Simple Landmark for Preservation of the Cochlea During Maximum Drilling of the Petrous Apex Through the Anterior Transpetrosal Approach

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Abstract

The cochlea is one of the most important organs to preserve during skull base surgery. However, no definite landmark for the cochlea has been identified during maximum drilling of the petrous apex such as anterior transpetrosal approach. The relationship between the cochlea and the petrous portion of the internal carotid artery (ICA) was assessed with computed tomography (CT) in 70 petrous bones of 35 patients, 16 males and 19 females aged 12–85 years (mean 48.6 years). After accumulation of volume data with multidetector CT, axial bone window images of 1-mm thickness were obtained to identify the cochlea and the horizontal petrous portion of the ICA. The distance was measured between the extended line of the posteromedial side of the horizontal petrous portion of the ICA and the basal turn of the cochlea. If the cochlea was located posteromedial to the ICA, the distance was expressed as a positive number, but if anterolateral, as a negative number. The mean distance was 0.6 mm (range -4.9 to 3.9 mm) and had no significant correlation with sex or age. The cochlea varies in location compared with the horizontal petrous portion of the ICA. Measurement of the depth and distance between the extended line of the posteromedial side of the horizontal intrapetrous ICA and the cochlea before surgery will save time, increase safety, and maximize bone evacuation during drilling of the petrous apex.

Key words: cochlea, internal carotid artery, anterior transpetrosal approach, skull base surgery, computed tomography

Introduction

Skull base approaches such as the extended middle cranial fossa approach, modified extended middle cranial fossa approach, and combined transpetrosal transtentorial approach are often used by otolaryngologists and neurosurgeons to treat skull base tumors, cerebral aneurysms of the posterior circulation, and other diseases. Knowledge of the exact anatomy is the essence of any type of surgery. The cochlea is one of the most important organs to preserve during skull base surgery. However, no definite landmark of the cochlea is established to allow maximum bone drilling of the petrous apex. The important landmarks for identifying the cochlea from the superior view of the petrous surface are the greater superficial petrosal nerve (GSPN), the geniculate ganglion, and the internal auditory canal. Drilling of the cancellous bone of the petrous apex exposes the hard bone of the cochlea. Further drilling will expose the blue line of the cochlea, but this procedure is difficult for inexperienced surgeons. Maximum bone drilling at the petrous apex will expose the horizontal segment of the internal carotid artery (ICA). The cochlea is located at the posterior corner of the bend of the intrapetrous ICA. Knowing the anatomical relationship between the cochlea and the ICA thus allows accurate identification of the cochlea.

The present study used computed tomography (CT) to assess the topographic relationship between the cochlea and the ICA preoperatively.

Materials and Methods

Thirty-five Japanese patients, 16 men and 19 women aged 12–85 years (mean 48.6 years) were admitted to our hospital for treatment of vestibular schwannoma in 14 cases, sudden deafness in 8, meningioma in 8, jugular foramen tumor in 2, hemangioblastoma in 1, epidermoid tumor in 1, and arachnoid cyst in 1. All patients underwent CT of the bilateral petrous bones. No patient had deformity of the petrous apex.
CT used a 16-detector multislice SOMATOME Sensation 16 (SIEMENS AG, Munich, Germany). After accumulation of volume data with multidetector CT, a 1-mm thick horizontal bone window image was obtained parallel to the orbitomeatal (OM) line (window width 3000 Hounsfield units [HU], window level 1000 HU). The distance between the extended line of the posteromedial side of the horizontal petrous portion of the ICA and the most medial part of the basal turn of the cochlea was measured on the axial images. If the cochlea was located posteromedial to the extended line of posteromedial line of the ICA, the distance was expressed as a positive number, but if the cochlea was anterolateral, as a negative number (Fig. 1). The depth of the cochlea from the superior surface of the petrous bone was also measured on the coronal image perpendicular to the OM line (Fig. 2). Values are given as mean ± standard deviation. The influence of sex and age on the distance and depth were statistically analyzed by Student’s t-test and Pearson’s correlation coefficient, respectively.

