Surface Landmarks for the Junction Between the Transverse and Sigmoid Sinuses: Application of the "Strategic" Burr Hole for Suboccipital Craniotomy

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Received, May 20, 2008.
Accepted, November 5, 2008.

OBJECTIVE: Localization of internal cranial anatomy based on superficial landmarks is paramount in identifying and avoiding various important structures and, thus, decreasing surgical morbidity. We have studied external skull bony landmarks to facilitate the placement of the initial "strategic" burr hole just inferior and medial to the junction of transverse-sigmoid venous sinuses during standard retrosigmoid craniotomy.

METHODS: One hundred adult skulls (200 sides) underwent intracranial drilling of a small hole from the inside surface of the cranium, 5 mm inferior and medial to the border of the transverse sigmoid sinus junction (defined as the ideal location for the center of the strategic burr hole). Localization of this hole from the external surface of the skull was made based on easily identifiable superficial landmarks, including the mastoid process and zygomatic arch. A horizontal line was established parallel to the superior border of the zygomatic arch ("zygomatic line"), and a vertical line was fashioned by connecting the mastoid notch superiorly to the squamosal suture ("mastoid line").

RESULTS: For left sides, 81% of the strategic burr holes were inferior to the zygomatic line and 86% were medial to the mastoid line. For right sides, 91% of the strategic burr holes were inferior to the zygomatic line and 97% were medial to the mastoid line. For left and right sides, the mean distance for the center of the burr holes from the zygomatic line was 4.5 and 7.7 mm, respectively. For left and right sides, the mean distance from the mastoid line was 9.1 and 9.8 mm, respectively.

CONCLUSION: Because landmark data in the literature for externally identifying the transverse sigmoid sinus junction is variable, we have attempted to refine this location with the largest sample size to date. These data can assist surgeons to localize the external cranial projection of the area just inferior and medial to the junction between the transverse and sigmoid sinuses when image guidance devices are not available. This localization is important in creation of appropriate size for craniotomy/craniectomy during the posterolateral approaches to the cranial base.

KEY WORDS: Burr hole, Landmarks, Sigmoid sinus, Suboccipital craniotomy, Transverse sinus

Neurosurgery 65[ONS Suppl 1]:ons37–ons41, 2009

DOI: 10.1227/01.NEU.0000341517.65174.63

External estimation of the intracranial venous sinuses is important to neurosurgeons. We have previously studied external superficial anatomic landmarks and their relationship to the superior sagittal and transverse sinuses (18, 19). One area that has had relatively little attention, however, is external landmarks for the region just inferior and medial to the junction between the transverse and sigmoid sinuses (5, 7, 14, 22). More specifically and germane to the neurosurgeon, is the location of the retrotransverse sigmoid junction for approaches to the posterior cranial fossa during suboccipital craniectomy/craniotomy. Accurate placement of the initial "strategic" burr hole just inferior and medial to the junction of the venous sinuses would limit venous sinus injury and resultant

ABBREVIATION: SD, standard deviation blood loss or sinus occlusion with the possible risk of venous infarction. The accurate placement of the initial burr hole would also assist with creation of an accurate and limited size craniectomy efficiently and laterally enough to decrease the risk of significant cerebellar retraction during approaches to the cerebellopontine angle. Accurate creation of the burr hole might also assist during the "keyhole" approach for microvascular decompression of the trigeminal nerve root entry zone.

Historically, the asterion has been cited and used as a superficial landmark to this juncture (12, 23). However, this osteological constellation has been refuted as a reliable landmark for this venous junction site and is often difficult to see in older adults. To provide the surgeon with more refined and reliable landmarks for identifying the transverse sigmoid sinus junction, the authors present the results of their anatomic study and a comprehensive review of the literature. Although modern technologies such as imaging guidance are often used, knowledge of superficial landmarks and their relationship to deeper intracranial structures may be useful to the neurosurgeon when, for example, these devices are not available.

