# Chapter 131 – Surgery for Vertigo

**William A. Wood,**
**Elizabeth H. Toh**

Vertigo may result from disorders of both the central and peripheral vestibular systems. The majority of patients may be managed conservatively with medical therapy and vestibular rehabilitation therapy. Critical to the management of patients with vertigo is the correct diagnosis of the underlying pathology. Those with peripheral vestibular disease who have symptoms refractory to medical management may benefit from surgery. Surgical options include those that address the specific pathology of the disease and those that ablate the peripheral vestibular organ. This chapter describes operative techniques for posterior semicircular canal occlusion (PSCO), endolymphatic sac decompression with or without shunting, labyrinthectomy, vestibular nerve section, and repair of superior semicircular canal dehiscence. Repair of perilymph fistulas is described in Chapter 119.

## *PATIENT SELECTION*

Several criteria should be met before considering surgery for vestibular disease. First, a definitive diagnosis of a unilateral peripheral vestibulopathy should be made. This can usually be established following a comprehensive history, physical examination, and vesti-bular testing. The latter aids in localizing the site of pathology and excluding any underlying central vestibular problems that will impair vestibular compensation following ablative surgery. Bilateral and central vestibular dysfunctions are contraindications for ablative surgery such as labyrinthectomy and vestibular nerve section.

Next, graduated and comprehensive medical management of the vertigo should be instituted. This should include a trial of pharmacotherapy and for uncompensated peripheral vestibulopathy, a course of vestibular rehabilitation therapy. If symptoms persist despite nonsurgical treatment and are disabling, surgical options may be considered.

Last, the age, comorbidities, and overall physical condition of the patient should be considered. In general, central vestibular compensation following ablative surgery is poorer in older individuals. Persistent disequilibrium may render that individual more disabled compared with their preoperative condition.

The most common peripheral vestibular disorders amenable to surgical intervention include benign paroxysmal positional vertigo (BPPV), Meniere's disease, uncompensated peripheral vestibulopathy, perilymph fistula, and superior semicircular canal dehiscence (SCDS) syndrome.

### Benign Paroxysmal Positional Vertigo

The current canalolithiasis theory holds that the pathophysiology of BPPV likely results from free-floating otoconia within the posterior semicircular canal (PSC). Intraoperative observations of particulate matter in the PSC in some patients with BPPV support this hypothesis.[1] Positional changes cause movement of the otoconia within the canal, which in turn produces endolymph currents that deform the cupula and cause vertigo. BPPV is usually idiopathic, but may also begin after head trauma or vestibular neuritis. Patients often complain of sudden, short-lived severe vertigo related to changes in head position, particularly when going to, rolling over in, or arising out of bed.

A variant of the theory of pathogenesis of BPPV holds that these detached crystals adhere to either the gelatinous cupula of the crista ampullaris ("cupulolithiasis"). A competing theory is that there is loss of inhibitory input from the damaged otoliths.[2] Also, magnetic resonance imaging (MRI) of patients with permanent or "atypical" BPPV has shown fractures or filling defects in the semicircular canals that are not seen in control subjects.[3,4]

Particle repositioning is the mainstay of treatment for BPPV. A recent meta-analysis of nine randomized controlled trials with a total of 505 patients found that canalith repositioning is very effective, while noting that approximately one third of patients experience spontaneous resolution within 3 weeks.[5] The most recent published case series notes that in a practice with more than 3000 patients evaluated and treated for BPPV over a 7-year period, less than 1% of patients required surgical intervention.[6]

For the small subset of patients with intractable and multiply recurrent BPPV, occlusion of the PSC is offered (PSCO). Success rates for PSCO, as defined by significant relief of symptoms, are greater than 90% in most, if not all, series. Postoperative sequelae commonly include unsteadiness that may persist for only a few weeks to more than a year, and occasionally sensorineural hearing loss (SNHL), which some authors attribute to comorbidities (e.g., coexisting Meniere's disease and previous otologic surgery). Division of the singular nerve (singular neurectomy) that innervates the PSC is no longer performed for BPPV. Preoperatively, the patient should undergo an enhanced MRI scan of the internal auditory canals to evaluate for the rare presence of a retrocochlear lesion that may present with BPPV symptoms.[7]

## Meniere's Disease

*Meniere's disease* is the traditional term for idiopathic symptomatic endolymphatic hydrops. Some authorities describe the classic constellation of symptoms—fluctuating hearing loss, vertigo, a sensation of aural fullness and/or tinnitus—as *Meniere's syndrome* and reserve the term *Meniere's disease* for the idiopathic form, because the symptom complex may also result from, for example, an infectious etiology such as syphilis.[8] The aural symptoms typically make localization self evident for the patient and physician, but the physician must elicit a directed and detailed history to narrow the differential diagnosis. The natural history of the disease varies greatly. A number of studies report long-term follow-up that seems to indicate some cases of Meniere's progressively worsen, whereas others stabilize. A number of longitudinal studies have noted progression to bilateral disease in one third or more of patients, increasing as the disease progresses.

