Evaluation of the inion and asterion as neurosurgical landmarks for dural venous sinuses: osteological study on a sample of South African skull specimens

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Abstract

Background: Sub-Saharan neurosurgeons most likely need to perform invasive procedures without the latest imaging and navigation technology in the operating room. Therefore, these surgeons need to utilize other methods such as superficial surface landmarks for neuro-navigation. Bony landmarks, including the inion and asterion, are commonly used during invasive procedures to pinpoint the location of the confluence of sinuses and transverse-sigmoid sinus junction, respectively. The purpose of this study was to investigate whether the inion and asterion can be used as superficial landmarks for the confluence of sinuses and the transverse-sigmoid sinus junction, respectively, in a South African population.

Methods: Fifty South African human skulls were used (25 male, 25 female). The micro-focus X-ray radiography and tomography facility (MIXRAD) at Necsa scanned and created three-dimensional virtual images of the skull specimens. Reference points were then inserted on the images and the relation between bony landmarks and venous sinuses was documented.

Results: The inion was directly related to the confluence of sinuses in 4% of the sample, whereas the asterion was directly related to the transverse-sigmoid sinus junction in 28% of the cases, on both the right and left sides.

Conclusions: This study confirmed that neither the inion, nor the asterion, are directly related the confluence of sinuses and transverse-sigmoid sinus junction, respectively. These bony landmarks are more likely to be located either inferior, or not related at all, to the investigated dural venous sinuses.

Key words: Tomography, X-ray; Surgeons; Radiography.

Presently knowledge and suitable technology is progressively available for the surgeon. The challenge, however, lies in the fact that surgeons are prevented from applying modern medical knowledge due to the lack of financial resources.[1] It is reported that in sub-Saharan Africa, there is one neurosurgeon for 3.1 to 6.4 million people. In South Africa, specifically, only approximately 50% of the population has access to neurosurgical services within two hours.[2] Further reports indicate that only 30% of operating rooms in sub-Saharan Africa has access to surgical technology.[3] Therefore, the sub-Saharan neurosurgeon most likely needs to use alternative methods to perform basic and vital surgical procedures. One of these methods is the use of superficial surgical landmarks.

Although various studies have been conducted to investigate the reliability of landmarks such as the inion and asterion for the dural venous sinuses, the methods have destructive effects on the skull specimens involved.[4-7] The inion and asterion are bony landmarks commonly used during invasive procedures in the posterior cranial fossa to pinpoint the location of the confluence of sinuses and transverse-sigmoid sinus junction, respectively.[4, 6, 8]

The inion is defined as "a point located on the external occipital protuberance at the intersection of the midline with a line drawn tangent to the uppermost convexity of the right and left superior nuchal lines (p.903)."[9] The literature refers to the inion as the central part of the external occipital protuberance and thus clearly distinguishes between the two different bony parts.[6] The confluence of sinuses is located at the internal occipital protuberance, and is the junction of the superior sagittal-, straight-, occipital- and transverse dural venous sinuses.[9, 10] Variations in the size and communications of the dural sinuses occur at the confluence of sinuses.[10]

The anatomical relation between the inion and the confluence of sinuses was previously investigated and described as the confluence of sinuses being primarily located towards the superior-right aspect of the inion.[6, 11]

The asterion is defined as "a craniometric point in the region of the posterolateral, or mastoid, fontanel at the junction of the lambdoid, occipitomastoid and parietomastoid sutures (p.158)."[9] The asterion corresponds with the mastoid- or posterolateral fontanel site found in neonatal skulls.[8, 10] The transverse sinuses are located within the attached border of the tentorium cerebelli, running along the squamous part of the occipital bone, then the mastoid angle of the parietal bone. Once it reaches the posterolateral aspect of the petrous part of the temporal bone, it leaves the attached border of the tentorium cerebelli, continues in a downward direction and becomes the sigmoid sinus.[10] The right transverse sinus is typically larger in diameter and located more inferiorly in comparison to the left transverse sinus.[6]

From the literature, it can be ascertained that the asterion has been suggested as a reliable landmark during neurosurgery[12] for the identification of the transverse-sigmoid sinus junction.[8, 11, 13] It is reported that substantial variations exist in the relationship between the asterion and the transverse-sigmoid sinus junction. Previous studies show that the asterion is directly related to the transverse-sigmoid sinus junction in 81% of cases, inferior to the junction in 15% of cases and superior to the venous junction in 4% of cases.[8, 11, 12]

This study focused on the inion and asterion as superficial surgical landmarks used during invasive procedures, as to better prepare the neurosurgeon in developing countries for navigation into the cranial cavity.