MATERIALS AND METHODS

One hundred adult human dry crania (200 sides) were used for this study. Once the groove for the transverse sinus ended by its vertical decent (sigmoid groove) as visualized from inside the cranium, this site was defined as the transverse sigmoid sinus junction. At this junction, a drill hole (C1 drill bit; Medtronic Midas Rex, Fort Worth, TX) was made 5 mm inferior to the inferior edge of the transverse sinus groove and 5 mm medial to the medial edge of the sigmoid sinus groove. The drill hole was made at an orthogonal direction to the skull. We made the drill hole 5 mm from the sinus edge because an actual burr hole during surgery is approximately 1 cm in diameter. Therefore, if the center of the actual strategic burr hole during surgery coincides with the location of the drill hole described in the present study, only the edges of the venous sinuses will be exposed by the burr hole, allowing their identification without their disruption.

On the outside surfaces of the skulls, the drill holes (approximately 2–3 mm in diameter) were identified and referenced to surface landmarks. A horizontal line (x coordinate) was established by extending a line parallel to the most superior border of the zygomatic arch ("zygomatic line") and a vertical line (y coordinate) was fashioned by connecting the mastoid notch superiorly to the squamosal suture ("mastoid line") (Fig. 1). The point on the squamosal suture that this line intersects is simply along a line parallel to the posterior border of the mastoid process. We used the zygomatic arch and mastoid notch to create our reference coordinates because these are both among the most readily palpable or visible bony landmarks in the surgical field of retromastoid craniotomy before or after skin incision. Using Student's t tests, statistical analysis between sides was performed (SPSS for Windows, Version 13; SPSS, Inc. Chicago, IL) with significance set at a P value of less than 0.05.

RESULTS

Based on examination of the internal surfaces of these skulls, a groove for the transverse and sigmoid sinuses was identified in all specimens on both left and right sides. For left sides, the mean distance of the drill hole from the zygomatic line was 4.5 mm (range, −16 to +15 mm [− signifies superior to this line and + signifies inferior to this line]; standard deviation [SD], 7.4 mm). For left sides, the mean distance from the mastoid line was 9.1 mm (range, −2 to +20 mm; SD, 7.48 mm). For right sides, the mean distance of the drill hole from the zygomatic line was 7.7 mm (range, −10 to +20 mm; SD, 8.35 mm). For right sides, the mean distance from the mastoid line was 9.8 mm (range, −2 to +23 mm; SD, 7.25 mm).