The majority of patients with Meniere's disease experience control of vestibular symptoms with medical treatment alone, although hearing loss generally progresses with time. This includes a combination of dietary salt and caffeine restriction, and diuretic therapy (Dyazide). Other medications used with some success in Meniere's disease include vasodilators, histamines, and steroids. When a 6-month trial of medical therapy fails to adequately control vertigo attacks, treatment options include surgery, intratympanic steroid or gentamicin therapy, and use of the Meniett device. The indications and techniques for intratympanic therapy are discussed in Chapter 107. All of these invasive treatment options aim to control the vertigo attacks only. Relief of tinnitus and aural fullness, and hearing stabilization or recovery is not consistently achieved. Surgical options for Meniere's disease include endolymphatic sac surgery, labyrinthectomy, and vestibular nerve section.

Endolymphatic sac surgery for Meniere's disease remains controversial. Surgery theoretically modulates endolymphatic sac function enough to control vertigo in approximately 60% of patients. The risk of additional hearing loss with sac surgery is minimal. Decompression alone is indicated for Meniere's disease in an only hearing ear because the theoretical risk of hearing loss is less compared with decompression with opening of the endolymphatic sac for shunt placement. One well-known randomized controlled trial comparing endolymphatic shunt placement with cortical mastoidectomy failed to show any therapeutic benefit of shunt surgery over mastoidectomy alone.[9] Subsequent statistical analyses of the same data set argue that the results support the efficacy of the shunt and do not support the placebo effect claimed by the original authors.[10] A subsequent randomized controlled study performed by Thomsen and colleagues compared shunt surgery with insertion of a tympanostomy tube and again failed to demonstrate any advantage to shunt surgery.[11]

Vestibular nerve section denervates the vestibular end organ with a small risk of additional hearing loss. Vertigo control for Meniere's disease alone using this procedure is greater than 90%. There are three surgical approaches for this procedure: retrolabyrinthine, middle fossa, and translabyrinthine. The retrolabyrinthine approach is the preferred approach for a hearing ear. The middle fossa approach is reserved for hearing patients with persistent vertigo following a retrolabyrinthine nerve section due to the presence of persistent vestibular nerve fibers in the distal internal auditory canal.

Labyrinthectomy involves surgical removal of the sensory epithelium of all five vestibular end organs and results in the loss of input to the central nervous system. The absence of this input facilitates better central compensation, as compared to aberrant input from an improperly functioning organ.[12] The procedure is offered only to patients with unilateral Meniere's disease and no useful residual hearing in the affected ear. Vertigo control is greater than 90%, although all residual hearing in the operated ear is sacrificed. For rare residual symptoms after labyrinthectomy, translabyrinthine vestibular neurectomy can be performed.

## Surgery for Uncompensated Peripheral Vestibulopathy

Uncompensated unilateral peripheral vestibulopathy causes long-term persistence of disequilibrium and dizziness following a unilateral peripheral vestibular insult. Most cases result from trauma, Meniere's disease, and vestibular neuritis. Despite vestibular rehabilitation therapy, these patients continue to experience disabling symptoms. Some patients develop concurrent or subsequent BPPV, which can usually be treated successfully with repositioning.[13] For patients with ongoing symptoms beyond the inciting episode who do not respond adequately to medical management and vestibular rehabilitation, vestibular ablation of the affected ear should be considered. Treatment options include chemical ablation with intratympanic gentamicin therapy, vestibular neurectomy, and labyrinthectomy, as described for Meniere's disease.

## Surgery for Superior Canal Dehiscence Syndrome

In 1998, Minor described a new syndrome with vertigo induced by sound (Tullio's phenomenon) or aural pressure

(Hennebert's sign), and computed tomography (CT) evidence of dehiscent bone over the superior semicircular canal (SSC).[14] Valsalva maneuvers, sneezing, and other activities that increase intracranial pressure may produce vertigo. Office pneumatic otoscopy should elicit upward eye movement in the plane of the SSC. If elicited, this provides sufficient clinical suspicion to proceed with a high-resolution CT scan of the temporal bone. Additional testing may include vestibular evoked myogenic potentials (VEMPs), measured via contractions of the tonically active sternocleidomastoid muscle to loud click noises presented in the ipsilateral ear. Audiometric testing in these patients may show a conductive hearing loss with intact stapedial reflexes resulting from an inner ear conductive loss created by the dehiscent SSC segment behaving as a “third window.”

