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# Application of Surface Landmarks Combined with Image-Guided Sinus Location in the Retrosigmoid Approach and Their Clinic-Image Relationship Analysis

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## Abstract

**Objectives** During craniotomy for cerebellopontine angle (CPA) lesions, the exact exposure of the margin of the venous sinuses complex remains an essential but risky part of the procedure. Here, we revealed the exact position of the asterion and sinus complex by combining preoperative image information and intraoperative cranial landmarks, and analyzed their clinic-image relationship.

**Methods** Ninety-four patients who underwent removal of vestibular schwannoma (VS) through retrosigmoid craniotomies were enrolled in the series. To determine the exact location of the sigmoid sinus and the transverse sinus and sigmoid sinus junction (TSSJ), we used preoperative images, such as computed tomography (CT) and/or magnetic resonance imaging (MRI) combined with intraoperative anatomical landmarks. The distance between the asterion and the sigmoid sinus was measured using MRI T1 sequences with gadolinium and/or the CT bone window.

**Keywords**
- retrosigmoid approach
- sinus localization
- image
- surface landmarks

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**Results** In 94 cases of retrosigmoid craniotomies, the asterion lay an average of 12.71 mm on the posterior to the body surface projection to the TSSJ. Intraoperative cranial surface landmarks were used in combination with preoperative image information to identify the distance from the asterion to the sigmoid sinus at the transverse sinus level, allowing for an appropriate initial burr hole (the margin of the TSSJ).

**Conclusion** By combining intraoperative anatomical landmarks and preoperative image information, the margin of the TSSJ, in particular, the inferior margin of the transverse sinus, can be well and thoroughly identified in the retrosigmoid approach.

## Introduction

The retrosigmoid approach is one of the most common approaches for CPA surgery.[1] Exposure of the sigmoid sinus and transverse sinus and sigmoid sinus junction (TSSJ) remains crucial but risky neurosurgical procedure.[2,3] Moreover, in most cases, individual variation between the asterion and TSSJ exists.[4] Therefore, using the traditional fixed distance to determine the positional relationship between the asterion and the TSSJ is inaccurate. As a result, exposing the venous sinuses before the TSSJ allows the exact localization of the burr hole over the margin of TSSJ to be determined, avoiding the need for a hazardous step into the venous sinuses and extensive bone removal.

The connection point of the sutura parietomastoidea, sutura occipitomastoidea, and sutura lambdoidea is defined as the asterion, an important cranial external landmark in the retrosigmoid approach. The projection of the transverse sinus (TS) roughly overlaps with the asterion; therefore, an imaginary beeline from the asterion to the TSSJ can be considered as the body surface reflection of the posterior margin of the TSSJ. Because of the strong anatomical association, we believe that it is vital to measure the distance between the asterion and the TSSJ margin, despite the variability among patients.

The use of the preoperative image as an orientation method for craniotomies in the retrosigmoid approach aids in the proper drilling of the burr hole. To avoid inadvertent entry into the sinus, an overly large craniotomy, and excessive bone removal, an exact intraoperative location of the surface projection of TSSJ are necessary. Hence, in this image-guided prospective anatomical study, we analyzed 94 cases of retrosigmoid craniotomies in an attempt to reveal the exact position relationship between the asterion and the TSSJ through measuring their distance using a preoperative image system. Meanwhile, the relationship between the external landmarks and the TSSJ during the following surgery was also investigated to confirm the accuracy of the preoperative image measurement.

## Materials and Methods

### Preoperative Image Preparation and Measurement

From February 2008 to November 2019, 94 patients (38 males and 56 females) who underwent removal of vestibular schwannoma (VS) through retrosigmoid craniotomies were included in our series. Male patients had a mean age of $46.26 \pm 14.60$ years, while female patients had a mean age of $47.96 \pm 11.84$ years. The 94 cases contained 188 sides. On each side, the lambdoid suture, parietomastoid suture, asterion, inion, occipital mastoid suture, posterior zygoma root, and mastoid process were identified. Thin-slice, 1-mm thick CT, and enhanced CT venography were performed and reconstructed by a neuroimaging specialist to establish the individual procedure of exposure to sinuses. Once formed, the three-dimensional (3D) structure of the sinuses could be manipulated and visualized in a 3D viewing window. Only the ipsilateral 3D skull with lesions was kept following the use of basic cutting and cropping tools on the anatomical structures of interest. The visualization method displayed the 3D reconstructed transverse and sigmoid sinuses and their projection on the ipsilateral 3D skull, as well as the precise spatial position relation between the asterion and sigmoid sinus (►**Fig. 1A**). Following the identification of key structures, the distance of the asterion to the surface projection of the posterior edge of sulci was measured for transverse and sigmoid sinuses on the outer surface. The red line represents the distance between the TSSJ and the occipitomastoid suture (►**Fig. 1B**).

