The anterior petrosal approach introduced by Kawase et al. was designed to enable wider and closer surgical exposure for treatment of ventral brainstem lesions. The technique provides easy access to large sphenopetroclival meningiomas, dumbbell-shaped trigeminal schwannomas, and giant acoustic neuromas located in front of the brainstem and basilar trunk aneurysms. The advantage of this technique is a lower possibility of postoperative hearing loss, vestibulopathy, and facial paresis in comparison with the transcochlear approach and/or combined middle fossa posterior approach, which both provide similar surgical fields.

To perform the anterior petrosal approach more safely, the use of possible anatomical landmarks, including the maxillary branch of the trigeminal nerve (V3), gasserian ganglion, greater superficial petrosal nerve (GSPN), petrous internal carotid artery (ICA), cochlea, geniculate ganglion, dura mater of the internal acoustic canal (IAC), labyrinthine portion of the facial nerve, vestibule, and superior semicircular canal can also be put to good use. Of these, the cochlea is well known to be located anterior to the fundus of the IAC, inferior to the geniculate ganglion. This relationship is frequently used as an anatomical landmark. In addition, the difference in bone density between the petrous bone and the cochlea can also be another clue for determining the location of the cochlea. However, surgeons may be faced with unexpected difficulty in applying these concepts in real surgical fields. In this study, based on dissection results in 5 fresh cadavers, we aimed to develop a practical landmark for the safe and easy identification of the cochlea when applying the anterior petrosal approach.

**Methods**

This study was approved by the institutional review board of Eulji University. Five fresh cadaver heads were dissected in the microdissection laboratory.

**Abbreviations**

GSPN = greater superficial petrosal nerve; IAC = internal acoustic canal; ICA = internal carotid artery; V3 = maxillary branch of the trigeminal nerve.

**Submitted** January 26, 2014. **Accepted** December 1, 2014.

**Disclosure**

This research was supported by EMBRI Grants 2013-EMBRI-DJ-0006 from Eulji University. The authors declare no conflict of interest.

* Drs. S. M. Kim and Lee contributed equally to this work.
Surgical Technique

The cadaver head was placed in the supine position, and the head was then turned 45° to 60° in the direction opposite to the side of surgery (Fig. 1). If a combined posterior petrosal approach is chosen, it is necessary to tilt the table more than 60° with proper head fixation.

A skin flap was elevated subfascially, and the muscles were elevated appropriately for maximum exposure of the temporal base. After elevation of a rectangular bone flap to expose the entire middle fossa base from the foramen rotundum to the posterior part of the petrous ridge, the middle fossa dura was elevated extradurally from the base. The middle meningeal artery was cut where it emerged from the foramen spinosum, and the dura was carefully elevated in the lateral-to-medial direction from the middle fossa floor to the GSPN. Further dissection of the GSPN from the attached dura was performed in the posterior-to-anterior direction to prevent damage to the facial nerve.

After identification of the posterior-most point of the petrous ridge, the dura was elevated anteriorly from that point to over the arcuate eminence. The detachment of the GSPN from the dura must be performed sharply using a blade or microscissors to avoid overstretching the nerve during the dissection. The outer dural layer of Meckel’s cave over V3 was peeled away medially from the inner membranous layer to expose the angle made by the gasserian ganglion and petrous ridge for complete exposure of the meatal plane. Finally, the meatal plane, arcuate eminence, and petrosal ridge were sufficiently exposed.

The imaginary parallelogram that is bounded by V3, the GSPN, the arcuate eminence, and the petrous ridge was the area of bone drilling for the anterior petrosectomy. High-speed drilling was initiated in this parallelogram area of the meatal plane at the junction of V3 and the GSPN angle (Fig. 2). Then the horizontal segment of the petrous ICA could be exposed.

The GSPN-ICA point (red dot in Fig. 3) was marked at the crossing of the GSPN over the exposed horizontal segment of the petrosal ICA. The petrosectomy was continued medially along the V3. The dura of the proximal portion of the IAC can be exposed by drilling the petrous ridge posteriorly from its junction with the gasserian ganglion. This procedure was continued more posteriorly to expose the dura at the meatal lip over the superior half of the circumference. The exposed dura of the IAC was then followed posterolaterally along the long axis of the canal. The line drawn over the apex of the superior circumference of the dura of the IAC was defined as the IAC line. The cochlear line was the line drawn from the GSPN-ICA point to the IAC line at a right angle. The meeting point of the 2 lines was the IAC point. Maximal exposure of the posterior fossa dura at the ventral brainstem could be achieved by application of this cochlear line.