Diagnosis of SCDS is confirmed on high-resolution CT imaging of the temporal bone in the coronal plane using a bone algorithm (Fig. 131-1). There is no advantage to additional Stenver and Pöschl views on CT imaging, which are digitally reformatted in planes perpendicular and parallel to the SSC, respectively.[15] One recent retrospective review evaluating radiologic findings alone in more than 400 temporal bone CT scans found evidence of a dehiscent-appearing SSC in 9% of studies, indicating a high sensitivity but low specificity for imaging in SCDS, given the apparent rarity of the clinical syndrome.[16]

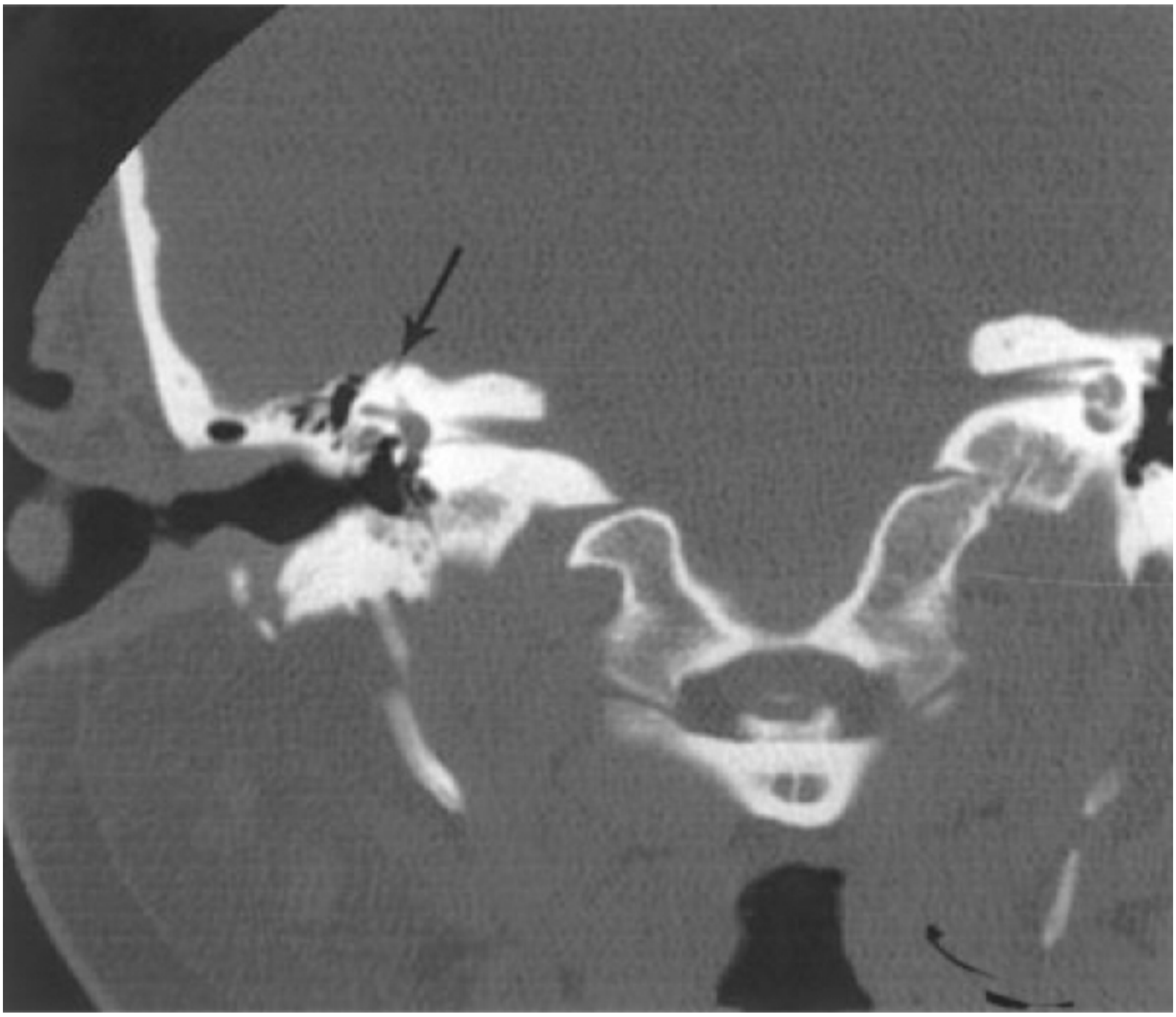

**Figure 131-1** Coronal computed tomography of temporal bone showing dehiscence of superior semicircular canal *(arrow)*.

Repair of the bony defect over the SSC may be offered for relief of severe and disabling noise- and pressure-induced vertigo. The SSC is surgically accessed through a middle fossa approach. The SSC is either plugged using a technique analogous to that used for posterior canal occlusion in BPPV, or the dehiscent canal is covered with a combination of fascia, bone, and fibrinogen glue. Minor reported a case series of 20 surgical repairs and found resolution of symptoms in 8 of 9 patients treated with plugging and 9 of 11 patients treated with capping without plugging.[17]

## PREOPERATIVE PLANNING

Following a complete medical evaluation, the patient's vestibular complaints can usually be localized to the central or peripheral vestibular organs. In the case of peripheral vestibular disease, when a reasonable trial of medical therapy fails to control vertigo and the patient is significantly disabled as a result of ongoing vestibular symptoms, the options for surgery and chemical ablation of the vestibular labyrinth should be discussed. The risks, complications, alternatives, and expected results of each procedure appropriate for the clinical situation are discussed with the patient.

