Brain and Spine 4 (2024) 102757

Contents lists available at ScienceDirect

Brain and Spine

journal homepage: www.journals.elsevier.com/brain-and-spine

The auricula as a new surgical landmark for the transverse-sigmoid-sinus-transition

Senne Broekx [a,*], Dylan Thomas Stevesyns [a], Tomas Menovsky [b]

[a] Department of Neurosurgery, Antwerp University Hospital, 2650, Edegem, Belgium
[b] Department of Neurosurgery and Faculty of Medicine, Antwerp University Hospital, 2650, Edegem, Belgium

ARTICLE INFO

Handling editor: W Peul

Keywords:
Anatomical landmark
Auricula
Retrosigmoid approach
Technical note
Transverse-sigmoid-sinus-transition

ABSTRACT

Introduction: The transverse-sigmoid-sinus-transition constitutes an important landmark during a retrosigmoid craniotomy. Due to anatomical variations, the location is highly variable. Landmarks for identification of the anterior border of the sigmoid sinus have been described extensively, such as the mastoid notch, digastric point, external auditory meatus and crux of the helix curvature. There is a paucity of landmarks for the identification of the posterior border, however.
Research question: We examined the relationship between the transverse-sigmoid-sinus-transition and the most-posterior-part-of-the-auricula.
Material and methods: We performed a retrospective analysis of one-hundred patients (38 males and 62 females) who underwent cerebral MRI examinations at Antwerp University Hospital (Belgium). Using Brainlab®, the transverse-sigmoid-sinus-transition and most-posterior-part-of-the-auricula coordinates were calculated and compared. Left and right sides were compared in both the anteroposterior and craniocaudal axis.
Results: Mean age was 56.4 ± 16.1 years. Mean MPPA-TSST-distance in the anteroposterior direction was −1.93 mm (right) and −1.96 mm (left). Mean MPPA-TSST-distance in the craniocaudal direction was −5.16 mm (right) and −5.04 mm (left).
Discussion and conclusion: The transverse-sigmoid-sinus-transition seems to be located more anterior and caudal with respect to the most-posterior-part-of-the-auricula, meaning that it can be considered a save landmark. A correction of five mm needs to be applied in order to identify the inferior border of the transverse sinus. Left/right and gender had no significant influence. The most-posterior-part-of-the-auricula can be considered a fast and practical anatomical landmark for identification of the transverse-sigmoid-sinus-transition, without affecting operative fluency, especially during an emergency craniotomy.

1. Introduction

The sigmoid sinus (SS) is a paired S-formed dural sinus located between the endosteum of the occipital bone and dura, originating at the superior border of the petrous bone and ending of the tentorium cerebelli. Together with the transverse sinus (TS), it forms the transverse-sigmoid-sinus-transition (TSST), which constitutes an important landmark during posterolateral skull base approaches, such as the retrosigmoid craniotomy. However, the location of the sigmoid sinus is highly variable and anatomical variations are well known. In order to help improve patient safety and avoid extensive bony defects, many authors have already reported on a diverse group of anatomical landmarks for the anterior border of the sigmoid sinus, such as the mastoid notch, digastric point, external auditory meatus and crux of the helix curvature. To our knowledge, this is the first study exploring the positional relationship between the transverse-sigmoid-sinus-transition/posterior border of the sigmoid sinus and auricula by means of MRI examinations.

2. Materials and Methods

2.1. Objectives

As a primary objective, we examined the anatomical relationship between the most-posterior-part-of-the-auricula (MPPA) and the transverse-sigmoid-sinus-transition (TSST), to examine whether or not the auricula can be used as a suitable and reliable anatomical landmark

* Corresponding author.
E-mail address: senne.broekx@gmail.com (S. Broekx).

https://doi.org/10.1016/j.bas.2024.102757
Received 22 July 2023; Received in revised form 29 December 2023; Accepted 21 January 2024
Available online 26 January 2024

List of used abbreviations

AP	Anteroposterior
EAM	External auditory meatus
CC	Craniocaudal
DP	Digastric point
MN	Mastoid notch
MPPA	Most posterior part of auricula
MRI	Magnetic resonance imaging
SS	Sigmoid sinus
TS	Transverse sinus
TSST	Transverse-sigmoid-sinus-transition

for identification of the TSST, as well as the posterior border of the SS, during a retrosigmoid approach. This new superficial anatomical landmark will be compared to other landmarks already described in current literature. As a secondary objective, we examined whether or not gender and left/right had a significant impact.

