Risk of Damage to the Endolymphatic Sac and Duct during Removal of the Posterior Meatal Wall: An Anatomic Study

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OBJECTIVE: With removal of the posterior meatal wall for intrameatal acoustic neurinoma, preservation of the structures adjacent to the internal acoustic meatus is important. The authors performed an anatomic study to clarify the risk of damage to the endolymphatic sac and endolymphatic duct during this maneuver.

METHODS: Twenty-seven sides of adult temporal bone were examined. Distances measured were between the posterior meatal lip and the upper limit of the endolymphatic ledge, at the upper extent of the endolymphatic sac, and between a reference line extending from the inferior margin of the internal acoustic meatus posteriorly (parallel to the petrous ridge), simulating the inferior margin of the drilling, and the upper limit of the endolymphatic ledge. Whether the latter was located on or above the line was also recorded. After posterior meatal wall drilling, the distance between the posterior meatal lip and the vestibular aqueduct surrounding the endolymphatic duct and the depth of the structure from the surface were assessed.

RESULTS: The shortest distances between the posterior meatal lip and the endolymphatic ledge and between the posterior meatal lip and the vestibular aqueduct were 6.80 mm and 4.68 mm, respectively. The upper limit of the endolymphatic ledge was present on or above the reference line in approximately half of the specimens.

CONCLUSION: During surgical maneuvers to remove the posterior meatal wall, the occasional close proximity of the endolymphatic sac and endolymphatic duct to the internal acoustic meatus should be kept in mind. Preoperative radiological evaluation of anatomic relationships is mandatory when preservation of hearing is the aim.

KEY WORDS: Acoustic neurinoma, Endolymphatic duct, Endolymphatic sac, Internal acoustic meatus, Temporal bone

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A membranous labyrinth consisting of the endolymphatic sac (ES) and endolymphatic duct (ED) contributes to inner ear homeostasis by endolymph production and resorption (12, 15, 21). Its functional importance and the hearing deterioration caused by damage to the component structure are well recognized, and their anatomic location has been determined precisely to facilitate preservation during posterior fossa surgery (1, 2, 4, 5, 14). For intrameatal acoustic neurinomas, the retrosigmoid lateral suboccipital approach is often chosen, but it has a risk of damage to the ES and ED during removal of the posterior meatal wall, because of their close anatomic proximity to the internal acoustic meatus (IAM) (3, 4, 16). Although the risk of injury to the semicircular canals during this procedure has been emphasized (16–18, 23), preservation of the ES and ED has received much less attention (4, 16). We present an anatomic study to clarify the risk of damaging the ES and ED with removal of the posterior meatal wall.

MATERIALS AND METHODS

Twenty-seven sides (18 right sides and nine left sides) of dried adult temporal bone were examined. On the posterior surface of the petrous part of the temporal bone, the following distances were measured by caliper: from the

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posterior meatal lip to the upper limit of the endolymphatic ledge at the upper extent of the ES, and from a reference line extending from the inferior margin of the IAM posteriorly, parallel to the petrous ridge, simulating the inferior margin of removal of the posterior meatal wall, to the upper limit of the endolymphatic ledge (*Fig. 1A*). Whether the latter was above or below the line was also recorded. After those measurements, posterior meatal wall drilling parallel to the petrous ridge, simulating opening of the IAM by the retrosigmoid lateral suboccipital approach, was performed under magnification. To facilitate identifying the vestibular aqueduct, the bony tunnel surrounding the ED, a thin thread was put in the aqueduct through its external aperture at the endolymphatic ledge before the drilling. In this drilling area, the distance between the posterior meatal lip and the aqueduct and the depth from the posterior surface of the bone needed to expose the aqueduct were measured (*Fig. 1B*).