The aim of this study was to determine whether superficial bony landmarks can accurately predict the internal location of the dural venous sinuses. Therefore, the objectives of this study were: 1) to investigate the relationship between the inion and the internal occipital protuberance and the confluence of sinuses in a sample of skull specimens; 2) to investigate the relationship between the asterion and the transverse-sigmoid sinus junction in a sample of skull specimens; 3) to investigate whether the variations found at these landmarks are linked to sex (male or female); and 4) to investigate whether the variations found at these landmarks are linked to side (left or right).

Materials and methods

A sample of 50 South African human skull specimens, located in the Department of Anatomy, Sefako Makgatho Health Sciences University, was used to determine the reliability of the inion and asterion as neurosurgical landmarks for the location of the confluence of sinuses and the transverse-sigmoid sinus junction, respectively.

Only 50 skull specimens were used for this study due to the lengthy period required for the micro-focus X-ray computed tomography (µXCT) scanning of each skull at Necsa, Pelindaba. The scanning parameters were set at 100 keV, 100 µA, 1000 projections in 360°- and 2-seconds exposure time for each projection. A convenient, non-probability, sampling method was used to select 25 male and 25 female skull specimens. Skull specimens with any visible damage to the inion, asterion, or impressions of the internally located dural venous sinuses on either the left or right sides of the skull, were excluded from this study.

Horizontal craniotomy of the specimens performed during routine student training dissection, enabled the researchers to make direct observations of the impressions of the dural venous sinuses. The variations concerning the dural venous sinuses, as well as the sex of the specimens, were documented.

Through the utilization of micro-focus X-ray computed tomography (µXCT) the skull specimens were scanned and the researchers were able to reconstruct three-dimensional (3D) virtual images of each skull specimen.[14] Reference-points of the inion, asterion and locations of the venous sinuses (Table I, Figure 1, 2), were inserted on the reconstructed images using VGStudio MAX (Version 2.2)® (Volume Graphics GmbH, Charlotte, NC, USA) 3D analytical software. These reconstructed images could be sectioned and/or rotated in order to visualize and confirm the landmarks and venous sinuses. Once inserted, all the reference points were visible, irrespective of the section or view of the skull specimen in the software program.

Before any analysis was performed, the reconstructed image of each skull was calibrated to its standard anatomical position, referred to as the Frankfurt horizontal plane or orbitomeatal plane.[9] This plane passes through the inferior margin of the orbit and the superior margin of the external acoustic meatus.[15] The relationship between the reference points was noted and documented as described below.

Regarding the inion (Figure 1: *a*):

- the level of the inion relative to the level of the internal occipital protuberance (Figure 1: *a*–*b*);
- the level of the inion relative to the most inferior part of the confluence of sinuses (Figure 1: *a*–*c*);

- the level of the inion relative to the most superolateral point on the right side (Figure 1: *a*–*d*) and left side (Figure 1: *a*–*e*) of the confluence of sinuses.

Regarding the asterion:

- the level of the asterion relative to the level of the superior curve of the transverse-sigmoid junction on the right side (Figure 2: *f*–*g*) and left side (Figure 2: *i*–*j*);
- the level of the asterion relative to the level of the inferior curve of the transverse-sigmoid junction on the right side (Figure 2: *f*–*h*) and left side (Figure 2: *i*–*k*).