### Intraoperative Exposure of Key Structures

During the craniotomy procedure, a linear skin incision almost parallel to the venous sinuses was designed, and was approximately 7 cm in length. After removing the soft tissue in bone sutures, saline gauze was used in the operative field make the bone sutures and the asterion clear and easily discriminated. The umbriferous position of the TSSJ was highlighted on the basis of preoperative image-guided individualized anatomical localization information and intraoperative skull surface landmarks. The asterion and the body surface projection of the posterior edge of the TSSJ were then ascertained as landmarks for determining the burr hole point. Next, the shortest distance between the asterion and the digastric point (projective TSSJ) was calculated (in mm). To avoid undesired sinus exposure, the burr hole was placed medially and inferiorly near the projection spot of the TSSJ (►**Fig. 1C**). After elevating the bone flap, the real position of the medial and the inferior margin of the TSSJ, along with the sigmoid sinus and TS, could be limpidly recognized (►**Fig. 1D**).

 

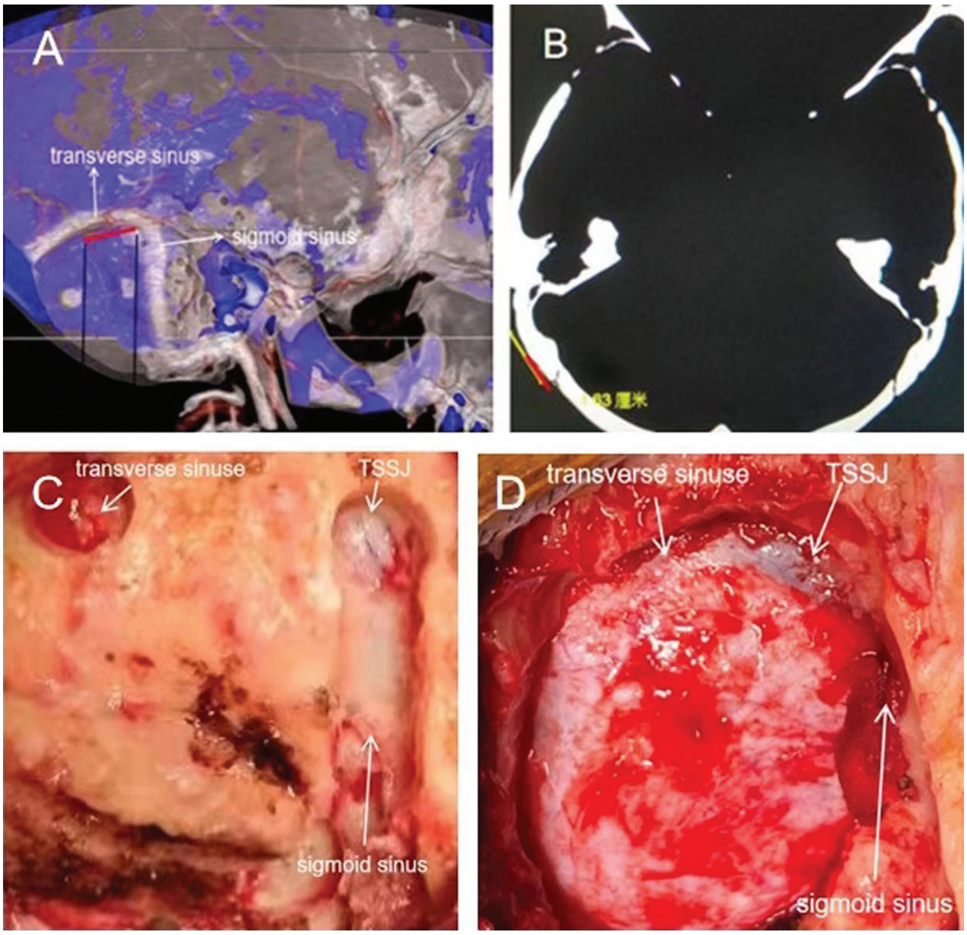


**Fig. 1** Three-dimensional reconstructed transverse and sigmoid sinuses and their projection on the skull (*right*). The red line is defined as the distance from the asterion to the body surface projection of the posteroinferior edge of the sulci for transverse and sigmoid sinuses on the inner surface (**A**). The red line indicates the shortest distance from the occipital mastoid suture to the posterior margin of the sigmoid sinus groove on the bone window of craniocerebral CT (**B**). Intraoperative photo showing that the burr hole exactly exposes the margin of the TSSJ and the sigmoid sinus (**C**). Intraoperative photo indicates the exposed margin of the TSSJ, sigmoid sinus, and transverse sinus (**D**).

### Statistical Analysis

Continuous variables are indicated as the mean ± standard deviation, and categorical variables are shown as counts and percentages. We applied the independent-samples *t*-test to compare the differences in the distance relationships between the sexes and the sides. The linear link between distance and age was investigated using a scatter plot and the Pearson product–moment correlation coefficient. A two-tailed $p$-value $<0.05$ was deemed statistically significant. IBM SPSS Statistics Version 20 was employed to perform all statistical analyses.