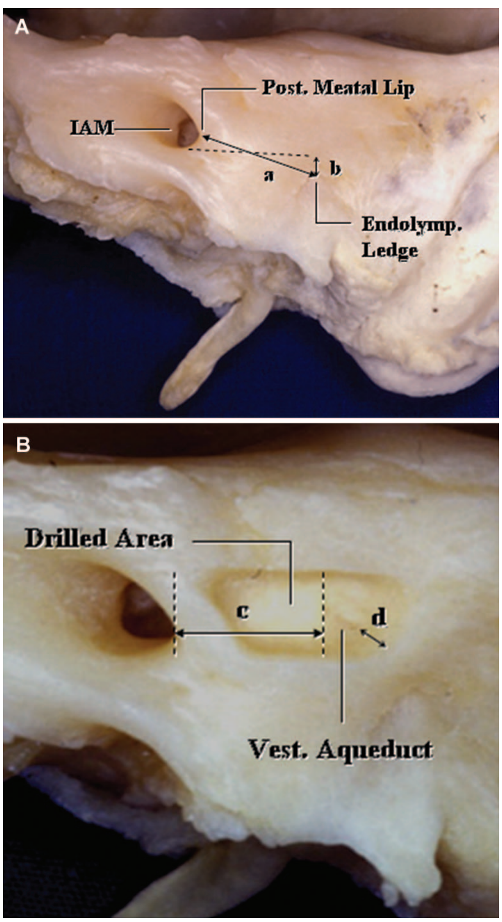

FIGURE 1. *Photographs demonstrating the medial view of the posterior surface of the right temporal bone before (A) and after (B) drilling of the posterior meatal wall. Measurements were made of the following:* a, *distance between the posterior meatal lip and the upper limit of the endolymphatic ledge;* b, *distance between the line extending from the inferior margin of the IAM posteriorly, parallel to the petrous ridge, and the upper limit of the endolymphatic ledge;* c, *distance between the posterior meatal lip and the vestibular aqueduct;* d, *depth of the aqueduct.* Endolymp., *endolymphatic;* Post., *posterior;* Vest., *vestibular.*

RESULTS

The distance between the posterior meatal lip and the upper limit of the endolymphatic ledge ranged from 6.80 to 18.67 mm (mean, 10.60 mm). Between the reference line extending from the inferior margin of the IAM posteriorly, parallel to the petrous ridge, and the upper limit of the endolymphatic ledge, the range was from 2.07 mm inferior to the line to 2.92 mm superior to the line. The mean location was 0.24 mm inferior to the line.

Distances between the posterior meatal lip and vestibular aqueduct ranged 4.68 to 10.92 mm (mean, 7.51 mm) and the depth from the posterior surface of the bone needed to expose the aqueduct ranged from 0.60 to 3.03 mm (mean, 1.48 mm). In six out of 27 sides (22.2%), the bulge of the common crus was located more medially than the aqueduct and, thus, was exposed first by the drilling. The distance between the posterior meatal lip and the medially bulged common crus was 6.14 to 8.21 mm (mean, 7.27 mm). Distributions of measurement values are shown in *Tables 1* through *4*.

DISCUSSION

The ES is located in the duplicated dura, posterolateral to the IAM on the posterior surface of the petrous part of the temporal bone. After passing the endolymphatic ledge, an external aperture of the vestibular aqueduct, the ES tapers and connects with the ED, the latter then entering the common crus, the union of the upper end of the posterior semicircular canal and the posterior end of the superior semicircular canal (*Fig. 2A*) (1, 11, 16).

TABLE 1. Distribution of distances between the posterior meatal lip and upper limit of the endolymphatic ledge for the 27 sides

Distance (mm)	No. of sides
6.00–6.99	1
7.00–7.99	2
8.00–8.99	3
9.00–9.99	0
10.00–10.99	8
11.00–11.99	7
12.00–12.99	2
13.00–13.99	3
14.00–14.99	0
15.00–15.99	0
16.00–16.99	0
17.00–17.99	0
18.00–18.99	1

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TABLE 2. Heights of the upper limit of the endolymphatic ledge from the internal auditory meatus[a]

Height (mm)	No. of sides
S 2.00–2.99	2
S 1.00–1.99	2
S < 1.00	5
O	4
I < 1.00	7
I 1.00–1.99	6
I 2.00–2.99	1

[a] S, superior to; O, on; I, inferior to the line extended from the inferior margin of the internal auditory meatus posteriorly, parallel to the petrous ridge.

