Dural Landmark to Locate the Internal Auditory Canal in Large and Giant Vestibular Schwannomas: The Tübingen Line

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BACKGROUND: In cases of large and giant vestibular schwannomas (VS), the visualization of the internal auditory canal (IAC) opening is difficult or impossible.

OBJECTIVE: To describe the Tübingen line and explore its relationships with the IAC as a landmark to help locate the IAC.

METHODS: Ten cadaveric heads were used in this study. Between 2004 and 2009, the senior author (M.T.) used the Tübingen line as a landmark to recognize the IAC in 300 consecutive patients with VS. To locate the Tübingen line, the initial step was to identify several vertical foldings of dura located around the area of the vestibular aqueduct. After this, foldings upward consistently reached a linear level where all of the foldings ended and the dura tightly adhered to the bony surface in a smooth, foldless shape.

RESULTS: The Tübingen line was identified in all temporal bones studied and in all 300 patients operated on, with the exception of 2 cases (<1%). Removal of the bone just above the Tübingen line located the IAC in all temporal bone specimens studied. Similarly, the surgical cases showed that the Tübingen line helped locate the IAC in all patients.

CONCLUSION: The Tübingen line is an easy, consistent, and safe method to locate the projection of the IAC along the posterior surface of the temporal bone.

KEY WORDS: Anatomy, Internal auditory canal, Retrosigmoid approach, Vestibular schwannoma

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Vestibular schwannomas (VS) account for 6 to 8% of all intracranial neoplasms and 80 to 90% of tumors of the cerebellopontine angle.[1] Because of the considerable progress in the treatment of VS in recent decades, complete tumor removal and functional preservation of cranial nerve function is possible in most cases.[2] The retrosigmoid transmeatal approach remains the procedure of choice for facial and cochlear nerve preservation in VS, and removal of the posterior wall of the internal auditory canal (IAC) is the key to this procedure.[3]

In cases of large and giant VS, the visualization of the IAC opening, on the posterior surface of the temporal bone, is difficult or impossible.

ABBREVIATIONS: IAC, internal auditory canal; **VS,** vestibular schwannomas

Although there are a number of articles that discuss the techniques to drill the posterior wall of the IAC during the retrosigmoid approach, with some of them describing a safety drilling zone to avoid opening the inner ear structures,[3-10] no previous articles are dedicated to an anatomical surgical landmark to locate the position of the IAC during retrosigmoid approach.

Surgical observations made by the senior author (M.T.) during IAC drilling by the retrosigmoid approach, in patients harboring VS, indicated a close relationship between a dural landmark on the posterior surface of the petrous part of the temporal bone and the IAC inferior limit. This linear landmark has been denominated Tübingen line.

This article describes the Tübingen line and explores its relationship with the IAC as a landmark to help locate the IAC to guide the initial drilling of this structure during the retrosigmoid approach.

MATERIAL, PATIENTS, AND METHODS

Ten cadaveric, formalin-fixed heads (20 temporal bones) were used in this study. The skull cap and brain were removed to expose the skull base and the posterior surface of the temporal bone, and they were examined under a 6× magnification of the surgical microscope (OPMI-1 Lab, Carl Zeiss, Germany). A pneumatic drill and 3-1 mm, cutting and diamond-coated burrs (Aesculap, Tuttlingen, Germany) were used to expose the IAC based on prior identification of the Tübingen line.

Between 2004 and 2009, the senior author (M.T.) used the Tübingen line as a landmark to recognize the IAC in 300 consecutive patients with VS. These operations were performed with the patient in a semisitting position. A retrosigmoid approach was performed and, under magnification of the surgical microscope, the cerebellar hemisphere was retracted just enough to expose the dura over the posterior surface of the temporal bone. At this point, the Tübingen line was identified, and the posterior wall of the IAC was drilled.