## Results

Preoperatively, 38 of the 94 patients diagnosed with VS were male, and 56 were female. When comparing male and female patients, the mean age of the male patients was 46.26 ± 14.60 years, while the average age of female patients was 47.96 ± 11.84 years. There was no significant difference between the ages of male and female patients ($p = 0.536$), excluding the impact of age on the distance between the TSSJ and the asterion (occipitomastoid suture). In male patients, the distance from the TSSJ to the asterion was 12.55 ± 5.26 mm, while in female patients, the distance was 12.82 ± 4.68 mm (►**Fig. 2**). The difference in the distance from the TSSJ to the asterion among males and females was not statistically significant ($p = 0.794$), illustrating that the distance between TSSJ and occipitomastoid suture may not be related to sex (►**Fig. 3**).

We analyzed the preoperative image data from 94 patients. There were 188 sides found in the investigation of bilateral sides. The measurement of the distance from the asterion to the posterior edge of the TSSJ on the preoperative CT or MRI was performed using the imaging system, and relationships between the surface landmarks and the TSSJ were analyzed in accordance with the image measurement during surgery. The distance from the asterion to the TSSJ varied among patients. The projection of the TS roughly overlapped with the asterion. On the preoperative image, the beeline from the asterion to the surface reflection of the posterior margin of the TSSJ was measured. There were 44 and 50 cases of tumors on the left and right side among the patients, respectively. Surprisingly, we found a substantial difference between the left and right sides regarding the distance from the TSSJ to the asterion ($p = 0.006$)

 

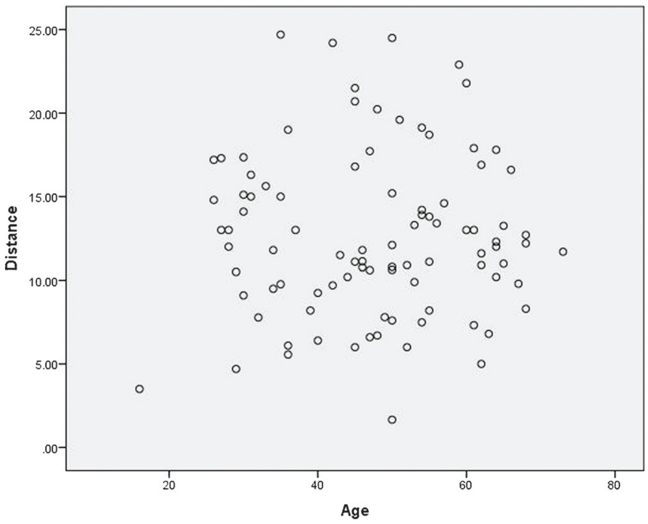


**Fig. 2** Scatter plot showing age in relation to the distance between the TSSJ and the asterion on 3D CT bone images. The vertical axis is a line connecting the asterion and the margin of the TSSJ, and the lateral axis is age. 3D, three dimensional; CT, computed tomography; TSSJ, transverse sinus and sigmoid sinus junction.