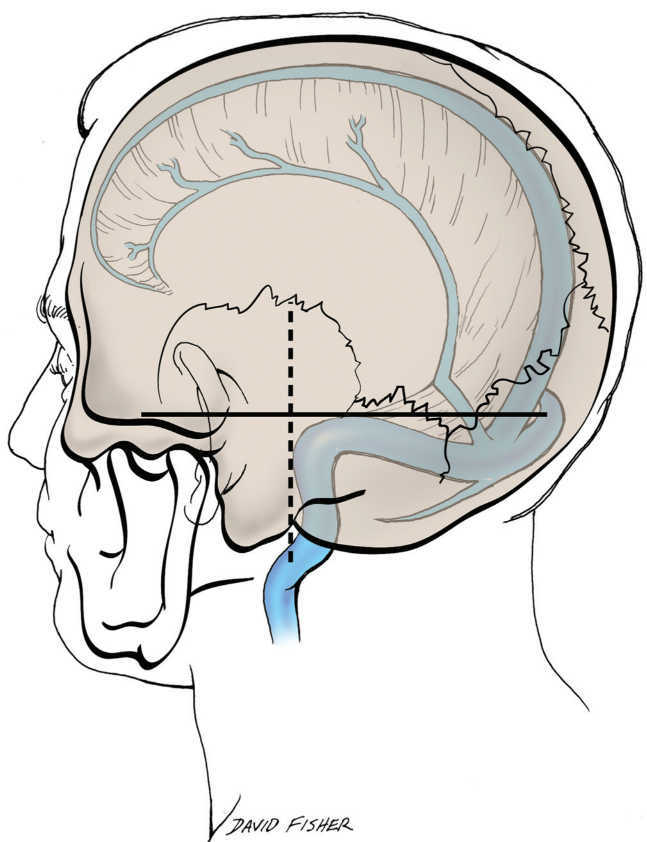

FIGURE 1. *Schematic drawing illustrating the intracranial transverse-sigmoid sinus junction and extracranial landmarks used in the present study. Note a horizontal line from the superior aspect of the zygomatic arch ("zygomatic line") and a vertical line from the mastoid notch ("mastoid line").*

For left sides, 81% of the drill holes were inferior to the zygomatic line and 86% were medial to the mastoid line. For right sides, 91% of the drill holes were inferior to the zygomatic line and 97% were medial to the mastoid line. When comparing left and right sides, we found that the drill holes were more likely to fall below and medial to the above noted lines on right versus left sides and this became significant only when considering the number of locations that were found below the zygomatic line for left versus right sides ($P < 0.05$, one-tail t test).

Specifically, for points that did not fall medial to the mastoid line or inferior to the zygomatic line, we found the following: for left sides, 19% and 14% of points were inferior to and lateral to the zygomatic and mastoid lines, respectively. For the left zygomatic line, points found superior to this line ranged from 1 to 16 mm (mean, 4 mm). For the left mastoid line, points found lateral to this line ranged from 1 to 2 mm (mean, 1.5 mm). For right sides, 9% and 3% of points were inferior to and lateral to the zygomatic and mastoid lines, respectively. For the right zygomatic line, points found superior to this line ranged from 1 to 10 mm (mean, 5 mm). For the right mastoid line, points found lateral to this line ranged from 1 to 5 mm (mean, 3 mm).

In relationship to the above noted lines, the asterion was most frequently found to lie on the zygomatic line, less frequently just inferior to this line, and rarely just superior to this line. In all specimens, the asterion was observed medial to the mastoid line.

DISCUSSION

Classically, the asterion has been cited as an external landmark for the transverse sigmoid junction (venous junction or sinodural angle) (7, 11, 14, 21). Rhoton (12) placed a vertical incision over the asterion and found the venous junction at the superolateral aspect of such an incision. Day et al. (3) demonstrated that the transverse sigmoid junction could reliably be placed at the anteroposterior level of the asterion. However, Avci et al. (1) declared the asterion to be variable in its anatomic relations to other identifiable structures and, thus, not a consistent landmark for intracranial structures. Moreover, this osteological feature is often difficult to palpate, especially through the skin and can be difficult to see, especially in older adults (6). The position of the asterion has been found to be located superficial to the transverse sigmoid sinus junction in 87% of all samples, inferior to the transverse sigmoid sinus junction in 11%, and superior to the transverse sigmoid sinus junction in 2% (20). Day and Tschabitscher (4) found the asterion over the posterior fossa dura in 32% of samples on the right and 25% on the left. Its position was over the transverse or sigmoid sinus complex in 61% of right sides and 66% of left sides. This landmark was located superior to the venous junction in 7% of samples on the right and 9% on the left. These authors concluded that the asterion is not a strictly reliable landmark for localizing the underlying posterior fossa dura because its location is very often directly over the transverse sigmoid sinus junction. Burr holes placed at the asterion may often open the bone directly over the sinus, leading to potential damage.

Ribas et al. (13) found the junction of the transverse and sigmoid sinuses 1 cm anterior to the asterion across the parietomastoid suture. The most superior part of the sigmoid sinus was located anterior to the occipitomastoid suture, with its posterior margin crossing this suture posteriorly to the most superior aspect of the mastoid process, which is located at the most superior level of the mastoid notch. Burr holes made at the midpoint of the inion-asterion line, at the asterion, 1 cm anterior to the asterion, just inferiorly to the parietomastoid suture, and over the occipitomastoid suture at the most superior level of the mastoid notch are appropriate to expose the inferior half of the transverse sinus at its midpoint, the inferior half of the transverse sinus at its most lateral aspect, the transverse and sigmoid sinuses' transition, and the posterior margin of the basal aspect of the sigmoid sinus, respectively (13). Unfortunately, all of these bony landmarks might not always be found in all patients consistently to localize the underlying structures during surgery.