Measurements

The microsurgical steps described above were performed on 10 sides of 5 injected cadaver heads. The cochlea, superior semicircular canal, and vestibule were opened to confirm their position. The validity of the cochlear line was evaluated by measuring the relationship between the line and the cochlea. The shortest distance between the cochlear line and the inner wall of the cochlear cavity was measured with a microruler in the surgical field (Fig. 4).

Results

The cochlear line marks the anteromedial perimeter of the cochlea at the angle of the GSPN and the IAC (Fig. 4). The anterolateral portion of the cochlea could be localized using the cochlear line anteromedially, the dura of the
IAC between the IAC point and Bill’s bar posteromedially, the labyrinthine portion of the facial nerve posteriorly, and the geniculate ganglion and proximal portion of the GSPN between the GSPN-ICA point and the geniculate ganglion laterally.

The shortest distance from the cochlear line to the inner wall of the cochlea was measured in 9 sides of 5 injected cadaver heads. The distances ranged from 1.50 mm to 3.00 mm (mean 2.25 ± 0.51 mm) in 9 sides; in 1 side, the cochlea was not found at the angle made by the GSPN and the dura of the IAC (Table 1). The side where the cochlea was not found at the GSPN-ICA angle was approached by the posterior petrosectomy, and the existence of the cochlea was confirmed. In this case, the cochlea was located more posteriorly, so it did not appear in the usual location. Overall, no cochlea went beyond the cochlear line.

We treated 29 patients with anterior petrosectomy alone or in combination with other skull base approaches (Table 2, Fig. 5). In all of the cases, we were able to preserve the cochlea by applying the concept of the cochlear line.

**Discussion**

Kawase et al. applied the otological concept of the middle cranial fossa approach presented by House to the conventional subtemporal transtentorial approach to create a more direct and wider corridor to the ventral brainstem. The extent of petrosectomy has been widened from the time of introduction of this approach in the neurosurgical field until recently, and this approach is known to be effective for accessing ventral mid- to upper pontine lesions in particular.1,4-6,9

In fact, when performing the anterior petrosectomy in the narrow space of the parallelogram-shaped anterior surface of the petrous bone, which is bounded by V3, the GSPN, the superior semicircular canal, and the petrous ridge, only approximately 3 cm² may not present a straightforward procedure with a manageable learning curve. Adding to the difficulty is the need to preserve the patient’s hearing in order to maintain quality of life; a previous comprehensive review reported that 12% of patients who received an anterior petrosectomy due to brainstem cavernous malformations experienced perioperative hear-
The cochlear line facilitates both hearing preservation and the securing of wider surgical corridors by providing evidence according to the approximate locations of the cochlea when performing the anterior petrosal approach. Using this line as a landmark results in a safety margin of approximately 2 mm around the cochlear cavity, which does not inhibit the view of the surgical trajectory to the brainstem. If the cochlea is localized in such a way, the remaining bone bounded by V3, the petrous ICA, the cochlear line, the IAC dura, and the superior petrosal sinus can be drilled inferiorly to the inferior petrosal sinus. In addition, the securing of the safety margin for the preservation of the cochlea using this line may aid in minimizing the possibilities of unintended hearing loss.

Therefore, applying the anterior petrous approach in conjunction with the identification of the cochlear line is advantageous in regard to safety and convenience, as such an approach is a simpler and less invasive surgical procedure than other approaches, such as the transcochlear approach and combined middle fossa approach, with similar surgical views.1,8

More to the point, a tangential view to the surgical field should be maintained to correctly apply the cochlear line during surgery. Looking at different angles may lead to different cochlear lines. Given the anatomical structure of the petrous apex, the patient is in a supine position with his or her head turned 40° to 60° from midline in the direction opposite to the side of surgery, and the head does not move excessively in the sagittal plane during the actual surgery (Fig. 1). If a combined posterior petrosal approach is chosen, it is necessary to tilt the table more than 60° with proper head fixation. The vertex should be in a neutral position or tilted down minimally to ensure that the anterior petrosal surface faces obliquely upward and is observed as flat by the surgeon (Fig. 1). The head position is important for securing a correct cochlear line, reducing the need for brain retraction, and ensuring a comfortable operating position for the surgeon. Moreover, peeling away of the temporal dura to the petrous ridge is very important for complete exposure of the petrous bone. For this, the extradural layer of the posterior cavernous sinus should be dissected and elevated, and the surgeon must meticulously control bleeding. Draining of cerebrospinal fluid by lumbar puncture can be helpful if complete elevation of the dura is not possible due to increased intracranial pressure.