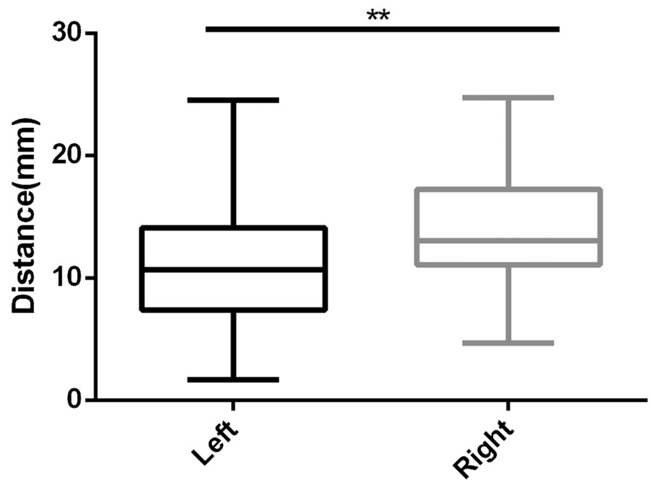


**Fig. 4** Box diagram illustrating that a significant difference exists between the left and right sides regarding the distance from the TSSJ to the occipitomastoid suture. TSSJ, transverse sinus and sigmoid sinus junction.

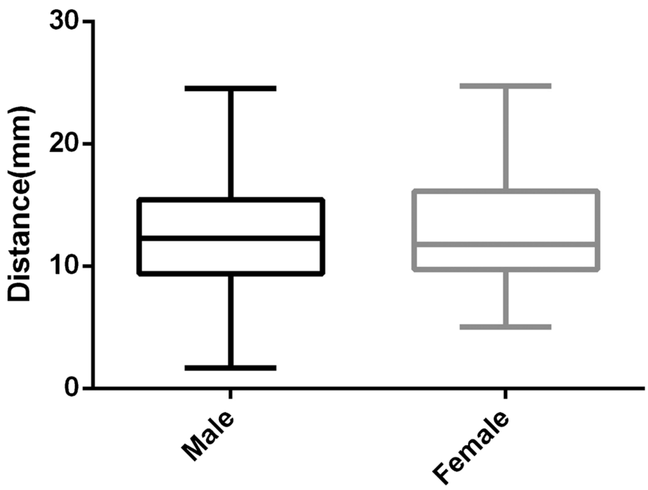


**Fig. 3** Box diagram illustrating that the distance between TSSJ and occipitomastoid suture does not significantly differ between sexes. TSSJ, transverse sinus and sigmoid sinus junction.

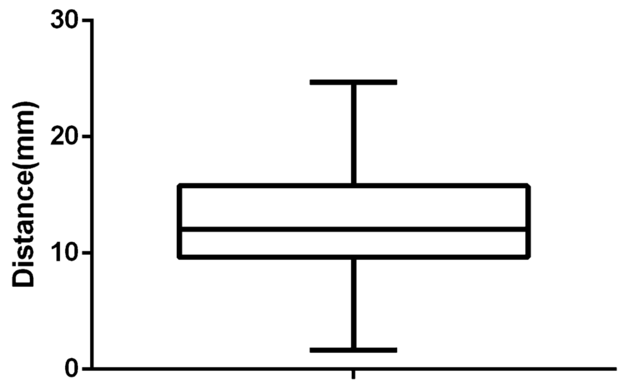


**Fig. 5** Box diagram illustrating the distance between the TSSJ and the occipitomastoid suture in our series. TSSJ, transverse sinus and sigmoid sinus junction.

(►**Fig. 4**). The TSSJ was 11.24 ± 5.14 mm anterior to the occipitomastoid suture on the left side, while the TSSJ was anterior to the asterion on the right side at a distance of 14.00 ± 4.32 mm. In our series, the location of the TSSJ was anterior to the asterion in all cases, with a distance of 12.71 ± 4.90 mm (►**Fig. 5**). The real margin of the TSSJ was clearly perceptible following the drilling of digastric point in each case. No patient experienced uncontrolled sinus bleeding. ►**Fig. 1D** depicts a desired duplication between the reckoned burr hole and the actual burr hole. After early surgery, a second CT of the skull base revealed that the burr hole was exactly on the margin of TSSJ and that the narrow bone defect only existed along the sigmoid sinus (►**Fig. 1D**); thus, the anatomical reconstruction is easily available. Patients were unable to touch appreciable bone defects in the operative area.