To locate the Tübingen line, both in cadaveric specimens and surgical patients, the initial step was to identify several vertical, delicate foldings of dura located around the area of the vestibular aqueduct. After this, foldings upward consistently reached a linear level where all of the foldings ended and the dura tightly adhered to the bony surface in

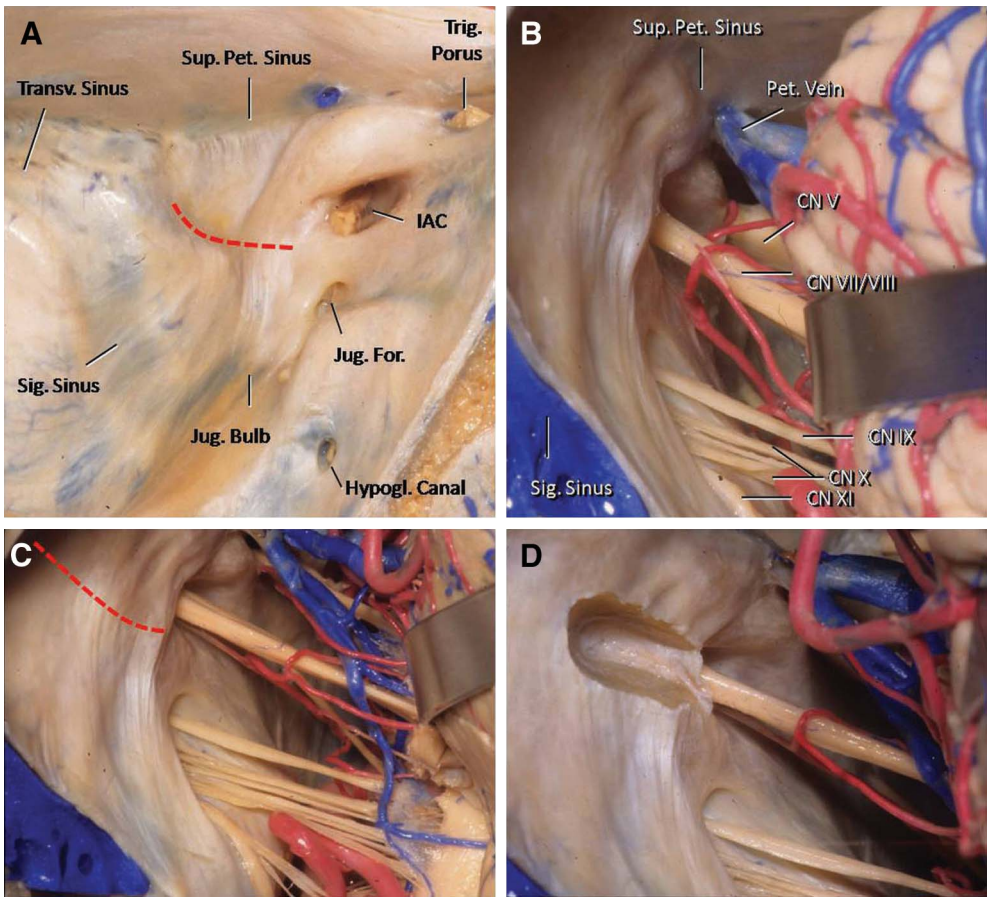

FIGURE 1. *Cadaveric pictures.* **A**, *medial to lateral view into the left posterior fossa. The posterior surface of the temporal bone is surrounded by venous sinus: the superior petrosal sinus, above, the junction of transverse and lateral portion of sigmoid sinus, laterally, the junction of medial portion of the sigmoid sinus and jugular bulb, inferiorly, and the basilar sinus, medially (not shown). The internal acoustic meatus is located between the trigeminal porus superomedially and the jugular foramen, inferolaterally. The Tübingen line (dotted red line) connects the ending points of the dural folds spanning the area comprised between the jugular foramen and the medial part of the sigmoid sinus inferiorly and extending cranially for 5 to 7 mm. This dural landmark points out the inferior limit of the internal acoustic meatus.* **B**, *retrosigmoid view into the left posterior fossa. Observe the presence of several, delicate dural folds around the area of the vestibular aqueduct. Following these folds upward reaches a linear level where the folds end and the dura tightly adheres to the bony surface.* **C**, *magnified view of* **B**. *The Tübingen line has been highlighted in red.* **D**, *same specimen shown in* **C**. *The internal acoustic meatus has been drilled to expose the dura in the canal, protecting the meatal portion of VII/VIII nerves. Tübingen line is a useful landmark for the lower limit of the internal acoustic meatus. CN, cranial nerve; For., foramen; Hypogl., hypoglossal; IAC, internal acoustic meatus; Jug., jugular; Pet., petrosal; Transv., transverse; Trig., trigeminal; Sup., superior.*

a smooth, foldless shape. The Tübingen line is the line projected on the dura by connecting the superior ending of the dural folds on the posterior wall of the temporal bone (Figures 1A–1C, 2A and 2B).