Marsot-Dupuch et al. (9) found that a burr hole centered on the asterion crossed the transverse sinus an average of 6 mm. Sripairojkul and Adultrakoon (16) found that 74.4% of the asterions on the right side were adjacent to the transverse sigmoid sinus complex compared with 58.1% on the left. In addition, 23.3% of the asterions on the right side and 32.6% of the asterions on the left side were found over the infratentorial dura. They also demonstrated that 2.3% and 9.3% of the asterions were located over the supratentorial dura on the right and left side, respectively. These authors confirmed that the asterion is not an appropriate landmark for locating the underlying posterior fossa structures. Furthermore, Martinez et al. (10) found that in 87.8% of their cases, the asterion was over the transverse sinus (72.2% over the sinus proper, 27.8% over the transverse sigmoid junction) and concluded that burr holes for posterolateral approaches to the posterior fossa must be located inferior to and posterior to the asterion.

Avci et al. (1) identified the "strategic burr hole" 1 cm inferior to the superior nuchal line and 1 cm medial to the top of the mastoid groove. Because the superior nuchal line often approximates the location of the zygomatic arch, this study further confirms our findings. We found that for left sides, 81% of venous junctions were inferior to the zygomatic line and 86% were medial to the mastoid line. For right sides, 91% of junctions were inferior to this horizontal line and 97% were medial to this vertical line. Bozbuga et al. (2) found that the sigmoid sinus descended along an axis defined by the junction of the squamosal-parietomastoid suture and the mastoid tip. They concluded that a burr hole placed just inferior to the superior nuchal line and posterior to the axis defined by the above noted landmark line is appropriate for both avoiding entry into the sinus and limiting the size of the craniotomy. Treves (17) depicted the transverse sigmoid junction on the external surface of the cranium and rendered this junction at the posterior edge of the mastoid process (i.e., mastoid groove). Lewis (8) illustrated the posterior aspect of the "knee" (upper genu) between the sigmoid and transverse sinuses as occurring just superior to the level of the zygomatic arch. Day et al. (3) found that a line drawn from the squamosal-parietomastoid suture junction to the mastoid tip reliably defined the axis of the sigmoid sinus through the mastoid. Lang and Samii (6) described this junction as lying approximately 30 mm from the Frankfurt horizontal plane (the plane established when the right and left poria and left orbitale are in the same horizontal plane). Schultze and Stewart (15) described the genu of the sigmoid sinus as reaching a point 0.125 to 0.25 of an inch posterior to a coronal plane through the posterior border of the external auditory canal on a level of the upper part of this canal. Yamashima et al. (23) described the sigmoid sinus as lying along a line from the squamosal-parietomastoid suture junction to the mastoid tip. Based on their study, a line connecting the root of the zygoma to the inion or the superior nuchal line marks the level of the transverse sinus.

Application of Our Study for Surgical Planning

Although our results mathematically determine the location of the strategic burr hole from the mastoid and zygomatic lines, easy-to-remember practical principles can be concluded from these data to assist during everyday surgical planning. Based on the results of the present study, the strategic burr hole should be placed (centered) approximately half the diameter of the burr hole below the zygomatic line along the vertical axis. As confirmed in the present study, the right-sided burr hole may be slightly more inferior than the left-sided hole because of the slightly wider course of the right dominant transverse sinus in the majority of patients.