A gadolinium-enhanced MRI scan of the brain and internal auditory canals is obtained as part of the initial diagnostic evaluation to exclude the presence of a retrocochlear or intracranial tumor. Additional CT imaging of the temporal bone as described earlier is obtained if there is clinical suspicion of SCDS. Vestibular function testing is used to localize the side of vestibular impairment and diagnose significant bilateral peripheral vestibular hypofunction or central vestibular dysfunction. The presence of bilateral or central vestibular dysfunction may significantly impair post-operative vestibular compensation and should therefore be taken into consideration when determining candidacy for vestibular ablation. The mobility and quality of life in older individuals with preexisting disequilibrium are severely impacted following any ablative procedure.

Preoperative hearing assessment is critical in selecting the appropriate surgical procedure and approach for each individual. Functional hearing is typically defined as a pure tone average of 50 dB or better and a word recognition score of 50% or better. These scores are used as general guidelines rather than absolute criteria for hearing preservation in vestibular surgery. The inability to perceive benefit from conventional amplification in the affected ear serves as an indicator of poor functional hearing in that ear. The hearing status of the contralateral ear is also assessed preoperatively. If treatment is being offered for an only-hearing ear, conservatism is the preferred approach.

## ***SURGICAL APPROACHES***

### Posterior Semicircular Canal Occlusion

The patient is positioned and prepped as for standard mastoid surgery. Facial nerve monitoring is not routinely used. Broad-spectrum antibiotics may be administered intravenously at induction of general anesthesia. Through a standard postauricular approach, the surgeon performs a limited cortical mastoidectomy to expose the mastoid antrum and lateral semicircular canal (LSC) in the usual fashion. A saline-soaked Gelfoam pledget is placed into the aditus ad antrum to reduce the amount of blood and bone dust that enter the middle ear space. The PSC lies posterior and perpendicular to the LSC. The surgeon uses a small diamond burr to skeletonize and blue-line the PSC. A 1- × 3-mm oval window of bone over the mid portion of the PSC is then carefully thinned using a small diamond burr without violating the membranous labyrinth. The lumen of the PSC may be occluded using bone wax,[18] bone paste (bone dust mixed with fibrinogen glue),[19] or soft tissue (Fig. 131-2). The selected material should be prepared and ready for application before exposure of the membranous labyrinth. Bone dust and bone wax are applied to the PSC on the back of a duckbill elevator (see Video 131-1). Suction should not be applied to the opened canal because this may disrupt the membranous labyrinth and cause SNHL. After occlusion of the canal, the PSC defect may be covered with fascia, additional bone paste, and/or autologous blood. The surgical site is then closed in a layered fashion as described in Chapter 115.