2.2. Data preparation, inclusion and exclusion criteria

We performed a retrospective analysis of one-hundred patients who underwent brain MRI examinations at Antwerp University Hospital (Edegem, Belgium) between November 2022 and January 2023. Data was collected from the patients' medical record files. We applied the inclusion and exclusion criteria presented in Table 1. For volumetric examinations, we used T1-weighted images after intravenous gadolinium infusion in the axial and sagittal planes, while T2-weighted imaging, T2 gradient echo, fluid-attenuated inversion recovery and diffusion-weighted sequences were used to exclude pathological conditions. All imaging sequences were obtained by a 3.0 T MRI-scanner.

After the exclusion process, corresponding MRI images were analysed using the Brainlab® workstation for all included patients (see Fig. 1). Only MRI images with the highest resolution were used. First, we calculated the MPPA coordinates for all patients, which was used as the baseline coordinate. During the MRI examination, the patient's head is secured by means of a head block, corresponding to the peroperative manual compression manoeuvre that is performed by the neurosurgeon in the determination of the skin incision. Second, we calculated the reference coordinate by depicting the position of the TSST. The TSST corresponded with the transition of the most caudal part of the TS and most posterior part of the SS. Third, by comparing the baseline and reference coordinates, the distance between both anatomical points was extracted. The distances were calculated in both the anteroposterior and craniocaudal directions for both ears.

When the reference coordinate was located more posterior or cranial with respect to the baseline coordinate, this resulted into a positive value, while a more anterior or caudal position resulted into a negative value (see Fig. 2). All MRI images were analysed separatly by two of the authors (S.B. and D.S.).

Table 1
The table depicts the exclusion criteria used during our study.

Exclusion criteria
Acromegaly
Congenital anomalies
Ear not completely visible on T1-weighted images
Fossa posterior pathology
Inflammatory diseases of the skull base/middle ear
Pediatric population
Previous skull base fractures
Tumors of the lateral face/ear region

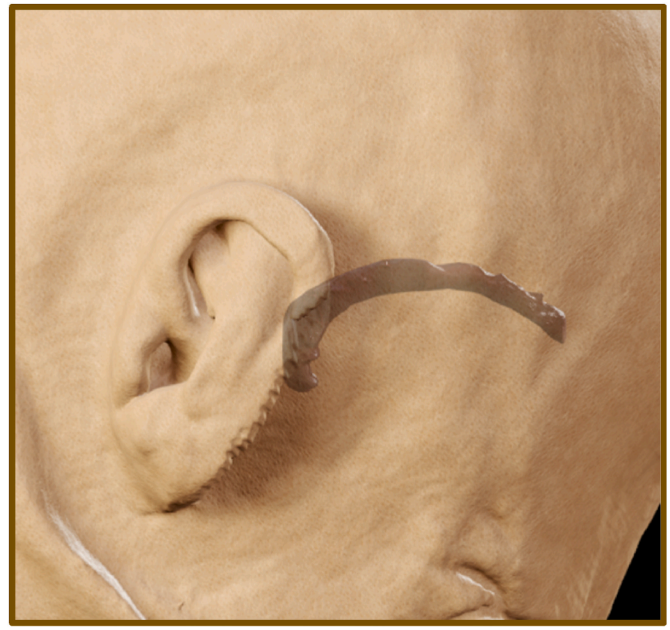

Fig. 1. Using the Brainlab® workstation, the borders of the transverse sinus, sigmoid sinus and transverse-sigmoid-sinus-transition are drawn, revealing the correlation of these venous sinus structures to the most posterior part of the auricula.

2.3. Peroperative determination of skin incision based on MPPA

In Fig. 3 we illustrate the installation of a patient in the preparation of a retrosigmoid approach. In this case, a left retrosigmoid approach was performed for a resection of a giant left vestibular schwannoma. First, the patient's head is fixed by using the Mayfield® skull clamp. The head is slightly elevated and turned to the opposite side. Second, based on the MPPA, the skin incision is drawn. The incision corresponds to the expected course of the caudal border of the TS, posterior border of the SS and the TSST. Finally, based on these skin marks, the borders of the craniotomy, as well as the course of the occipital artery and posterior auricular nerve are delineated.