Table I. *Descriptions of the reference-points inserted on the reconstructed images of the skull specimens*

Reference points related to the inion	Symbol allocated
Tip of the inion	A
Internal occipital protuberance	B
Most inferior point on the confluence of sinuses	C
Most superolateral point on right side of confluence of sinuses	D
Most superolateral point on left side of confluence of sinuses	E
Reference points related to the asterion	
Asterion on the right side	F
Superior curve of the transverse-sigmoid sinus junction on the right side	G
Inferior curve of the transverse-sigmoid sinus junction on the right side	H
Asterion on the left side	I
Superior curve of the transverse-sigmoid sinus junction on the left side	J
Inferior curve of the transverse-sigmoid sinus junction on the left side	K

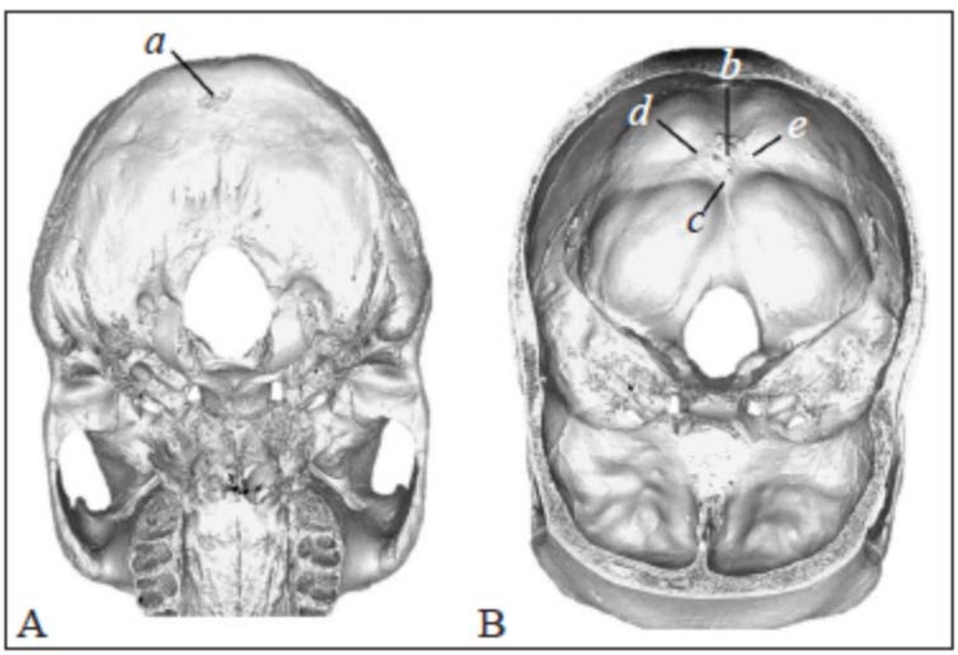

Figure 1. Reference points *a*, *b*, *c*, *d* and *e* pertaining to the inion and its relationship to the confluence of sinuses, inserted on the 3D reconstructed images produced by VGStudioMax 2.2® (Volume Graphics GmbH, Charlotte, NC, USA), as seen: A) on the inferior surface; and B) the internal aspect of the skull.