RESULTS

Identification of Tübingen Line

The Tübingen line was easily identified in all temporal bones studied and in all 300 patients operated on, with the exception of 2 cases (< 1%). The dural folds guiding its identification spanned the area between the jugular foramen and distal part of the sigmoid sinus inferiorly and extended 5 to 7 mm cranially. The line connecting the ending points of the dural folds sloped upward from medial to lateral, forming a slightly upward concavity or rather an ascending path (Figures 1A–1C, 2A and 2B).

In 2 cases the Tübingen line was not useful because the anteroinferior cerebellar artery was located and also attached in the dura over the posterior wall of the internal auditory canal; thus, in both patients it was impossible to recognize the line, because the line was hidden by the artery.

Relationship Between Tübingen Line and the IAC

Removal of the bone just above the Tübingen line located the IAC in all temporal bone specimens studied (Figure 1D), demonstrating that this landmark consistently lead to the inferior limit of the IAC. Similarly, the analysis of the relationship between the Tübingen line and the IAC in surgical cases showed that the Tübingen line helped locate the IAC in all cases and consistently marked its inferior limit (Figure 2B and 2C).

DISCUSSION

The incidence of giant tumors among all cases of VS has been estimated to be up to 2% in Western countries,[11] but in developing countries, as in skull base referring centers, they are seen with a significantly higher incidence.[2] The final goal of VS surgery is to achieve complete microsurgical tumor resection with functional preservation of facial and cochlear nerves.[12]

Removal of the posterior wall of the IAC is an essential step in VS surgery via the retrosigmoid approach.[13] Of the many factors influencing hearing preservation, inadvertent fenestration of the labyrinth, during IAC exposure, is one of the more common and perhaps one of the more avoidable complications.[14] Thus, different guides to work out the amount of drilling needed at the distal most lateral end of the canal that may be performed to maximize exposure while preserving inner ear structures—specifically, the posterior semicircular canal, vestibule, and common crus—have been advised by a number of authors.[3-10] Tatagiba et al[14] and Yokoyama et al[15] attempted to estimate the preoperative risk of opening inner ear structures via the retrosigmoid approach by introducing the sigmoid-fundus line.[13] Other authors have stated that the predictive value of this anatomical line is limited, and that the labyrinth is in danger whenever exposure of the fundus is attempted.[3,16]

In cases of large tumors, the medial end of the canal can also offer difficulties. Large tumors typically hide the IAC opening and might require tumor displacement to locate the IAC. This maneuver usually causes bleeding at the dural-tumor interface. The resulting clots may obliterate the surgical field, and continued bleeding might require bipolar coagulation, risking the nearby cranial nerves.