2.4. Statistical analysis

We calculated descriptive statistics of patient's characteristics and distances between aforementioned coordinates. We computed 95 % confidence intervals for mean distances. We identified outliers above the 150 % of the interquartile range and calculated descriptive statistics with and without outlier. We classified distances in classes with five mm ranges in order to calculate frequencies. We compared distances between both sides with paired t-tests in the whole sample, as well as in men and in women separately. For all tests performed, we used a cut-off value of five percent, meaning that a P-value less than 0.05 was considered to be statistically significant. All statistical analyses were performed using Stata/SE 17.0.

3. Results

3.1. Patient profile

In all patients, the anatomical relationship between the MPPA and the TSST was well-depicted bilaterally on both sagittal and axial MRI images. The sample consisted of one-hundred patients (38 males and 62 females). Mean age was 56.4 ± 16.1 years. 70 % of our patients had a supratentorial pathology without influencing structures within the

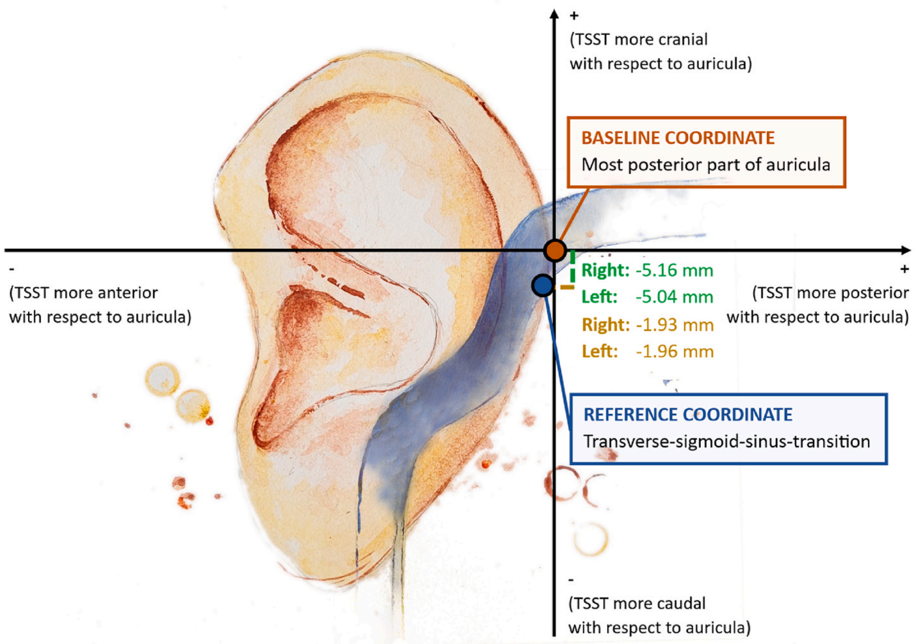

Fig. 2. The figure depicts the correlation between the baseline coordinate (most posterior part of auricula) and the reference coordinate (transverse-sigmoid-sinus-transition). When the reference coordinate was located more posterior or cranial with respect to the baseline coordinate, this resulted into a positive value, while a more anterior or caudal position resulted into a negative value. The figure also depicts the mean distances for both ears. Own illustration.

Fig. 3. Figure showing the peroperative installation of a retrosigmoid approach for the treatment of a giant left vestibular schwannoma. After fixation within the Mayfield® skull clamp, the courses of the caudal border of the TS, posterior border of the SS and the TSST are drawn. The course of the occipital artery (blue) and posterior auricular nerve (yellow) can be seen as well. Informed consent was obtained.

Table 2
The table shows the characteristics of patients included in our study.

Total patients included	100
Male/female	38/62
Age	
Mean	56 years
Median	58 years
Minimum	18 years
Maximum	91 years
Supratentorial pathology	
Yes (contusion, sphenoid meningioma etc.)	70
No	30

posterior fossa, in particular the course of the SS, TS and TSST. Patient profiles are summarized in Table 2.