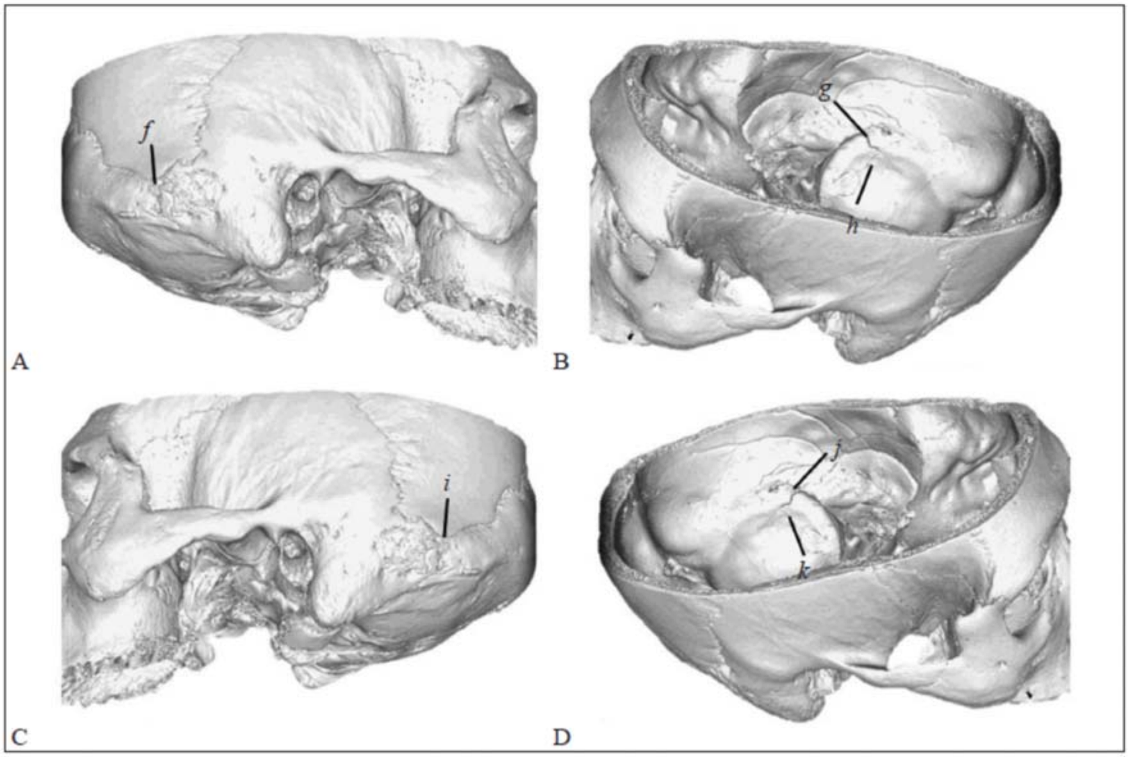

Figure 2. Reference points *f*-*k* pertaining to the asterion and its relationship to the transverse-sigmoid sinus junction, inserted on 3D reconstructed images produced by VGStudioMax 2.2® (Volume Graphics GmbH, Charlotte, NC, USA), as seen: A) on the lateral aspect of the right side of the skull; B) the internal aspect of the right side of the skull; C) the left side of the skull; and D) the internal aspect of the left side of the skull.

In order to determine the exact location of each of the reference points, the software program provided coordinates (X, Y and Z) for these points. The relation between these reference-points was determined by making use of the X-axis and Y-axis and was then further classified into one of four categories: Above the venous sinus, directly related to the venous sinus, below the venous sinus, not related.

Statistical analysis

All the data obtained was statistically analysed to determine whether variations of the dural venous sinuses and their superficial landmarks are linked to sex (male or female), or the side of the skull specimen (left or right). Statistical tests included the Fischer's exact test for sex and the McNemar's test for symmetry on the left and right sides of the skull specimens.

Ethical approval to conduct this study was obtained from the Ethics Committee of the Sefako Makgatho Health Sciences University in 2014 (Project number: MREC/P/325/2014: IR). Skull specimens used in this study were handled according to the rules and regulations set out in the National Health Act, (2003) of South Africa, which clearly states that human tissue may be used for health sciences research.

Results

The position of the inion in relation to the confluence of sinuses was determined by using three different relationships: Figure 1 – *a*-*c*, *a*-*d* and *a*-*e*. For the inion (Figure 1: *a*) to be directly related to the confluence of sinuses, reference point Amust lie between *c*, *d* and *e*, which was the case in only 4% (N.=2) of the sample where the inion was directly related to the confluence of sinuses. In 10% (N.=5) of the cases the inion was superiorly related to the confluence of sinuses and in 66% (N.=33) of the cases the inion was located below the inferior border of the confluence of sinuses. In the remaining 20% (N.=10) of the skulls, the inion was not related to the confluence of sinuses. Male and female skull specimens were compared, and no statistically significant difference (P value of 0.46) was found between these samples (Table II).

Table II. *Comparison of the relation of the inion to confluence of sinus between male and female skull specimens*

Relation of inion to confluence of sinuses	Male sample (N.=25)	Female sample (N.=25)	Total sample (N.=50)
Superiorly related	3 (12%)	2 (8%)	5 (10%)
Directly related	2 (8%)	0	2 (8%)
Inferiorly related	13 (52%)	20 (80%)	33 (66%)
Not related	7 (28%)	3 (12%)	10 (20%)

The percentage value is indicated in brackets.