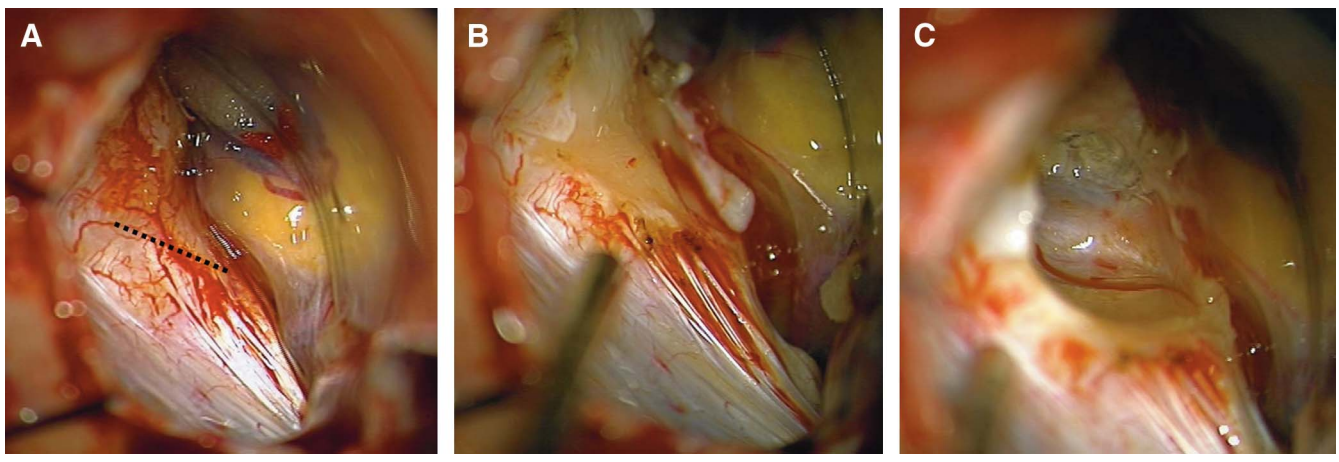

FIGURE 2. *Surgical pictures.* **A**, *retrosigmoid view into the left posterior fossa. The Tübingen line has been highlighted in dotted black line.* **B**, *the dura covering the posterior wall of the IAC has been removed in order to start the drilling. Observe that the inferior limit of the drilling is at the level of the Tübingen line.* **C**, *the posterior wall of the IAC was already drilled. Note that the Tübingen line corresponds with the inferior limit (floor) of the IAC.*

Pillai et al[17] proposed using frameless navigation based on high-resolution computed tomographic scans and the aid of the endoscope to locate and guide the opening of IAC. Samii et al[13] studied the role of image-guided opening of the IAC via the retrosigmoid route and concluded that this method is promising but still limited. Thus, opening of the IAC via the retrosigmoid route remains today based mainly on careful analysis of preoperative computed tomographic findings and the personal experience of the surgeon.[13]

Before surgery, all patients had a CT scan to analyze, among other surgical details, the position of the jugular bulb. In those cases in which the jugular bulb was diagnosed as high, the Tübingen line was extremely useful during surgery, because the drilling was started 3 to 5 mm above the line, avoiding the possibility of damaging that highly situated jugular bulb. To avoid a postoperative CSF fistula through the middle ear, in all patients of this series, after the tumor was completely removed, a piece of muscle and a bit of fibrin glue were put in the internal auditory canal.

CONCLUSION

The Tübingen line is an easy, consistent, and safe method to locate the projection of the IAC along the posterior surface of the temporal bone and to guide the initial drilling of the IAC in large VS tumors.

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

The authors report on their confirmational cadaveric study of an observation that appears useful in determining the path of the internal auditory canal when approaching it via a retrosigmoid transmeatal technique. I agree with the authors that, in the cases of very large vestibular schwannomas, it can be difficult to localize the porus acusticus before any tumor removal or debulking. I would suggest, though, that the authors' technique may suffer from the same limitations in exposure even in larger tumors. Nevertheless, my preferred tactic is to perform an initial debulking of these large tumors before performing the canal removal. A sufficient amount of tumor must be removed before this maneuver to avoid traction on the nerves in the canal by the remaining mass as it is separated from any attachment at the dura around the porus acusticus.

I think it will be useful to keep the anatomical relationship found through these authors' work in mind when dealing with acoustic neuromas via the retrosigmoid approach.

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Tips on anatomical localization, such as the one proposed by the authors, can assist those early on the learning curve of advanced skull base techniques. While lacking the precision of frameless stereotaxis, these landmarks can assist in getting the drilling started in the appropriate region, especially when large tumors obscure the canal orifice. With the popularity of radiosurgery, fewer small tumors will be surgically removed, leaving only the larger ones for lesser experienced surgeons to advance their skills. Identifying helpful regional landmarks such as the "Tubingen Line" along with judicial use of stereotaxis, supplemented with practice in the cadaver lab, will lead to increasingly successful surgical outcomes.

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