3.2. Distance between MPPA and TSST

The mean distance between the MPPA and the TSST in the anteroposterior (AP) direction was −1.93 mm (median −1.5 mm) and −1.96 mm (median −1.8 mm), for the right and left ear, respectively. The mean distance between the MPPA and the TSST in the craniocaudal (CC) direction was −5.16 mm (median −5.65 mm) and −5.04 mm (median −4.95 mm), for the right and left ear, respectively (see Fig. 1 and Table 3). However, in 25 % and 22 % of patients, the TSST (and posterior border of the SS) was located 5 mm more posterior with respect to the MPPA for the right and left ear, respectively.

On the right side, 45 % of patients had a TSST located within the range of 1 cm more anterior with respect to the TSST, while in 38 % of

Table 3
Location and spread statistics of distances (n = 100). A positive index means that the TSST was located more posterior or cranial with respect to the most posterior part of the auricula. A negative index means that the TSST was located more anterior or caudal with respect to the most posterior part of the auricula. CI = confidence interval | SD = standard deviation | IQR = interquartile range.

Variables	Mean [95 % CI] ± SD (in mm)	Median (in mm)	IQR (in mm)	Range (in mm)
Right ear distance X-axis	−1.93 [-3.42; −0.43] ± 7.53	−1.50	[-6.90; 3.10]	[-20.70; 17.10]
Left ear distance X-axis	−1.96 [-3.49; −0.43] ± 7.72	−1.80	[-7.55; 3.00]	[-17.70; 15.70]
Right ear distance, Y-axis	−5.16 [-6.95; −3.37] ± 9.01	−5.65	[-12.05; 0.40]	[-24.70; 17.00]
Left ear distance Y-axis	−5.04 [-6.74; −3.34] ± 8.56	−4.95	[-11.05; −0.10]	[-26.60; 19.30]

patients the TSST was located within the range of 1 cm more posterior to the MPPA. In contrast, on the left side, the TSST was located within the range of 1 cm more anterior with respect to the MPPA in 41 % of cases, while in 37 % of cases it was situated within the range of 1 cm more posterior. In half of cases, the TSST was located within the range of ±5 mm with respect to the right MPPA, while in 46 % of cases, the TSST was located within the range of ±5 mm with respect to the left MPPA. In contrast, the frequencies of distances in the CC direction showed more variation (see Table 4).

There was one outlier for the left ear distance in the CC direction with a value of 19.30. Without the outlier, the mean left ear distance in the CC direction would be −5.29 mm [−6.93; −3.65] ± 8.24, the median would be −5.00 mm, the IQR [−11.70; −0.10] and the full range [−26.6; 13.2]. Results are summarized in Tables 3 and 4.

3.3. Comparison of distance between MPPA and TSST between both genders

There was no significant difference between MPPA-TSST-distances on the right and left side, both in the AP and CC directions. Furthermore, there were no significant differences when analyzing the distances for genders separately.

There seems to be a trend showing that the MPPA is a more reliable predictor for the location of the TSST in women (both in the AP and CC direction), although there were no significant differences between both genders.

In the general population, the location of the TSST is more accurately determined in the AP direction on the right side, while its location is more accurately determined in the CC direction on the left side. The left side showed more reliable distances in the AP and CC directions in men.

Table 4
Frequencies of distances (n = 100). A positive index means that the TSST was located more posterior or cranial with respect to the most posterior part of the auricula. A negative index means that the TSST was located more anterior or caudal with respect to the most posterior part of the auricula.

Distance (in mm)	Anteroposterior		Craniocaudal	
	Right	Left	Right	Left
−30.00 to −25.01	0	0	0	1
−25.00 to −20.01	2	0	2	3
−20.00 to −15.01	3	3	11	9
−15.00 to −10.01	7	15	18	14
−10.00 to -5.01	**20**	**17**	**22**	**21**
−5.00 to -0.01	**25**	**24**	**19**	**28**
0.00 to 4.99	**25**	**22**	**14**	**12**
5.00 to 9.99	**13**	**15**	**7**	**7**
10.00 to 14.99	4	5	5	4
15.00 to 19.99	1	2	2	1

Table 5
Comparison of distances between both sides. A positive index means that the TSST was located more posterior or cranial with respect to the most posterior part of the auricula. A negative index means that the TSST was located more anterior or caudal with respect to the most posterior part of the auricula. CI = confidence interval | SD = standard deviation.