The location of the strategic burr hole along the horizontal axis is determined by the turn of the transverse sinus to become sigmoid sinus. The lines described herein could be marked on the skull before prepping and draping. The strategic burr hole should be placed approximately the diameter of the burr hole medial to the mastoid line along the horizontal axis. A craniotomy/craniectomy can then be performed and additional bony removal along the lateral and superior edges of the craniotomy allows tracing of the venous sinuses.

Limitations of the Present Study

The exact location where the transverse sinus turns to become the sigmoid sinus (the transverse-sigmoid junction) may be subjective by a slight distance (millimeters). The authors selected the first sign of descent of the transverse sinus as the location for the venous sinus junction. Placement of the strategic burr hole at this location might place the craniotomy more on the transverse sinus portion of the junction rather than at the sigmoid sinus segment. Because bony removal is often more readily performed over the transverse sinus (because sigmoid sinus is often embedded in and adherent to the bony groove in which it resides,) this fact may increase the safety of the strategic burr hole. In addition, the mastoid emissary vein often drains into the sigmoid sinus around the venous junction; this vein can be avoided using this method of initial burr hole placement.

The range and standard deviation for the drill hole coordinates were notable. This confirms the findings of other studies that have demonstrated the variability in the location of the dural venous junction relative to surface landmarks and the importance of careful examination of the preoperative imaging studies to further improve the estimation for the location of the transverse-sigmoid junction. We were unable to find "clues" that predicted the points found in our study that did not fall inferior to the zygomatic line and medial to the mastoid line. This point emphasizes the biological variation of humans and the need for careful observation when using such bony landmarks to predict underlying venous anatomy. However, for points located superior to the zygomatic line or points located lateral to the mastoid line, the most distal points were found on the left side (e.g., 19% of points were superior to the zygomatic line and 14% of points were lateral to the mastoid line).

CONCLUSIONS

Landmarks that assist the neurosurgeon in identifying the transverse-sigmoid sinus junction will maximize surgical access into the posterior fossa and decrease surgical morbidity. We have chosen easily identifiable landmarks (e.g., mastoid process and zygomatic arch) to spatially locate a "strategic burr hole" along horizontal and vertical axes. The asterion, which has been classically used to localize this venous junction, might be difficult to find and is not always reliable in defining underlying intracranial venous structures. We stress that superficial bony landmarks are not always precise and in the age of intraoperative navigation systems, should be used only as a supplement.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

This anatomic study of 210 cranial sides relates the external skull correlate of the transition from transverse to sigmoid sinus to the intersection of lines extending parallel to those traversing externally palpable landmarks. Tubbs et al. found the center of an "ideal" 1-cm burr hole (placed just inferomedial to the transition) to be: 1) a mean of 4.5 mm (left side) and 7.7 mm (right) beneath the zygomatic line; and 2) a mean of 9.1 mm (left) and 9.8 mm (right) medial to the mastoid line. Of note, the ranges for these measurements were 31, 30, 22, and 25 mm, respectively. The authors conclude that the burr hole should be centered 5 mm below the zygomatic line and 10 mm medial to the mastoid line.

The method of the anatomic study is both clever and simple, the findings are clearly presented, and the conclusion is justified, with the caveat that the range of anatomic variation is substantial. According to the Discussion, this is at least the 15th method of locating this burr hole that has been suggested in the literature. Despite Figure 1, in which the guidelines would place about half of the burr hole over the sinus, the method seems at least as accurate as the others reviewed.

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The correct placement of the "strategic" burr hole for a posterior craniotomy to give access to the cerebellopontine angle is paramount in obtaining optimal exposure in this region that Harvey Cushing at one time described as the "gloomy corner of neurosurgery." The craniotomy should extend up to the inferior aspect of the transverse sinus and along the border of the proximal sigmoid sinus, with exposure of the junction of the transverse sinus and the sigmoid sinus being particularly important. My preference has been to perform a craniotomy with placement of 3 burr holes, the initial hole being placed at the junction of the transverse sinus and sigmoid sinus, with the second burr hole being approximately 2 cm medial, along the transverse sinus, and the third being caudally in the squamous occipital bone. In undertaking a craniotomy, it must be noted that the dura is often thin and adherent, particularly in the elderly, and care must be taken to preserve at least the edges of the dura to allow for a watertight closure.

