied Sciences, Faculty of Science, Prince of Songkla University for their support of this research, and thank Mrs. Anna Chatthong for her assistance with the English language. The authors are grateful to the supporting team of the anatomy program for their help and to those who donated their bodies for anatomical study.

WIRAKIAT, W.; KAEWBORISUTSAKUL, A. & KANKUAN, K. W. Posición anatómica del asterion y sus implicancias en el procedimiento neuroquirúrgico. *Int. J. Morphol.*, 39(5):1429-1435, 2021.

RESUMEN: El asterion es la unión de las suturas lambdaidea, parietomastoidea y occipitomastoidea. Clasificado en dos tipos, el tipo I muestra huesos pequeños o hueso laminar, mien-

tras que en el tipo II, el hueso laminar es inexistente. En este trabajo se estudiaron 40 cadáveres y se observó el asterion en ambos lados de los cráneos correspondientes, mostrando una proporción aproximada de tipo II y tipo I de 3:2. El asterion se localizó midiendo las distancias asociadas a puntos de referencia del cráneo: el inion, la raíz del arco cigomático y el ápice del proceso mastoideo. La distancia media entre el asterion y el inion fue de $62,9 \pm 6,0$ mm. La distancia media entre el asterion y la raíz del arco cigomático fue de $58,3 \pm 6,1$ mm, mientras que la distancia media entre el asterion y el ápice del proceso mastoideo fue de $51,1 \pm 5,3$ mm. La localización más común relacionada con el asterion fueron los senos venosos duros en el 65 % de los lados evaluados, seguido de la duramadre infratentorial y la dura supratentorial (25 % y 10 %, respectivamente). Sin embargo, los autores no encontraron diferencias entre sexo, lados y tipo en ninguna estructura subyacente.

PALABRAS CLAVE: Asterion; Cráneo; Seno venoso dural; Cadáver; Tailandés.

REFERENCES

- Avcı, E.; Kocaogullar, Y.; Fossett, D. & Caputy, A. Lateral posterior fossa venous sinus relationships to surface landmarks. *Surg. Neurol.*, 59(5):392-7, 2003.
- Bellary, S. S.; Steinberg, A.; Mirzayan, N.; Shirak, M.; Tubbs, R. S.; Cohen-Gadol, A. A. & Loukas, M. Wormian bones: a review. *Clin. Anat.*, 26(8):922-7, 2013.
- Berry, A. C. & Berry, R. J. Epigenetic variation in the human cranium. *J. Anat.*, 101(Pt. 2):361-79, 1967.
- Cirpan, S.; Aksu, F. & Mas, N. The incidence and topographic distribution of sutures including wormian bones in human skulls. *J. Craniofac. Surg.*, 26(5):1687-90, 2015.
- Day, J. D. & Tschabitscher, M. Anatomic position of the asterion. *Neurosurgery*, 42(1):198-9, 1998.
- Deepak, S. & Dakshayani, K. R. Morphometric features of asterion in adult human skulls. *Int. J. Res. Med. Sci.*, 3(6):1325-8, 2015.
- Duangthongpon, P.; Thanapaisal, C.; Kitkhuandee, A.; Chaiciwamongkol, K. & Morthong, V. The relationships between asterion, the transverse-sigmoid junction, the superior nuchal line and the transverse sinus in Thai cadavers: Surgical relevance. *J. Med. Assoc. Thai.*, 99 Suppl. 5:S127-31, 2016.
- Gharehdaghi, J.; Jafari-Marandi, H.; Faress, F.; Zeinali, M. & Safari, H. Morphology of asterion and its proximity to deep vein sinuses in Iranian adult skull. *Br. J. Neurosurg.*, 34(1):55-8, 2020.
- Gnanakumar, S.; Abou El Ela Bourquin, B.; Robertson, F. C.; Solla, D. J. F.; Karekezi, C.; Vaughan, K.; Garcia, R. M.; Hassani, F. D.; Alamri, A.; Höhne, J.; *et al.* The World Federation of Neurosurgical Societies Young Neurosurgeons Survey (Part I): demographics, resources, and education. *World Neurosurg.* X, 8:100083, 2020.
- Hall, S. & Gan, Y. C. P.s Anatomical localization of the transverse-sigmoid sinus junction: Comparison of existing techniques. *Surg. Neurol. Int.*, 10:186, 2019.
- Hardy, E. & Fernandez-Patron, C. Destroy to rebuild: The connection between bone tissue remodeling and matrix metalloproteinases. *Front. Physiol.*, 11:47, 2020.
- Lang Jr., J. & Samii, A. Retrosigmoidal approach to the posterior cranial fossa. An anatomical study. *Acta Neurochir. (Wien)*, 111(3-4):147-53, 1991.

- Li, R. C.; Li, K.; Qi, L.; Xu, G. F.; Xie, W. F.; Wang, M. D. & Bao, G. A novel reference coordinate system to locate the inferomedial point of the transverse-sigmoid sinus junction. *Acta Neurochir. (Wien)*, 156(11):2209-13, 2014.
- Manjula, P. & Santosh, S. Sexual dimorphism among the Wormian bone in adult human skulls. *J. Indian Acad. Forensic Med.*, 34(2):124-7, 2012.
- Mwachaka, P. M.; Hassanali, J. & Odula, P. O. Anatomic position of the asterion in Kenyans for posterolateral surgical approaches to cranial cavity. *Clin. Anat.*, 23(1):30-3, 2010.
- Pavan, P. H.; Shruthi, B. N.; Hussain Saheb, S. & Henjarappa, K. S. Morphological study on types of asterion. *Int. J. Integr. Med. Sci.*, 2(10):167-9, 2015.
- Raabe, A. *The Craniotomy Atlas*. New York, Thieme, 2019.
- Ribas, G. C. & Rodrigues, A. J. J. The suprapetrosal craniotomy. *J. Neurosurg.*, 106(3):449-54, 2007.
- Ribas, G. C.; Rhoton Jr., A. L.; Cruz, O. R. & Peace, D. Suboccipital burr holes and craniectomies. *Neurosurg. Focus*, 19(2):E1, 2005.
- Singh, R. Incidence of sutural bones at asterion in adults Indians skulls. *Int. J. Morphol.*, 30(3):1182-6, 2012.
- Sripairojkul, B. & Adultrakoon, A. Anatomical position of the asterion and its underlying structure. *J. Med. Assoc. Thai.*, 83(9):1112-5, 2000.
- Standring, S. *Gray's Anatomy: The Anatomical Basis of Clinical Practice*. 41st ed. New York, Elsevier, 2016.
- Ucerler, H. & Govsa, F. Asterion as a surgical landmark for lateral cranial base approaches. *J. Craniomaxillofac. Surg.*, 34(7):415-20, 2006.
- Xia, L.; Zhang, M.; Qu, Y.; Ren, M.; Wang, H.; Zhang, H.; Yu, C.; Zhu, M. & Li, J. Localization of transverse-sigmoid sinus junction using preoperative 3D computed tomography: application in retrosigmoid craniotomy. *Neurosurg. Rev.*, 35(4):593-8, 2012.

Corresponding author:

Wilairat Kankuan Kaewborisutsakul, Ph.D
Anatomy Program
Division of Health and Applied Sciences
Faculty of Science
Prince of Songkla University
Hat Yai, Songkhla 90110
THAILAND

E-mail: wilairat.k@psu.ac.th

Received : 22-06-2021

Accepted : 28-07-2021