	n	Right ear distance Mean [95 % CI] ± SD (in mm)	Left ear distance Mean [95 % CI] ± SD (in mm)	Difference Mean [95 % CI] ± SD (in mm)	p-value
Anteroposterior					
Whole sample	100	−1.93 [-3.42; −0.43] ± 7.53	−1.96 [-3.49; −0.43] ± 7.72	0.03 [-1.50; 1.56] ± 7.72	0.97
Men	38	−3.71 [-6.40; 1.02] ± 8.19	−2.36 [-5.21; 0.49] ± 8.67	−1.35 [-4.29; 1.59] ± 8.95	0.36
Women	62	−0.84 [-2.60; 0.93] ± 6.93	−1.71 [-3.53; 0.10] ± 7.15	0.88 [-0.85; 2.60] ± 6.80	0.31
Craniocaudal					
Whole sample	100	−5.16 [-6.95; −3.37] ± 9.01	−5.04 [-6.74; −3.34] ± 8.56	−0.12 [-1.75; 1.52] ± 8.23	0.89
Men	38	−6.37 [-9.37; −3.37] ± 9.13	−6.14 [-9.48; −2.80] ± 10.16	−0.23 [-3.43; 2.96] ± 9.72	0.88
Women	62	−4.42 [-6.68; −2.15] ± 8.92	−4.37 [-6.25; −2.49] ± 7.41	−0.05 [-1.89; 1.80] ± 7.26	0.96

In contrast, the distances between the MPPA and TSST were more reliable in the AP direction on the right side in women, while more reliable in the CC direction on the left side. These results were not significant, however. Results are summarized in Table 5.

4. Discussion

4.1. Sigmoid sinus

The SS is a paired S-formed dural sinus located between the endosteum of the occipital bone and dura. It originates at the superior border of the petrous bone and ending of the tentorium cerebelli, where the TS and superior petrosal venous sinuses join (Sarmiento et al., 2004). From this point, it changes direction in the vertical plane towards the medial portion of the mastoid cavity, terminating at the jugular foramen where it continues into the jugular bulb of the internal jugular vein (Sarmiento et al., 2004).

The location of the SS is highly variable and anatomical variations are well known (Sarmiento et al., 2004). Since the right TS is usally larger and receives the majority of the drainage from the superior sagittal sinus, it is stated that the right SS contains blood from the superficial parts of the brain (Kili et al., 2008). The left SS mainly contains blood from the deeper parts of the brain drained by the internal cerebral, basal and great veins (Kili et al., 2008). Furthermore, the SS receives venous blood from the cavernous sinuses through the superior and inferior petrosal sinuses (Kili et al., 2008). Along its course, it receives variable tributaries from the mastoid emissary veins, condylar emissary vein, the venous plexus of the hypoglossal canal, inferior cerebellar veins and small vessels from the pons and medulla oblongata (Kili et al., 2008).

4.2. Anatomical landmarks

To our knowledge, there is no study exploring the anatomical relationship between the MPPA and the TSST/posterior border of the SS by means of MRI examinations. Posterolateral skull base approaches around the SS are frequently used for middle and posterior fossa pathologies, such as the retrosigmoid approach for lesions in the cerebellopontine angle (Hoz et al., 2022; Raso et al., 2011). Accurately localizing the anterosuperior and inferomedial points of the TSST, as well as the course of the SS, on the external surface of the cranium is important in lateral skull base craniotomies (Li et al., 2020; Day et al., 1996). An abberant course of the SS forms a risk factor for unexpected bleeding during surgery (Tsutsumi et al., 2020). Anatomical landmarks help improve patient safety and outcome during surgery, while minimizing extensive bony defects (Hoz et al., 2022; Li et al., 2020; Day et al., 1996). Although navigation is routinely used, the consequences of errors or navigation failure can not be underestimated (Hoz et al., 2022). However, the use of navigated mixed-reality can help in the peroperative visualization of intraosseous structures (such as venous sinuses) through the neurosurgeon's oculars. Therefore, anatomical landmarks should always be used as an adjunct to neuronavigation rather than a replacement, since interindividual anatomical variability is common (Hoz et al., 2022).