The relation of the asterion to the transverse-sigmoid sinus junction was determined by using two relationships on each side of the skull: Figure 2 – *f-g* and *i-j* on the right side and *f-h* and *i-k* on the left side. On the right side of the skull, the asterion was directly related to the transverse-sigmoid sinus junction in 28% (N.=14) of the cases, superiorly related to this sinus in 22% (N.=11) of the cases and inferiorly related to this sinus in 14% (N.=7) of the cases. On the left side of the skull, the asterion was directly related to the transverse-sigmoid sinus junction in 28% (N.=14) of the cases, superiorly related to this sinus in 16% (N.=8) of the cases and inferiorly related to this sinus in 28% (N.=14) of the cases. The asterion was not related to the transverse-sigmoid junction in 36% (N.=18) of the cases on the right side and 28% (N.=14) of the cases on the left side. The male and female skull specimens were compared to determine the relation of the asterion to the transverse-sigmoid sinus junction. No statistically significant difference was found in the relations documented for the asterion relative to the level of the inferior curve of the transverse-sigmoid junction on the left side (Table III). The female and male samples were also compared. No statistically significant difference was noted on the right side (P=0.136) or the left side (P=0.836) of the skulls.

Table III. *Comparison of the relation of the asterion to the transverse-sigmoid sinus junction between male and female skull specimens, for both left and right sides of the skull. The percentage values are indicated in brackets.*

Relation of asterion to transverse-sigmoid sinus junction	Male sample (N.=25)	Female sample (N.=25)	Total sample (N.=50)
Right asterion			
Superiorly related	5 (20%)	6 (24%)	11 (22%)
Directly related	8 (32%)	6 (24%)	14 (28%)
Inferiorly related	2 (8%)	5 (20%)	7 (14%)
Not related	10 (40%)	8 (32%)	18 (36%)
Left asterion			
Superiorly related	4 (16%)	4 (16%)	8 (16%)
Directly related	9 (36%)	5 (20%)	14 (28%)
Inferiorly related	7 (28%)	7 (28%)	14 (28%)
Not related	5 (20%)	9 (36%)	14 (28%)

The left and right sides of the skull specimens were compared for symmetry of the level of the asterion, by means of the McNemar's test. The level of the asterion relative to the level of the superior curve of the transverse-sigmoid junction on the right side and left side showed no statistically significant difference (P=0.0956). However, a statistically significant difference was noted in the level of the asterion relative to the level of the inferior curve of the transverse-sigmoid junction between the right and left sides (P=0.0439).

Discussion

The external valuation of the dural venous sinuses is important for neurosurgeons before attempting any invasive procedure.[6] Variations in the locations of the dural venous sinuses might pose a potential challenge for a neurosurgeon planning an interventional procedure. Examples of such procedures include the surgical treatment of cerebrovascular diseases,[16] midline suboccipital craniotomy[17] and retrosigmoid craniotomy.[18, 19] Certain superficial land-marks have been established to assist the neurosurgeon in placing the initial burr hole to limit injury to the venous sinuses,[4, 20] particularly in key-hole methods during microvascular decompression[5] and surgical approaches to the posterior cranial fossa.[15] Landmarks include the inion, asterion, superior nuchal line, sutures of the skull and the apex of the mastoid process.[15, 18] The risk of iatrogenic injury to the venous sinuses is great should the initial burr-holes be positioned close or directly over the dural venous sinuses.[15, 18, 21, 22]

The relation of the inion to the confluence of sinuses has been previously described in two separate studies documented in the literature[7, 11] One of these studies had a sample size of 15 cadavers and found that the inion was directly related to the confluence of sinuses in only 27% of the cases.[7] The sample of the other study consisted of 100 CT angiograms and reported that the inion was directly related in 89% of the cases.[11] In this research study, consisting of a sample of 50 skull specimens, a direct relation between the inion and the confluence of sinuses was observed in only 4% of the cases, which is considerably lower than the results reported in the literature. Different investigation techniques were used in all the above-mentioned studies which included burr-holes made in the skulls of human adult cadavers, CT angiograms and micro-focus X-ray computed tomography.