In addition to this study, previous studies have reported on diverse anatomical landmarks that aid in preserving the cochlea during an anterior petrosal approach. Hisselberger et al., in their study of the middle fossa transpetrous approach for the treatment of petroclival meningiomas, reported that the horizontal petrous ICA should be skeletonized from the posterior loop to V3, and this dissection should not be extended behind the posterior loop due to the close relationship of the cochlea and the lesions.7 Day et al. stated that the cochlea may be considered to be located within the lateral half of the premeatal triangle bounded by the ICA genu, the geniculate ganglion, and the medial lip of the IAC.2 Similar to the basic concepts of the cochlear line, the measurement of the carotid-cochlear distance (mean 4.3 mm) was also emphasized. This distance was defined as the distance from 1 cm from the posterior aspect of the geniculate ganglion to the most anterior entry of the basal turn. By estimating the distance using a Sheehy knife curette (diameter 2.8 mm), the dense bone surrounding the cochlea can be safely removed.3 In this study, it was also reported that 64% of surgical specimens showed crossing of the GSPN along with the petrous ICA from the medial to lateral side. We assumed that if this crossing phenomenon is observed after identification of the petrous ICA, the cochlear line may be the first reliable evidence that allows approximation of the location of the cochlea. In contrast, if the GSPN does not cross the petrous ICA, using the carotid-cochlear distance may be better than using the cochlear line.

Our study has several limitations. We did not compare the use of the cochlear line with previously reported methods or measure other distances to confirm the best way to safely identify the cochlea. Instead, we introduced our practical method for surgeons to preserve the cochlea while performing an anterior approach. Although our hypothesis is supported by our clinical data, an additional study will be performed to compare the cochlear line with other indicators such as carotid-cochlear distance.

Conclusions

We observed that the mean distance from the cochlear line to the margin of cochlear cavity was 2.25 mm, and this distance ensures that the cochlear line can be used as

### TABLE 1. Distances from the cochlear line to the inner wall of the cochlea in 5 cadavers

<table>
<thead>
<tr>
<th>Cadaver No.</th>
<th>Right Side</th>
<th>Left Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.50</td>
<td>*</td>
</tr>
<tr>
<td>2</td>
<td>1.50</td>
<td>2.00</td>
</tr>
<tr>
<td>3</td>
<td>2.75</td>
<td>3.00</td>
</tr>
<tr>
<td>4</td>
<td>2.25</td>
<td>2.25</td>
</tr>
<tr>
<td>5</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>2.25 ± 0.51 mm</td>
<td></td>
</tr>
</tbody>
</table>

* In this cadaver, the left cochlea was not found within the angle made by the GSPN and the dura of the IAC.

### TABLE 2. Clinical data from 29 cases in which patients were treated with the anterior petrosal approach alone or in combination with other skull base approaches

<table>
<thead>
<tr>
<th>Disease</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tumor</td>
<td></td>
</tr>
<tr>
<td>Trigeminal schwannoma</td>
<td>12</td>
</tr>
<tr>
<td>Petroclival meningioma</td>
<td>7</td>
</tr>
<tr>
<td>Chordoma</td>
<td>3</td>
</tr>
<tr>
<td>Vascular disease</td>
<td></td>
</tr>
<tr>
<td>Basilar trunk aneurysm</td>
<td>4</td>
</tr>
<tr>
<td>Other (e.g., arteriovenous malformation)</td>
<td>3</td>
</tr>
</tbody>
</table>
a safe landmark that enables the preservation of the cochlea while allowing a wider surgical field.

References


Author Contributions

Conception and design: HK Kim, SM Kim, Lee. Acquisition of data: HK Kim, SM Kim, Zabramski. Analysis and interpretation of data: HK Kim, SM Kim, Lee. Drafting the article: HK Kim, Lee. Critically revising the article: HK Kim, SM Kim, Lee. Reviewed submitted version of manuscript: HK Kim, SM Kim, Lee. Approved the final version of the manuscript on behalf of all authors: HK Kim. Statistical analysis: HK Kim, Lee. Administrative/technical/material support: HK Kim, SM Kim. Study supervision: HK Kim, SM Kim.

Correspondence

Han Kyu Kim, Department of Neurosurgery, Kosin University Gospel Hospital, Kosin University, Busan, Gamcheon-ro 262, Seo-Gu, Pusan 602-702, Korea. email: rosamund@hanmail.net.