Cerebral digital subtraction angiography studies have already reported a SS asymmetry in 51 % of cases, while there was a right dominance or right exclusiveness in 36 % of cases (Raso et al., 2011). In most individuals, the right SS is wider compared to the left side (Raso et al., 2011). Cadaveric studies have also shown significant differences between craniometric measures on the right and left sides (Raso et al., 2011). This phenomenon can also be extracted from our results, in which the posterior border of the SS was closer to the MPPA on the right side, leading to a smaller MPPA-TSST-distance in the AP direction (not significant).

Although the localization of the anterior border of the SS is extensively studied in current literature, there is a paucity of superficial anatomical landmarks for localization of the posterior border of the SS (Hoz et al., 2022). These reference points can be grossly devided into landmarks for the upper limit and lower limit of the SS (Raso et al., 2011).

Tsutsumi et al. explored the relationship between the external auditory meatus (EAM) and the anterior border of the SS using thin-sliced contrast MRI (Tsutsumi et al., 2020). They divided their patients into three categories: superior type (anterior edge of SS located above the upper margin of the EAM), intervening type (anterior edge of SS between the upper and lower margins of EAM) and inferior type (anterior edge of SS located below the inferior margin of EAM). The superior type was seen in 12 % and 9 % of cases on the right and left side, respectively. The inferior type was encountered in 85 % and 86 % of cases on the right and left side, respectively, while the intervening type was observed in 4 % and 5 % of cases on the right and left side, respectively (Tsutsumi et al., 2020). In general, the intervening type was most frequently observed, accounting for up to 85 % of cases, followed by the superior (11 %) and inferior (4 %) types (Tsutsumi et al., 2020). The authors concluded that the shortest distance between the posterior wall of the EAM and anterior margin of SS was highly variable and measured 12.3 ± 3.9 mm (mean $\pm$ SD) on the right side (range 2.2–21.4 mm) and 13.0 ± 2.9 mm on the left side (range 5.9–20.5 mm) (Tsutsumi et al., 2020). Moreover, in two percent of cases, the distance was less than five mm (three out of 170 examinations), all on the right side (Tsutsumi et al., 2020). This is in line with our results, in which the MPPA-TSST-distance was shorter in the AP direction on the right side, which may correlate with the suggested right SS dominance. Based on their retrospective analysis of eightyfive patients, the authors concluded that the distance between the posterior wall of the EAM and the anterior border of the SS was highly variable and inconsistent due to an inconsistent shape of the EAM and left-right asymmetry (Tsutsumi et al., 2020). Although we also did encounter some variability, there were no significant differences between both sides according to our results.

Hoz et al. examined the crux of the helix curvature (an internal fold of the pinna above the EAM, formed by underlying cartilage) as an anatomical landmark for the anterior border of the SS (Hoz et al., 2022). In this human cadaveric study, a presigmoid mastoidectomy was performed on five cadaveric heads exploring left and right sides (ten samples in total) (Hoz et al., 2022). The authors performed a straight incision over the retroauricular sulcus along the anterior edge of the mastoid process, which is the posterior extension of the crux of the helix (Hoz et al., 2022). In 60 % of samples, the crux of the helix curvature was superimposed on the anterior border of the SS, while in 40 % of samples, the curvate was situated within five mm of the anterior border (Hoz et al., 2022). Since only ten samples were examined, these results should be validated on a larger patient cohort.

Other possible landmarks for the anterosuperior point of the TSST are the squamosal-parietomastoid suture junction or the insertion of the supramastoid crest with the squamosal suture (Li et al., 2020). The asterion, the junction of the parietomastoid, lambdoid and occipitomastoid sutures, can be used as a reference point for the inferomedial point of the TSST (Li et al., 2020). The peroperative recognition of the asterion can be difficult, since the sutures are frequently covered by soft tissues (Li et al., 2020). Therefore, Li et al. explored the mastoid notch (MN) as a deep surgical landmark for the TSST (Li et al., 2020). The MN is a groove on the medial aspect of the mastoid process (Li et al., 2020). In this cadaveric study, forty-three samples were analysed on both sides (eighty-six samples in total). The anterosuperior point of the TSST was located 1.92 mm anterior and 27 mm superior to the top of the mastoid notch in both males and females, independent of skull side. The inferomedial point was located at a mean of 3.6 mm (males) and 7.84 mm (females) posterior and 14.4 mm (males) and 19.7 mm (females) superior to the top of the MN (Li et al., 2020).