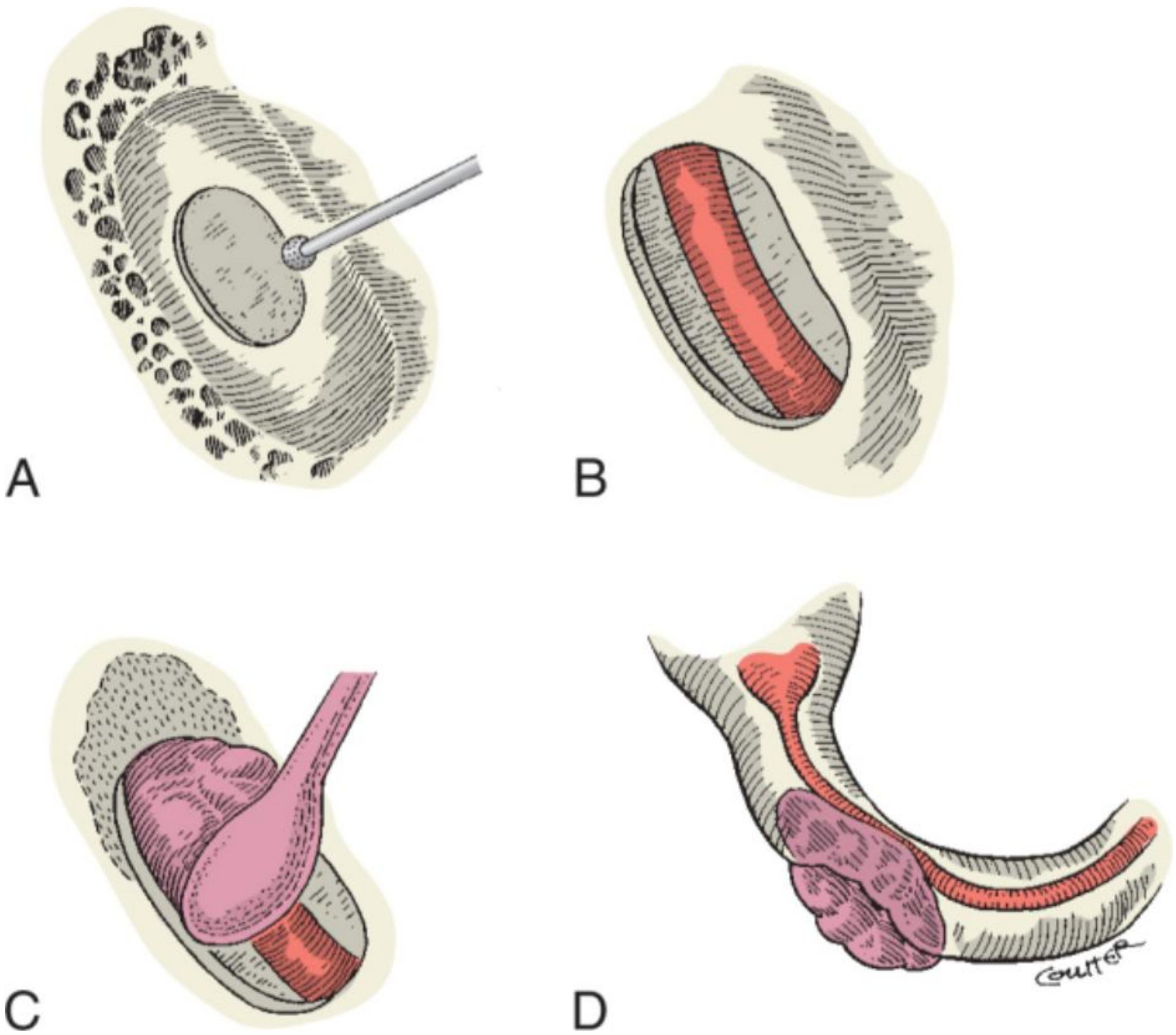


**Figure 131-2** Technique for posterior semicircular canal (PSC). **A,** Skeletonization of midportion of PSC using small diamond burr. **B,** PSC fenestrated without violating membranous labyrinth. **C,** Bone wax, bone paste, or soft tissue is applied to the fenestrated portion of the PSC using a duckbill elevator. **D**, The membranous labyrinth within the PSC is compressed and occluded.

Most published reports describe mechanical plugging as the mainstay of PSCO. The $CO_2$ laser may also be used for ablation of the membranous labyrinth as an adjunct to mechanical plugging of the PSC.[20] Either technique should prevent circulation of endolymph within the occluded membranous PSC and relieve the disabling symptoms of BPPV.

## Endolymphatic Sac Decompression or Shunt

The patient is positioned and prepped as for standard mastoid surgery. Facial nerve monitoring is routinely used. Perioperative antibiotics are not routinely administered. A postauricular incision is made approximately 1 to 2 cm posterior to a standard postauricular incision for mastoid surgery because such an incision may be used in the future to perform a retrolabyrinthine nerve section for patients with persistent vertigo following endolymphatic sac surgery. A complete mastoidectomy is then performed. The mastoid antrum is entered and the LSC is identified. The sigmoid sinus is then skeletonized down to the proximal jugular bulb (Fig. 131-3). A saline-soaked Gelfoam pledget is placed into the aditus ad antrum to reduce the amount of blood and bone dust that enter the middle ear space.