A scatter plot was used to assess whether there was a linear correlation between the distance and age. The results showed a correlation coefficient of –0.003, indicating that the distance between the TSSJ and occipitomastoid suture is unrelated to age (►**Fig. 2**). Preoperative images determining the distance from the asterion to the sigmoid sinus at the TS level enabled the intraoperative location of the TSSJ to be determined in all 94 cases, with an accuracy defect of <2 mm. Only one case had a laceration of the sigmoid sinus during craniotomy.

## Discussion

The retrosigmoid craniotomy is widely adopted to gain access to the CPA area. Nevertheless, relying on superficial anatomical landmarks alone might make detecting the accurate location of venous sinuses difficult, resulting in hazardous and/or complicated surgical access.[5–7] The exact localization of venous sinuses, particularly the TSSJ is critical to reduce the risk of venous sinus injury in such procedures and is available through osteal landmarks combined with the preoperative image-guided sinus localization approach. In our clinical practice, we confirmed that the approach employing preoperative image information with intraoperative skull anatomical landmarks is both accurate and practical for determining the TSSJ and establishing the association between the location of the asterion and TSSJ in retrosigmoid craniotomy.

With the least amount of risk, a burr hole medial to the TSSJ can reveal the margin of the TSSJ. However, until now, no recognized initial burr hole has been recommended.[8] The majority of previous studies have investigated how to achieve the correct orientation before drilling the key hole for retrosigmoid craniotomy.[9–11] Classically, neurosurgeons intend to use the asterion to determine the surface projection of TSSJ to place the initial burr hole; however, an increasing number of studies have reported that the asterion is an unreliable landmark.[12–14] To precisely expose the inferior edge of the transverse (superiorly) and the posterior margin of the sigmoid sinuses (inferiorly), an optimal initial burr hole is in proximity to the margin of the TSSJ, allowing exposure without damage.

In this study, the asterion was found to lie immediately over the inferior margin of the TS in 97.87% of cases, highlighting that the distance from the intersection of the asterion and occipitomastoid suture to the TSSJ is the shortest between the occipitomastoid suture and the sigmoid sinus. The posterior margin of the sigmoid sinus can be determined using the posterior border of the mastoid process.[15] In the retrosigmoid method, the illumination of mastoid air cells correlates well with the sigmoid sinus.[16] However, in clinical practice, we discovered that these methods do not accurately reflect the exact position of the sigmoid sinus and that the number of mastoid air cells varies greatly between patients.

In retrosigmoid craniotomy, neurosurgeons are frequently dependent on surface landmarks and their experience to assess the position of venous sinuses and estimate appropriately an initial burr hole, which is inaccurate due to the variability between patients. Many neurosurgeons have developed their own methods for locating the sigmoid sinus. Indeed, in a previous study, the $x$ and $y$ coordinates of the anterosuperior point of transverse-sigmoid sinus junction and the squamosal-parieto mastoid suture junction were measured to define a rectangular coordinate system.[11] Nonetheless, the measurement is based on skull samples rather than patients, which could lead to some measurement bias. The sample size of this previous study was also too small to apply this strategy in a clinical setting. The authors located the TSSJ based on 3D-CT in retrosigmoid craniotomy, although 3D-CT images are not available in all hospitals, and have limited accuracy.[17] In our present study, we introduce a simplified procedure based on MRI and CT to localize the TSSJ in retrosigmoid craniotomy, as well as the location of the sigmoid sinus. In 94 patients who underwent retrosigmoid craniotomy, the internal view of the skull in MRI, the distance between TSSJ and the intersection of the asterion, and the occipitomastoid suture were measured. A red line designated on the outer surface of the cranium, as seen in ►**Fig. 1B**, reflects this distance. This simple method may assist in the localization of the sigmoid sinus and TSSJ, preventing the risk of sinus injury and minimizing bone defects. Because this method does not require the establishment of a coordinate system, it is convenient but sufficiently precise for practical application in surgical planning.