**Results**

The distance between the extended line of the posteromedial side of the horizontal intrapetrous ICA and the medial part of the basal turn of the cochlea was 0.4 ± 1.7 mm (range −4.9 to 3.9 mm) in the right temporal bones, 0.8 ± 1.7 mm (range −4.2 to 3.7 mm) in the left temporal bones, and 0.6 ± 1.7 mm (range −4.9 to 3.9 mm) in the bilateral temporal bones. There was no significant difference between the distance in males (0.3 ± 1.9 mm) and in females (0.5 ± 1.6 mm) (p = 0.6122), and no significant correlation between the distance and age (p = 0.0824).

The basal turn of the cochlea was posteromedial to the extended line of the posteromedial side of the horizontal intrapetrous ICA in 44 of 70 temporal bones, anterolateral in 18, and accordant in 8 (11%) (Fig. 3). Positional relationship indicated symmetric pattern in 23 patients. The basal turn of the cochlea in the symmetric 23 patients was posteromedial to the ICA in 16, anterolateral in 6, and accordant in 1. Six of the 12 asymmetric patients had accordant in one side, and the other 6 patients had posteromedial in one side and anterolateral in the other.

The depth of the cochlea from the superior surface of the petrous bone was 4.5 ± 1.5 mm (range 2.0 to 7.9 mm) in the right temporal bones, 4.5 ± 1.4 mm (range 2.6 to 8.0 mm) in the left temporal bones, and 4.5 ± 1.4 mm (range 2.0 to 8.0 mm) in the bilateral temporal bones. There was no significant difference between the depth in males, 4.6 ± 1.4 mm (range 2.0 to 6.8 mm) and in females, 4.5 ± 1.5 mm (range 2.5 to 8.0 mm) (p = 0.7054). There was no significant correlation between age and the depth of the cochlea (p = 0.1198).
**Discussion**

The lateral limits of maximum bone drilling of the petrous apex without hearing loss are the ICA and cochlea. The ICA can be mobilized anterolaterally if the GSPN, tensor tympani muscle, or eustachian tube are sacrificed, whereas the cochlea cannot be translocated. Therefore, the accurate location of the cochlea is important to maximize evacuation of the petrous apex.

The area of drilling is surrounded by the trigeminal ganglion anteriorly, the cochlear organ posteriorly, the sphenopetrosal groove laterally, and the carotid canal and internal auditory canal inferiorly, but how to identify the cochlea remains unclear.\(^7\) The rhomboid construct was drilled in an anatomical investigation with 38 temporal bones, which showed that the cochlea lies within the lateral one-half of the premeatal triangle, which is defined by the ICA genu, the geniculate ganglion, and the medial lip of the internal auditory canal, but individual differences were not assessed.\(^2\)

Cadaveric studies of the relationship between the cochlea and the ICA have shown that the plane tangential to the internal side of the cochlea is also tangential to the internal edge of the horizontal segment of the carotid artery.\(^15\) The cochlea is separated from the artery by a 2.1-mm thickness of bone (range 0.6 to 10.0 mm) and can be injured during exposure of the intrapetrous carotid artery.\(^14\) A line extending from the tip of Bill’s bar to the junction of the petrous carotid artery and the mandibular branch of the trigeminal nerve passes through the superior portion of the basal turn of the cochlea.\(^9\) The carotid canal is partially covered by the cochlea.\(^4\) The bone surrounding the membranous cochlea is formed by the otic capsule, which is compact and always devoid of pneumatization. The otic capsule is distinctly dense and lighter in color than the remaining bone in the petrous apex.\(^9\) The basal turn of the cochlea can be skeletonized until only a thin shell of compact bone surrounding the membranous labyrinth of the basal turn remains.\(^9\)

The structures in the temporal bone vary greatly between individuals, so preoperative investigation is very important.\(^3,10\) Use of the carotid artery-cochlea angle allowed removal of bone posterior to the genu and lateral to this plane (lateral to the 0-degree line of the carotid artery-cochlea angle). This technique can be used as long as the depth of bony removal does not exceed the capacity of the 2.8-mm-diameter Sheehy weapon knife to estimate this distance, and this technique significantly increased exposure of the posterior genu of the horizontal petrous carotid artery.\(^3\) The cochlea was measured from the lateral side.

We believe that measurement of the cochlea from the medial and superior aspects is also useful. The posteromedial surface of the horizontal segment of the petrous ICA can be exposed without sacrifice of the GSPN. The cochlea is seated at the posterior corner of the intrapetrous ICA. Measurement of the depth of the cochlea and the distance between the extended line of the posteromedial horizontal intrapetrous ICA and the cochlea will give an indication of the safety area for drilling (Fig. 1).