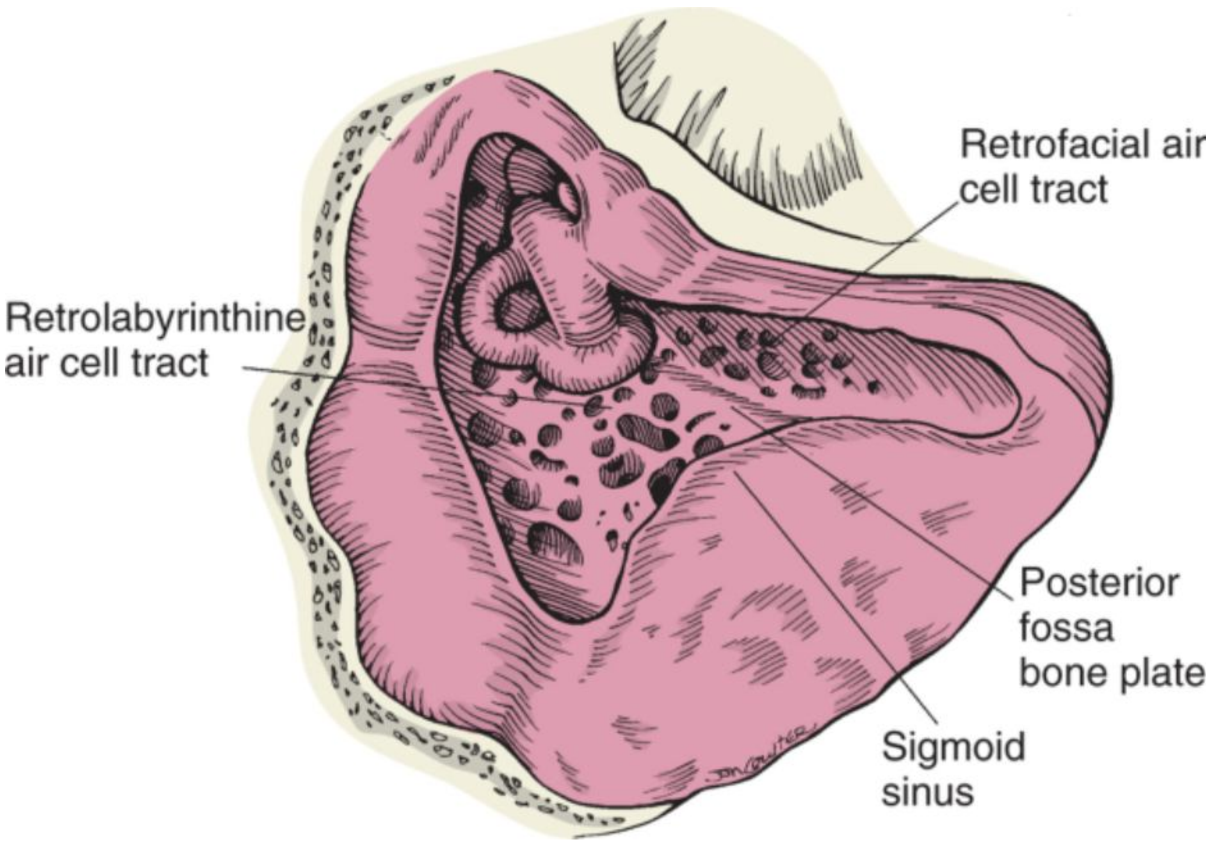


**Figure 131-3** Complete mastoidectomy with skeletonization of the posterior semicircular canal, retrolabyrinthine and retrofacial air cells, sigmoid sinus, jugular bulb, and posterior fossa bone plate.

The endolymphatic sac lies deep to the posterior fossa bone plate, between the PSC and the sigmoid sinus. It is consistently inferior to “Donaldson's line,” an imaginary line extending posteriorly from the plane of the LSC. The vertical facial nerve is identified, using the LSC as a landmark, and skeletonized, as is the PSC, before opening the retrofacial air cells between the facial nerve laterally and the posterior fossa plate medially. The retrolabyrinthine air cell tract over the posterior fossa plate leads to the junction of the PSC and the posterior fossa dura, and removal of these air cells expose the operculum of the vestibular aqueduct (Fig. 131-4). Opening the retrofacial air cell tract exposes the junction of the ampullated limb of the posterior semicircular canal and posterior fossa plate overlying the endolymphatic sac.