In a study conducted by Gharabaghi *et al.*, hospital based computed tomography (CT) images of 100 patients were evaluated for the comparison between the asterion and the landmarks for the respective transverse-sigmoid sinus junctions.[23] On the left side, the asterion was directly related to the transverse-sigmoid sinus junction in 65% of the cases and 75% of the cases on the right side. Although differences were noted between the left and right sides, these differences were not statistically significant.[23]

Other studies investigating the asterion include one with a sample of 100 skull specimens, that used a transillumination and skiagrams technique. The study reported that the asterion was directly related to the transverse-sigmoid sinus junction in 91% of the cases (left: 43, right: 48), superiorly related in 2% and inferiorly related in 7% of the skulls.[8] Another study investigated 50 skull specimens and reported that the asterion was directly related in 62% and in 32% of the cases, below to the transverse sinus.[22] The current study, using a sample of 50 skull specimens, reported a direct relation between the asterion and the transverse-sigmoid sinus junction in 28% of the skulls on both the right and left sides.

A statistically significant difference (P=0.0327) between the level of the asterion relative to the level of the inferior curve of the transverse-sigmoid junction was noted between the right and left sides, in this study. This might be attributed to the fact that common laterality of the dural venous system does exist, and in the majority of cases, the right transverse sinus has a larger diameter and is more inferiorly located in comparison to the left transverse sinus.[7, 16] Therefore, the right asterion is more likely to be either directly, or superiorly related to the right transverse-sigmoid sinus junction, in comparison to the left side (Table III). Similar results were reported by Demir and *et al.* (2015), mentioning that their sample consisted of neonatal cadavers aged between 38-40 gestational weeks.[19]

This study confirms that variations in the relation of the inion to the confluence of sinuses, as well as the relation of the asterion to the transverse-sigmoid sinus junction, do exist, especially when compared with other studies, as previously reported. Variations found in the location of the asterion might be ascribed to population-specific locations or sexual dimorphism.[24, 25] It has been reported that the asterion is located higher on the skull in males, in comparison to females.[24, 25] However, in the current study, no statistically significant difference was found between males and females for the asterion and its relation to the transverse-sigmoid sinus junction.

Different investigation techniques might contribute to the variations reported in direct relationship between in the inion and the confluence of sinuses (4-89%), and the direct relationship between the asterion and transverse-sigmoid sinus junction (14-91%). The samples used in the reported studies varied and ranged from 15-100 live individuals or cadaveric specimens. These studies were conducted on several continents, which might imply that the direct relationship between the superficial landmarks and the dural venous sinuses differ between the population groups as mentioned by Kemkes and Gobel (2006).[24] However, very few of these studies mention the population which constituted the sample. Some of the population samples observed included Portugese,[24] German[24] and Kenian[25] specimens.

Although the inion might not be the most reliable surface landmark for the confluence of sinuses, it is still used during the infratentorial supracerebellar approach to the pineal region, in line with the bregma, to guide the neurosurgeon safely inferior of the straight sinus.[26]

Conclusions

This study used a non-destructive method to investigate the relationship between superficial bony landmarks and the dural venous sinuses in such a way which would not have been possible otherwise. By working with reconstructed three-dimensional images of the skull specimens, this study confirmed that the inion is not a consistent landmark for the precise location of the confluence of sinuses. Therefore, the inion can be used as a surgical point of entry as it is mainly found inferior to the confluence of sinuses. The asterion did not prove to be a better landmark to locate the transverse-sigmoid sinus junction either. However, should the asterion be used as a point of surgical approach for the initial burr-hole, it should be noted that as per this South African sample, there is only a slim probability that the burr-hole will be directly related to the transverse-sigmoid sinus junction, but rather inferior to this junction. Neurosurgeons, more specifically those without access to the latest neuro-navigation technology, should not only be aware of the normal location of the dural venous sinuses, but also the relation and reliability of superficial landmarks such as the inion and the asterion, which can be used in practice, to locate the venous sinuses. Future research is needed which includes studies with larger samples and more mention of population groups. More consistent superficial landmarks should be investigated, especially those related to the confluence of sinuses.

Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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