We have shown that the distance between the TSSJ and the occipitomastoid suture is unrelated to age or sex, which pushes our work to a more universal level and makes it simpler to apply to most patients. Traditional reliance on the asterion for the margin of the TSSJ is unreliable because of the anatomical heterogeneity across cases. For clinical practice, individual anatomical information from preoperative imaging data are required for different patients. CT scan, specifically the bone window, is superior to MRI for studying bone features, but the T1WI MRI sequence was clearer in indicating the transverse and sigmoid sinuses, which were beneficial in determining the distance from the intersection of the asterion and occipitomastoid suture to the TSSJ.[11,15] In our series, the distance data from the asterion to the margin of the TSSJ on the base of CT scan images combined with MRI images can be acquired preoperatively. Based on this information, together with intraoperative osseous anatomical landmarks, the location of the burr hole on the cranium surface could be identified and corresponds to the projection of the margin of the TSSJ.

As the surface landmark in the literature for identifying the transverse TSSJ junction is unreliable, we refined this localization method with the greatest sample size to date. These data will assist neurosurgeons in localizing the preoperative projection and intraoperative location of the TSSJ when the surface landmark is not exact. The relationships between the external landmarks and the venous sinuses have been studied, and the results have shown variability in anatomical positions. Knowing where the venous sinuses are located avoids inadvertent intrusion into the venous sinuses and limits the size of the bony opening.

Interestingly, a substantial difference was observed between the left and right sides regarding the distance from the occipitomastoid suture to TSSJ ($p = 0.006$) in our series. On average, the distance on the right side was longer than on the left side at a distance of 2.76 mm. This might be due to the different sizes of the TS between the left and right sides, as Hwang et al found, the sizes of the right and left TS were variable, and the right TS was more often larger than the left TS.[18] Because the tumor is on opposite sides, neurosurgeons may be guided to pay attention to such a disparity during craniotomy. Ribas et al measured 50 sinuses from 25 dried skulls, and showed that TSSJ occurred approximately 1 cm in front of the asterion, which is consistent with our findings.[17] Anatomical landmarks complemented with preoperative images provide a simple and reliable means for identifying the TSSJ position for retrosigmoid craniotomy. This method significantly improves the speed and safety of the retrosigmoid approach, while also decreasing venous sinus injuries, demonstrating the reliability of our study in the location of TSSJ in all cases of our series.

Some authors have reported a high incidence of venous injury on the basis of image-guided retrosigmoid craniotomy alone.[2,3] This is not the case in our series, and no sigmoid sinus burst occurred. In this study, the umbriferous position of the TSSJ onto the external surface of the cranium, which was indirectly located by the preoperative image with intraoperative landmarks, can confirm the burr hole placement throughout the surgery. The asterion (occipitomastoid suture) and the TSSJ have a unique positional relationship in each subject, and the morphometric data from CT and MRI scans makes precise localization of venue structure possible in each patient.

Although neuronavigation can achieve an accurate orientation of the target area, the installation of Mayfield clamps and other preoperative and intraoperative procedures result in further damage to patients.[16] Generally, neuronavigation is considered to be invasive, time-consuming, and expensive.

## Limitations

A limitation of our study is that we only measured the distance between the TSSJ and the occipitomastoid suture in the asterion plane. The TSSJ was also found to be below the asterion plane, which is uncommon. Another limitation was that most of our patients were adults, limiting the applicability of our research to younger patients. However, the method combining preoperative image data and intraoperative anatomical landmarks eliminates the use of complicated coordinate systems and provides a simple approach for neurosurgeons to locate the TSSJ in a practical and precise manner.

## Conclusion

By combining intraoperative anatomical landmarks with preoperative image information, we discovered that the asterion lies an average of 12.71 mm posterior to the TSSJ, and directly above the inferior margin of the transverse sinus in many cases. Therefore, the distance from the intersection of the asterion and the occipitomastoid suture to the TSSJ is the shortest between the occipitomastoid suture and the sigmoid sinus. Surface landmarks together with image-guided sinus is a simple and quick procedure for localizing the transverse-sigmoid sinus complex in the retrosigmoid approach. This procedure also closely matches the anatomy of individual patients, and minimizes the risk of injury to the hidden venous sinuses, avoiding wide craniotomy and extensive bone removal.

**Conflict of Interest**
None declared.

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