TABLE 3. The distribution of distances between the posterior meatal lip and the vestibular aqueduct

Distance (mm)	No. of sides
4.00–4.99	1
5.00–5.99	3
6.00–6.99	4
7.00–7.99	10
8.00–8.99	6
9.00–9.99	0
10.00–10.99	3

TABLE 4. Depth from the posterior surface of the temporal bone needed to expose the vestibular aqueduct

Depth (mm)	No. of sides
<1.00	4
1.00–1.99	18
2.00–2.99	4
3.00–3.99	1

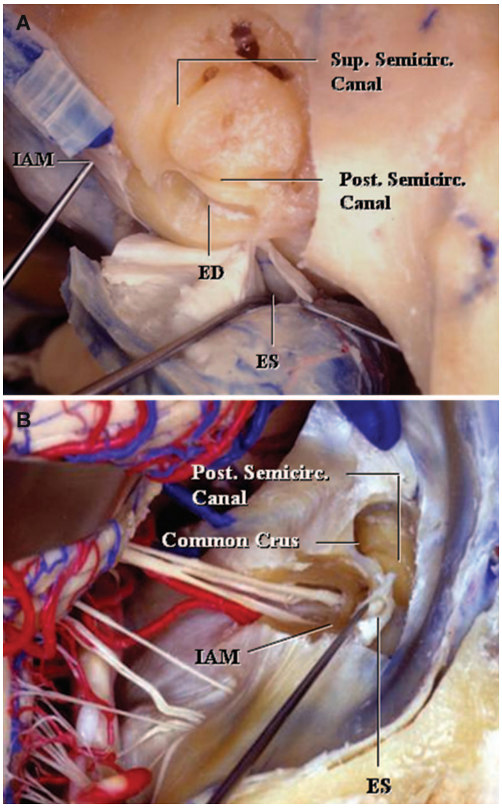

FIGURE 2. A, *photograph of a wet specimen showing the relationships among the IAM, ES, ED, common crus, and semicircular canals on the right side. The dura containing the ES is reflected.* B, *photograph of a specimen after removal of the posterior meatal wall laterally to expose the meatal fundus. The ES is situated next to the lateral limit of drilling and the ED has been damaged.* Post., *posterior;* Semicirc., *semicircular;* Sup., *superior.*

During removal of the posterior meatal wall for intrameatal acoustic neurinomas, the ES and ED may be damaged both during incision and dissection of the dura and on drilling of the bone overlying the IAM. For dural incisions along the IAM, the distance between the posterior meatal lip and upper limit of the ES and the height of the upper limit of the ES are important for assessment of the risk of damage. The shortest distance obtained was 6.80 mm, and an endolymphatic ledge overlying the IAM was observed in 13 out of 27 sides (48.1%). A previously described shortest distance between the posterior meatal lip and ES, 6 mm, was shorter than ours (9, 10). An ES located in an anterior and high position is at greater risk of being incised.

The ED may be damaged by a too lateral extension of the drilling. However, the present study showed that even drilling limited to the medial part may damage these structures occasionally (*Fig. 2B*). The shortest distance between the posterior meatal lip and vestibular aqueduct was only 4.68 mm; thus, the definite safe zone for drilling is less than 4 mm. A distance of less than 8.00 mm was observed in 18 out of 27 sides (66.7%), and the most frequent distribution was 7.00 to 7.99 mm in 10 out of 27 sides (37.0%). This means that the ED is at greater risk of being damaged when trying to expose the fundus of the IAM, with minimum depth of 7.3 mm (9, 10). In addition, the longer drilling area posterior to the IAM needed for exposure of the fundus through smaller cranial openings increases the risk of ED damage (3). Although it has been suggested that sacrifice of the ED is unavoidable to expose the lateral part of the IAM by the suboccipital approach (4), the present study showed that it is not inevitable in patients in whom the ED is located in a more posterior position. The depth of the aqueduct or medially bulged common crus from the posterior surface of the petrous part was 1.00 to 1.99 mm in the vast majority of sides (18 out of 27; 66.7%).