Sarmiento et al. stated that the course of the SS within the mastoid cavity is highly inconsistent (Sarmiento et al., 2004). The distance between the SS and the mastoid cortex is highly variable due to the variable space occupied by the mastoid air cells (Sarmiento et al., 2004). Therefore, the degree of mastoid pneumatization and mastoid length could have a significant impact on SS course (Sarmiento et al., 2004). The authors state that the SS is the only anatomical structure that is not subject to modification by pathological processes in the mastoid cavity, such as osteoma or cholesteatoma (Sarmiento et al., 2004).

Day et al. performed an anatomical study based on fifteen cadaveric preparations (thirthy sides measured) for usage in posterolateral cranial base approaches (Day et al., 1996). They conclude that a line drawn from the zygoma-root to the external protuberance/superior nuchal line can reliably locate the rostrocaudal aspect of the TS (Day et al., 1996). Moreover, a line between the squamosal-parietomastoid suture junction and the mastoid tip defined the axis of the SS through the mastoid (Day et al., 1996). They also concluded that the junction of the squamosal and parietomastoid sutures projected over the anterior border of the upper curve of the SS (Day et al., 1996).

Finally, Raso et al. examined the digastric point (DP) as a surgical landmark for identifying the anterior border of the SS (Raso et al., 2011). The DP is defined as the point immediately above the posterior belly of the digastric muscle, which completely fills the MN (Raso et al., 2011). Therefore, the DP is located at the top of the MN in the mastoid portion of the temporal bone (Raso et al., 2011). In this cadaveric study, 127 samples (254 sides) were analysed (Raso et al., 2011). There was a significant difference in distance between the DP and the SS in both genders (Raso et al., 2011). In males, there was a significant difference in distance between both sides (Raso et al., 2011). The DP–SS–distance was smaller on the right side in both genders (mean 2.78 mm, SD 3.01 mm), which is in line with the results of our study (Raso et al., 2011). The DP was located onto the SS (DP–SS–distance 0 mm) in 49.6 % and 29.9 % of samples on the right and left side, respectively (Raso et al., 2011). The mean DP–SS–distance was 3.1 mm regardless of side and gender, while 3.45 mm and 2.23 mm in males and females, respectively (Raso et al., 2011).

In contrast to other studies which focused on the anterior border of the SS, we defined an anatomical landmark that is located posterior to the SS. Therefore, this landmark was used to calculate distances with respect to the posterior border of the SS. On average, the TSST was located more anterior and caudal with respect to the MPPA, meaning that the MPPA can be seen as a save superficial landmark for delineating the posterior border of the SS. However, a small correction of five mm needs to be applied in order to identify the caudal border of the TS.

Moreover, the MPPA seems to be a more reliable marker for the AP direction of the TSST compared to the CC direction. These results can be explained by the fact that, due to the morphology of the auricula, the CC coordinates of the MPPA show more interobserver variations with respect to the coordinates in the AP direction.

5. Limitations

There are some limitations that need to be addressed. First, surface landmarks are generally considered less accurate compared to bony anatomical landmarks. However, we still believe the auricula provides additional information for the neurosurgeon for diverse reasons. As with other superficial landmarks, it provides the surgeon with an instant estimation of the location of the TSST, aiding in choosing the location and length of the skin incision, without affecting the operative fluency and even shorten operative time, especially during an emergency craniotomy when neuronavigation is not available (Hoz et al., 2022). While other landmarks (EAM, MN etc.) are located more anterior with respect to the SS, the auricula is located more posterior. This offers benefits during a retrosigmoid craniotomy in which the SS is approached from a posterior direction. This landmark can be combined with other deep anatomical landmarks, such as the asterion and DP.

Second, we encountered some interindividual variability in the relationship between the MPPA and the TSST. Image-guided surgical planning and neuronavigation can overcome extreme individual variations, although these examinations are more expensive and time-consuming (Li et al., 2020). Anatomical landmarks should always be used as an adjunct to neuronavigation rather than be considered a replacement.

Third, one could argue that the position of the auricula during surgery differs from the position during the MRI examination. However, since the patient's head is secured by means of a head block during the MRI examination, the position of the auricula corresponds to the peroperative manual compression manoeuvre that is performed by the neurosurgeon in the determination of the skin incision.