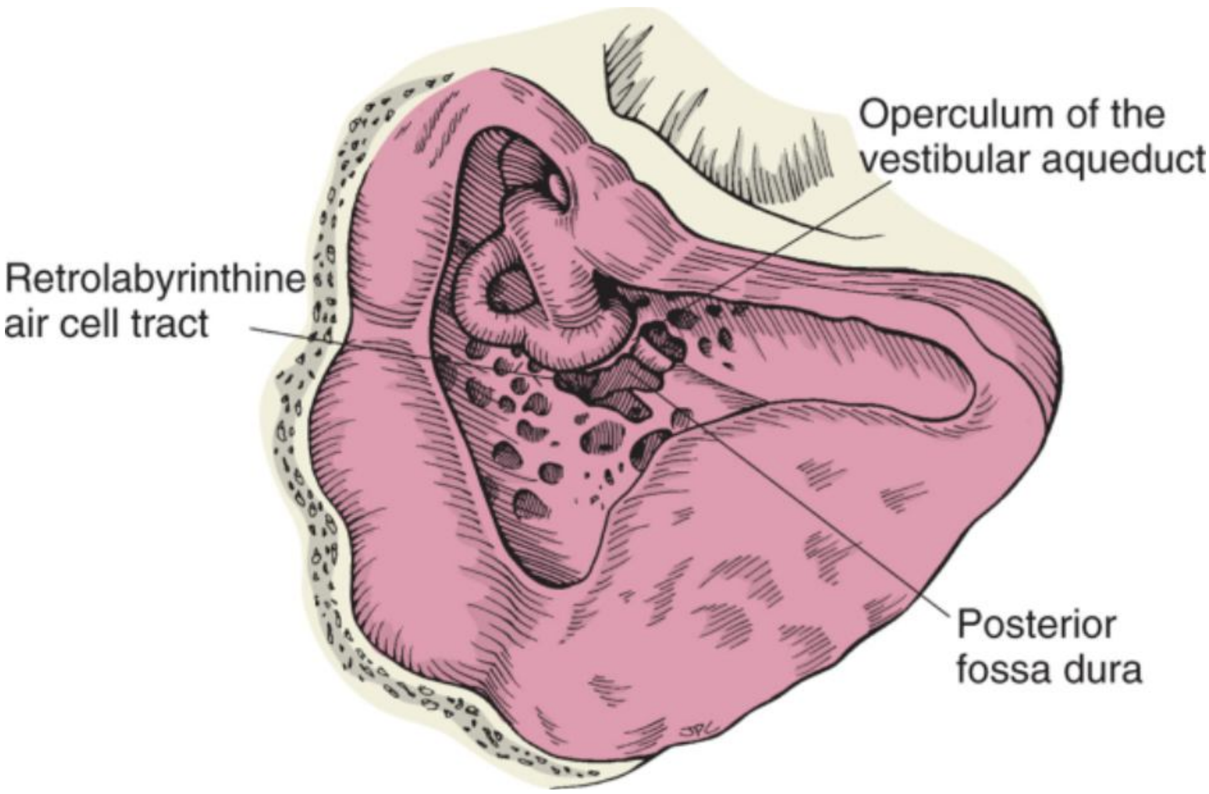


**Figure 131-4** The retrolabyrinthine air cell tract is opened, leading to the junction of the posterior semicircular canal and the posterior fossa dura near the operculum of the vestibular aqueduct.

Once the posterior fossa plate has been thinned to an eggshell thickness from the anterior border of the sigmoid sinus to the PSC, the thin remaining bone over the dura is removed using a Freer elevator or a large diamond burr to widely expose the endolymphatic sac (Fig. 131-5). The sac appears as a fan-shaped thickening of the dura spreading out from just deep to the PSC, posterolaterally toward the sigmoid sinus (Fig. 131-6). The dura medial to the PSC can be palpated to define the operculum and endolymphatic duct (Fig. 131-7).