To avoid damaging the ES and ED, the following measures are recommended. Before removing the dura, the location of

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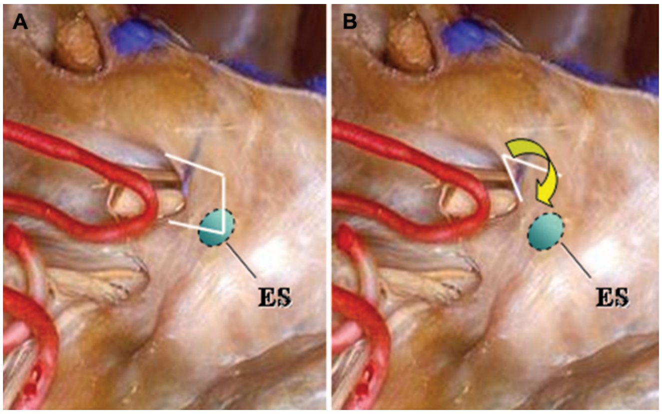

FIGURE 3. *Photograph showing the relationships between the ES and dural incisions (*white lines*) for removal of the posterior meatal wall. An unidentified ES (*broken-lined circle*) may be damaged by standard dural incision (*A*), but dissection of the dural flap from the cephalad to caudal regions may help to identify and preserve the structure (*B*).* Curved arrow *shows the direction of the dura incised.*

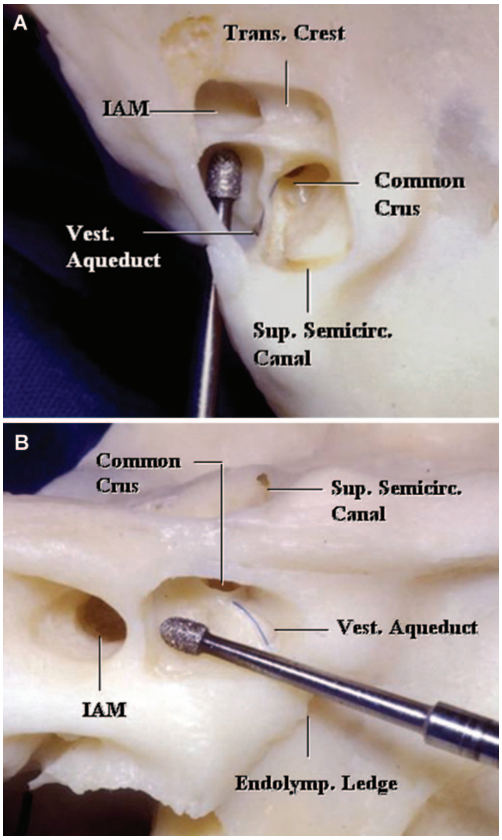

FIGURE 4. *Photographs showing the relationships among the IAM, ES, vestibular aqueduct, common crus, and semicircular canals during removal of the right posterior meatal wall: superior view (*A*) and medial view (*B*). The aqueduct is situated just lateral to the area of drilling, and is thus difficult to identify in the posterior, actual surgical view. A thread is placed in the vestibular aqueduct through the endolymphatic ledge.* Endolymp., *endolymphatic;* Semicirc., *semicircular;* Sup., *superior;* Trans., *transverse;* Vest., *vestibular.*