Fourth, since modern neurosurgery (augmented reality and virtual reality for surgery planning) includes obligatory usage of neuronavigation, some could argue that anatomical surface landmarks are not usefull anymore. However, as mentioned above, we believe that these surface landmarks should be seen as an addition to neuronavigation and therefore improve a more intraoperative security, in particular when equipment is not available, such as during an emergency craniotomy.

Finally, although the study population is rather limited, the number of patients included in our study is more extensive compared to similar cadaveric or imaging-based studies in current literature. However, study results should be interpreted with caution due to the limited number of included individuals.

6. Conclusions

The location of the sigmoid sinus is highly variable and anatomical variations are well known. Accurately localizing the course of the posterior border of the sigmoid sinus and transverse-sigmoid-sinus-transition is important in order to prevent unexpected bleeding during a retrosigmoid craniotomy. Although the localization of the anterior border of the sigmoid sinus is extensively described in current literature, there is a paucity of landmarks for the identification of the posterior border.

Based on our results, the transverse-sigmoid-sinus-transition is located more anterior and caudal with respect to the most-posterior-part-of-the-auricula, meaning that this landmark can be seen as a save superficial landmark. The most-posterior-part-of-the-auricula seems to be a more reliable marker for the anteroposterior direction of the transverse-sigmoid-sinus-transition compared to the craniocaudal direction. Therefore, a correction of five mm needs to be applied in order to identify the inferior border of the transverse sinus. Gender and left/right had no significant impact. Our patient population of one-hundred individuals forces us to make rather humble conclusions.

To our knowledge, there is no study exploring the anatomical relationship between the most-posterior-part-of-the-auricula and the transverse-sigmoid-sinus-transition. Anatomical landmarks should always be used as an adjunct to neuronavigation rather than to be considered a replacement, nevertheless can be extremely helpful in emergency situations when neuronavigation is not available. The most-posterior-part-of-the-auricula can be seen as a fast and practical superficial anatomical landmark for identification of the transverse-sigmoid-sinus-transition, without affecting operative fluency.

Ethical approval

For this type of study formal consent is not required.

Informed consent

Additional informed consent was obtained from all individual participants for whom identifying information is included in this article.

Submission declaration

The authors confirm that this manuscript is original and has not been published previously nor is under consideration.

Consent to participate

Consent to participate was obtained from all individual participants for whom identifying information is included in this article.

Consent for publication

Consent for publication was obtained from all individual participants for whom identifying information is included in this article.

Code availability

We used the Brainlab® workstation for this review. All statistical analyses were performed using Stata/SE 17.0.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors Constribution

Broekx Senne: conceptualization, methodology, validation, investigation, original draft, review & editing, critical revision, visualization, project administration. **Dylan Thomas Stevesyns**: conceptualization, methodology, critical revision. **Menovsky Tomas**: conceptualization, validation, resources, critical revision, supervision.

Declaration of competing interest

None.

Acknowledgements

We would like to thank Jason Bouziotis for his support with the statistical analyses.

References

Day, J.D., et al., 1996. Surface and superficial surgical anatomy of the posterolateral cranial base: significance for surgical planning and approach. Neurosurgery 38 (6), 1079–1083. ; discussion 1083-4.

Hoz, S.S., et al., 2022. The crux of helix curvature: a potential surface landmark for the anterior border of the sigmoid sinus in minimally invasive presigmoid approaches. Surg. Neurol. Int. 13, 430.

Kili, T., Akakin, A., 2008. Anatomy of cerebral veins and sinuses. Front Neurol Neurosci 23, 4–15.

Li, R., et al., 2020. Mastoid notch as a landmark for localization of the transverse-sigmoid sinus junction. BMC Neurol. 20 (1), 111.

Raso, J.L., Gusmão, S.N., 2011. A new landmark for finding the sigmoid sinus in suboccipital craniotomies. Neurosurgery 68 (1 Suppl. Operative), 1–6. ; discussion 6.

Sarmiento, P.B., Eslait, F.G., 2004. Surgical classification of variations in the anatomy of the sigmoid sinus. Otolaryngol. Head Neck Surg. 131 (3), 192–199.

Tsutsumi, S., Ono, H., Ishii, H., 2020. Positional relationship between the external acoustic meatus and sigmoid sinus: an MRI study. Surg. Radiol. Anat. 42 (7), 791–795.