The authors have studied the external skull bony landmarks to facilitate the placement of the initial "strategic" burr hole, which they suggest should be just inferior and medial to the junction of the transverse and sigmoid sinuses. Classically, the asterion has been mentioned as the external landmark for the transverse sigmoid junction, but this may be variable in position and is not a consistent landmark for intracranial structures. The authors used the zygomatic arch and the mastoid notch to create their own reference coordinates, with their rationale being that both are palpable or visible bony landmarks, both before and after skin incision. These landmarks will certainly be helpful in planning the position of the burr hole, but the zygomatic arch may not be easily palpable after the patient has been positioned and draped and the wound has been opened. At that time, the superior nuchal line may be visible, if the incision has extended sufficiently superior, and as indicated, this landmark often approximates the location of the line of the zygomatic arch, with the "strategic" burr hole being placed 1 cm inferior to this line.

Nevertheless, it must be emphasized that, no matter how much care is taken with positioning the burr hole, it is essential that care is taken in performing the "strategic" burr hole, and I usually use loupe magnification with headlight illumination to minimize the risk of damage to the venous sinuses and to preserve the dura just beneath the burr hole, in order to accurately insert the foot-plate of the craniotome. In addition, I frequently need to drill away a little more bone laterally to obtain optimal access to the cerebellopontine angle, and of course, any air cells must be carefully waxed. The authors have provided a helpful study for optimizing the placement of the "strategic" burr hole for this common operation.

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In this anatomic study, the authors studied the optimal location to place the burr hole for a retrosigmoid craniotomy. For years, I have used the landmarks used by the authors to place burr holes. In practice, all of our patients have had an enhanced magnetic resonance imaging scan (or computed tomographic scan with contrast) before surgery, and the anatomy of the sinuses should be carefully studied by the surgeon. If possible, a magnetic resonance venogram can be obtained, and this will show anatomic variations such as a single dominant sigmoid sinus or a large occipital or circular sinus, and even some of the important collateral veins in the event of sinus occlusion. Having this information eliminates the guesswork of where to place the burr hole. If even greater precision is required, frameless neuronavigation may be used, but this is rarely necessary if the anatomic information, and magnetic resonance imaging information are considered together.

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Tubbs et al. present an anatomic contribution that is remarkable for its size. They studied 100 adult skulls (200 sides) to clarify the relationships between the external bony landmarks and the transverse sinus-sigmoid junction. This was done to correctly place the "strategic" initial burr hole for posterior cranial fossa surgery. As said, the main merit of this work is its wide scope, which is notable and, to my knowledge, larger than that of the previous reports in the neurosurgical literature dealing with this topic.

The conclusions of the authors are rather similar to what is already known: the asterion is not a reliable landmark (in most cases, it overlies the sinuses, but it may be also superior or inferior). The best approximation to the location of the junction corresponds to the crossing of 2 lines, 1 along the retromastoid sulcus, and 1 horizontal, which the authors call the "zygomatic line" (other authors use the term "supramastoid crest" or refer to the connection between the external acoustic meatus and the inion). Once it is known where the junction is, the initial drilling is carried out approximately 1 cm lower and medial to this point, with reasonable safety. Moreover, it is worth remembering that the sinus on the right side is generally lower than the left one, and this detail is stressed in this article better than in others.

I agree with the authors about the necessity of teaching anatomic orientation, in spite of the diffusion of neuronavigation systems; these systems can be used to validate traditional anatomic orientation. Of course, all of the measurements must be done before draping the patient.

In conclusion, this technical report, although not new, is useful for young neurosurgeons, so that inadvertent and potentially catastrophic lacerations of the posterior fossa venous sinuses can be avoided.

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