the ES can be identified by inspection or palpation by a dissector to feel the ballottement (16), although this may be difficult in patients with a small ES. The smallest recorded values for the ES (width and height) and the width of the external aperture of the vestibular aqueduct are 2.0 and 2.5 mm and 1.0 mm, respectively (1, 2). In such cases, dissection of the dural flap from the cephalad to caudal regions may help to identify the endolymphatic ledge, and the ES can be preserved (*Fig. 3*). Magnetic resonance imaging, introduced for cases of Ménière's disease or large vestibular aqueduct syndrome (6–8, 19, 22), is applicable for preoperative localization of the ES. The existing most accurate sequence to depict the configuration of the ES is proton density-weighted imaging (8). The normal-sized ED is difficult to visualize, even on magnetic resonance imaging scans, because of its fine diameter, but localization may be estimated from the location of the ES and common crus, structures visible on magnetic resonance imaging scans (11); the ED is situated between them. For depiction of the ED, fine slice bone window computed tomography is more useful (3).

In the drilling process, it should be considered that identification of the posterior margin of the posterior meatal lip as a landmark is difficult in patients with a funnel-shaped deformity of the IAM. Also, difficulty in identifying the ED in actual surgical views (posterior or posterolateral view) should be kept in mind during this process *(Fig. 4*). Several factors may contribute to postoperative hearing deterioration in acoustic neurinoma surgery, despite anatomic preservation of the cochlear nerve: retraction of the cochlear nerve, ischemia of the nerve resulting from dissection and coagulation of small vessels, avulsion of the nerve from the lamina cribrosa at the meatal fundus, heat and vibration damage during drilling, and opening of the labyrinth (4, 13, 16, 20, 23). In addition, injury to the ES and ED may be a cause, so care should be taken at each step of removal of the posterior meatal wall when preservation of hearing is the aim.

CONCLUSION

From the anatomic relationships of the ES and ED to the IAM, their possible close proximity should be kept in mind for preservation of these structures and avoidance of postoperative hearing deterioration during removal of the posterior meatal wall. The occasional unexpected juxtaposition may be an anatomic factor restricting removing the posterior meatal wall posterolaterally, as well as the presence of a high-projection jugular bulb.

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COMMENTS

This is an excellent anatomic delineation of the endolymphatic system as seen from the suboccipital approach. It should be noted, relative to hearing preservation, that the key structure that should be avoided is the endolymphatic duct (ED). Surrounding the ED is a plexus of vessels that remove fluid from the endolymphatic system. These vessels are not present over the endolymphatic sac (ES). If the ED is interrupted, there is, indeed, likelihood for development of endolymphatic hydrops and inner ear malfunction. If the ES is lacerated or even removed, the likelihood of damage to the inner ear is minimal. This has been my experience in performing more than 800 retrolabyrinthine vestibular nerve sections. In this operation, the ES is routinely interrupted without any deleterious effect on the inner ear.

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This is an elegant anatomic study of 27 temporal bone sides that was used to elucidate the potential risk of lesion to the ES and ED in acoustic neurinoma surgery. During removal of the posterior lip of the internal auditory canal, those lesions are likely to occur.

To avoid lesions to the ES and to better orientate the dural opening in the anteroposterior and craniocaudal direction, two measurements were made. The posterior meatal lip and the inferior margin of the internal auditory meatus (IAM) were used as landmarks. The results demonstrate that the shortest distance between the posterior meatal lip and the ES was 6.8 mm and that this structure was 0.2 mm from the inferior limit of the IAM. These anatomic correlations may help to identify the ES, especially when it is not evident either by visualization, palpation with a dissector, or through the recognition of the dura duplication.

To avoid lesions to the vestibular aqueduct and the ED and better orient the drilling of the meatal lip, third and fourth measurements were made. The posterior meatal lip was used as a landmark together with the depth of the aqueduct. The authors demonstrated that, to preserve the vestibular aqueduct, the removal of the posterior lip of the internal auditory canal could not be greater than 4 mm from the IAM (average, 7.5 mm). In 22% of the cases, medially bulged common crus was located 7.27 mm from the IAM. This study describes anatomic landmarks that can be used in the operating room for the acoustic neuroma removal or any other surgery that requires internal auditory canal opening. However, it should be emphasized that all the measurements that used the posterior meatal lip as a major landmark are of limited value when the tumor enlarges and sometimes erodes the IAM.