The axial image simulates the view from above, in contrast to the more superolateral surgical view. Neurosurgeons should consider the direction to be drilled and should assess both the horizontal and vertical anatomical relationships such as the depth of the cochlea. If the cochlea is deep from the superior surface of the petrous bone, there is low risk of sacrifice through the routine anterior transpetrosal approach. To maximize the operative window in cases such as lesions at the vertebrobasilar union carries more risk of sacrificing the cochlea because the bone must be drilled deeper posteroinferiorly. The white compact bone must be spared to preserve hearing function at all times.

Skull size varies with sex and age, but the distance between the extended line of the horizontal intrapetrous ICA and the cochlea showed no correlation in our cases. In addition, the depth of the cochlea had no relationship to sex or age. Therefore, drilling of the petrous apex should depend on individual location of the cochlea based on measurements on CT scans of the depth and distance between the extended line of the posteromedial side of the horizontal intrapetrous ICA and the cochlea before surgery. Such precautions will save time, increase safety, and maximize bone evacuation during drilling of the petrous apex.

**References**


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Commentary

This is an interesting presentation of utilizing simple landmarks while drilling the petrous apex to maximize the likelihood of preserving the cochlea. The landmarks are well seen on thin slice high quality CT. Understanding the location of the cochlea before drilling is crucial and correlating it with the tangent of the intrapetrous carotid is an interesting approach. The depth as seen on the coronal images is equally important. However, nothing will equal experience in exposing this area and being comfortable with the entire anatomy. As with any operation we do, understanding that particular patient’s anatomy is what is most important.

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In this study, Seo et al. provide a well articulated discussion of the complex and irregular osteology of the subtemporal petrous ridge when approached for a traditional middle fossa or expanded anterior petrosectomy. Specifically, they address the lack of a definitive landmark for the cochlea during maximum drilling of the petrous apex. The authors’ elegantly-designed study describes the position of the cochlea in relation to the genu of the petrous internal carotid artery (ICA). However, the paper reiterates previously reported anatomical and surgical information, and other data well documented in the otologic literature. Sparing hearing (i.e., preventing injury to the internal auditory canal [IAC] contents or cochlea itself) is an important aspect of numerous skull base approaches, including the extended middle cranial fossa/anterior petrosal approach. Improving surgical results and minimizing iatrogenic injury continues to gain importance, particularly in comparing these results with the results of increasingly popular use of stereotactic radiation for treatment of skull base tumors.

It is probably not well known, even by those that perform these approaches, that the cochlea can be medial, lateral, or in-line with the medial wall of the horizontal petrous ICA. Using thin-section CT scans, the authors assessed the cochlea’s location relative to the middle cranial fossa floor and petrous ICA. Although tumors and vascular anomalies are often diagnosed by MRI, MRA, and CT-angiography or standard angiography (respectively), the authors advocate for use of CT scans to preoperatively localize the anatomy of the petrous apex, specifically defining the relationships among the ICA, cranial nerve V and the VII/VIII complex, and otic capsule. Thus, because the cochlea is intolerant of any penetration of its basal...
turn, there is the potential to limit the risk of cochlear injury and subsequent profound sensorineural loss.

We concur with the authors that these approaches can be daunting for those inexperienced in performing the anterior petrosal approach. Therefore, skull base surgeons, both neurosurgeons and neurotologists, wisely practice and hone their skills and techniques in the cadaveric temporal bone lab before undertaking these demanding procedures in the operating room. Blue-lining the cochlea is not without significant risk. Moreover, while the pneumatization pattern of any given temporal bone may make the dissection more or less challenging, the key areas for safe dissection are still defined by the surgeon’s ability to:
1. Avoid the transition plane between the vertical and horizontal petrous carotid artery;
2. Define the fundal area of the IAC; and most importantly
3. Work ventral-medially below the horizontal petrous carotid, anteriorly to the basal turn of the cochlea. Finally, although mobilization of the petrous carotid is anatomically possible, the risk-benefit ratio of this maneuver is high and the procedure is ill advised.

The authors’ study could include the use of intraoperative image-guidance systems to further reduce the risk of cochlear injury. We hope to learn in their future studies how they combine preoperative scans with intraoperative surgical management and postoperative results, particularly related to hearing preservation.

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