Another consideration is that lesions of the ES or the ED are rarely associated with hearing loss. An elective opening of the vestibular aqueduct is sometimes necessary to treat the Ménière's disease or endolymphatic hydrops. The hearing loss is more likely to occur with lesions that are closer to the cochlea. In acoustic neurinoma surgery, the lesions that are more likely to be associated with hearing loss are those that occur in the posterior or the superior semicircular canals or the common crus. This study shows that, to preserve this last structure, the surgeon could drill up to 6.14 mm (average, 7.27 mm) from the posterior lip of the IAM. If the ES is used as a landmark, any drilling of the posterior wall medial to it (average, 6.8 mm from the

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IAM) is safe to avoid the common crus injury in most of the cases. The combination of those anatomic landmarks with high-quality computed tomographic scans and the magnetic resonance imaging scans helps to minimize the risk of surgical complications.

A medially extended craniotomy will offer a better exposition of the internal auditory canal fundus with less drilling of the temporal bone. This minimizes the risk of labyrinthine injury. The use of a small craniotomy is restricted to those cases in which the tumors do not fill the entire internal acoustic canal.

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The authors report an anatomic study, the purpose of which is to clarify the risk of damage to the ES and ED during drilling of the posterior lip of the internal auditory canal through the retrosigmoid approach when performing acoustic tumor surgery with the goal of preserving hearing. The authors did an excellent job in making these measurements in a significant number of temporal bones. The authors did notice that significant discrepancies exist between their numbers and others published in the literature.

As indicated by the measurements, the variations are too wide to be useful for practical purposes while dissecting the posterior lip. One has to rely on the experience of the surgeon and the ability to identify the sac and duct while performing the dissection. As noted by the authors, in a certain percentage of cases, the labyrinth will be entered before identifying the duct, making it impossible to preserve hearing in those cases in which the sac and duct are used only as landmarks.

It remains true that dissecting tumors in the fundus of the internal auditory canal through this approach and attempting hearing preservation is an impossible task because the lateral half of the posterior lip cannot be opened without getting into the vestibule. Therefore, for dissection of intracanalicular tumors, we prefer the middle fossa craniotomy approach. It has also been our experience that manipulating the intracranial portion of the ES has no deleterious effect on the hearing mechanism. This is a thorough report on the anatomy of the intracranial portion of the ES as it relates to posterior internal auditory canal exposure during the retrosigmoid approach.

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This is a carefully illustrated anatomic study depicting the situation of the ED, ES, and vestibular aqueduct in relation to the internal acoustic meatus. The authors describe the temporal bone anatomy from a surgeon's point of view. Although not all of the presented measurements are completely new (1, 2), the presented images are instructive for surgeons dealing with the microsurgical opening of the internal acoustic meatus. The images underline the need for preoperative evaluation of high-resolution computed tomographic scans of the posterior fossa.

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2. Lang J: Cerebellopontine angle and temporal bone, in Kobayashi S (ed): *Surgical Anatomy for Microneurosurgery*. Tokyo, Scimed Publications, 1989, pp 37–47.

This is an excellent and well thought-out anatomic study of the microanatomy of the posterior-medial surface of the temporal bone. Preservation of the ES and ED when drilling the posterior meatal lip of the internal auditory canal is challenging and subject to significant anatomic variation. In addition, the biological behavior of the tumor and the degree of bone remodeling secondary to tumor growth can alter the bony landscape. Certainly, hearing preservation in acoustic neuroma surgery is a multifactorial issue. In addition to anatomic preservation of the VIIIth nerve, care must be taken to avoid stretching and devascularization. Furthermore, a thorough knowledge of temporal bone anatomy is essential to prevent fenestration of the labyrinth. This study provides the surgeon with additional anatomic guidelines to facilitate the meatal removal. The degree to which damage of the sac and duct are responsible for hearing loss during acoustic tumor surgery is unknown. However, following the guidelines proposed in this article will serve as an adjunct to refining the surgical technique.

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