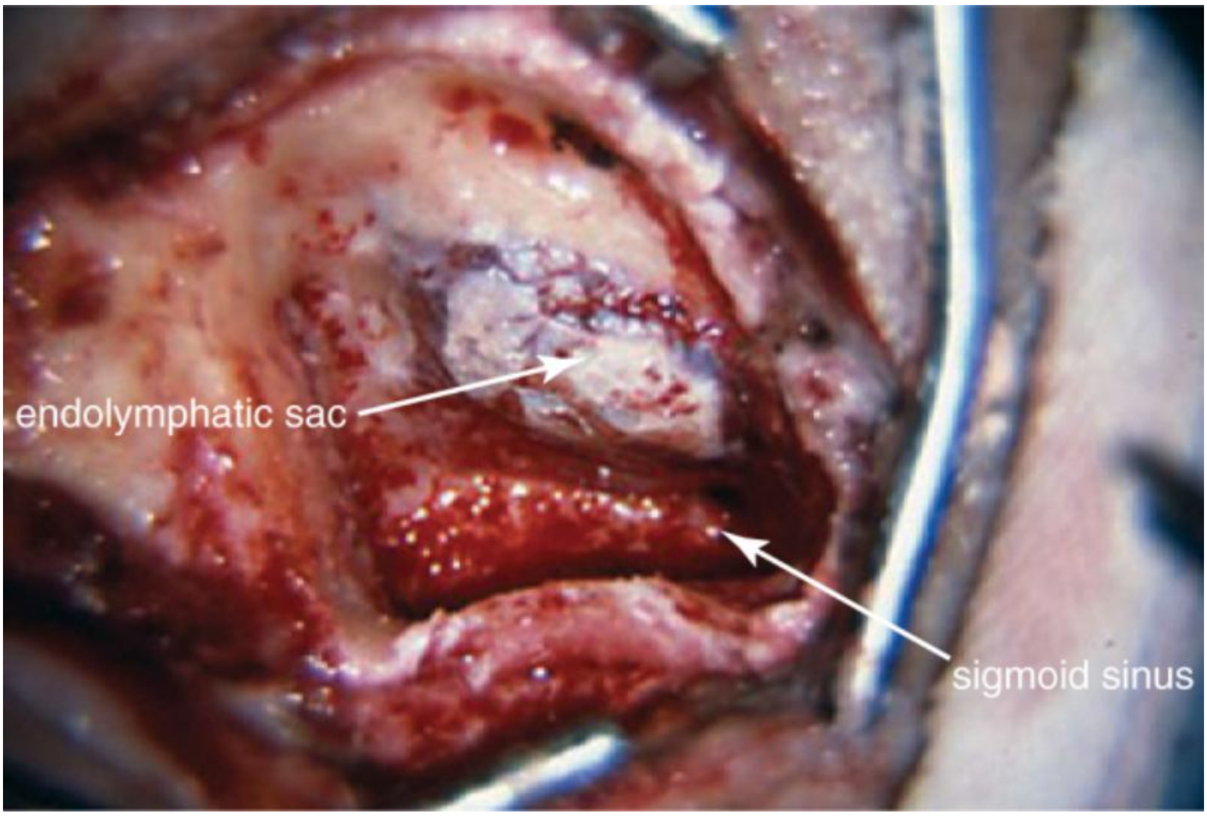

**Figure 131-5** The dura of the posterior fossa is widely exposed. The endolymphatic sac is visible as a thickening of the dura fanning out from the posterior semicircular canal to the sigmoid sinus.

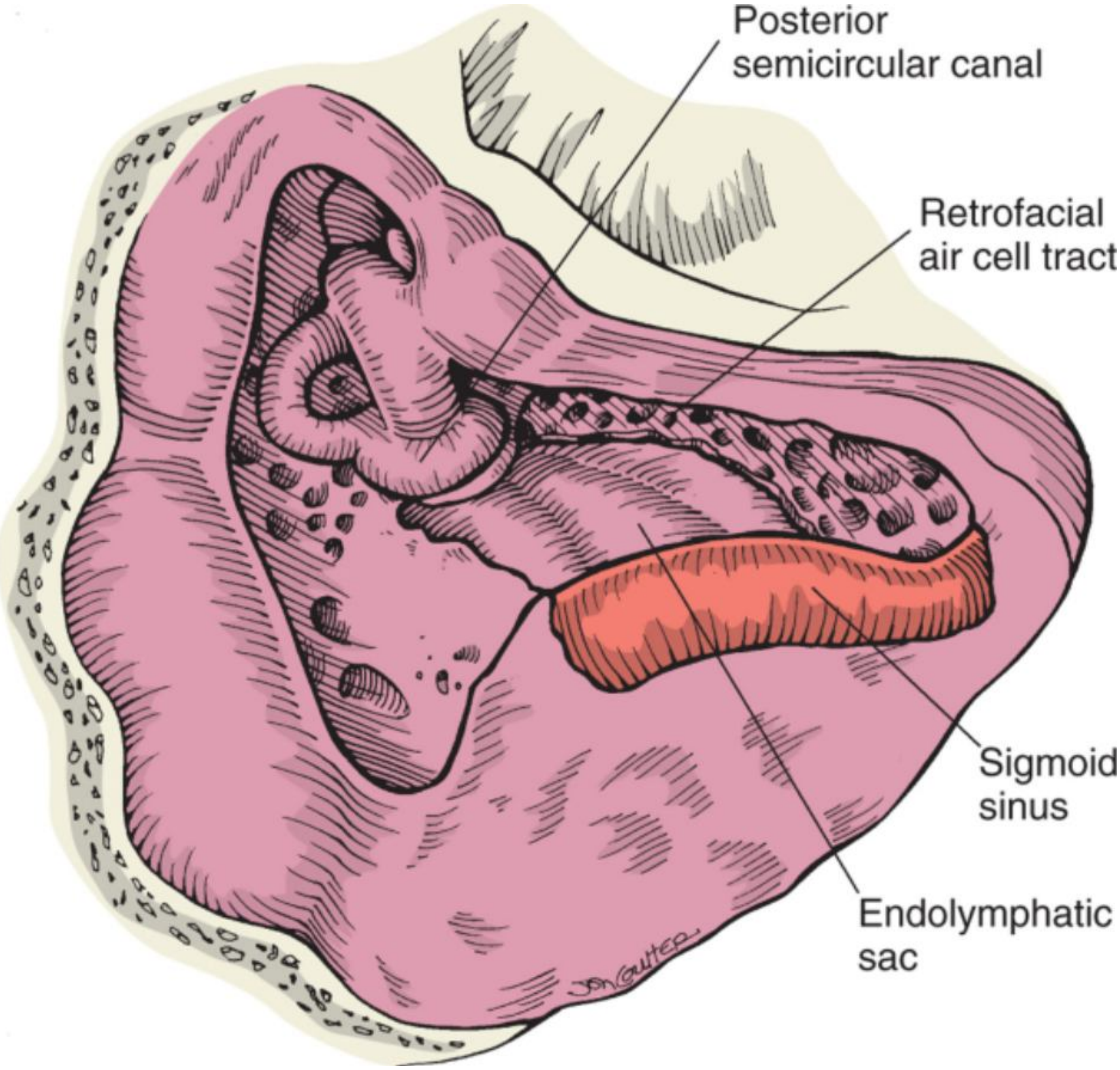


**Figure 131-6** Location of the endolymphatic sac between the posterior semicircular canal and sigmoid sinus.

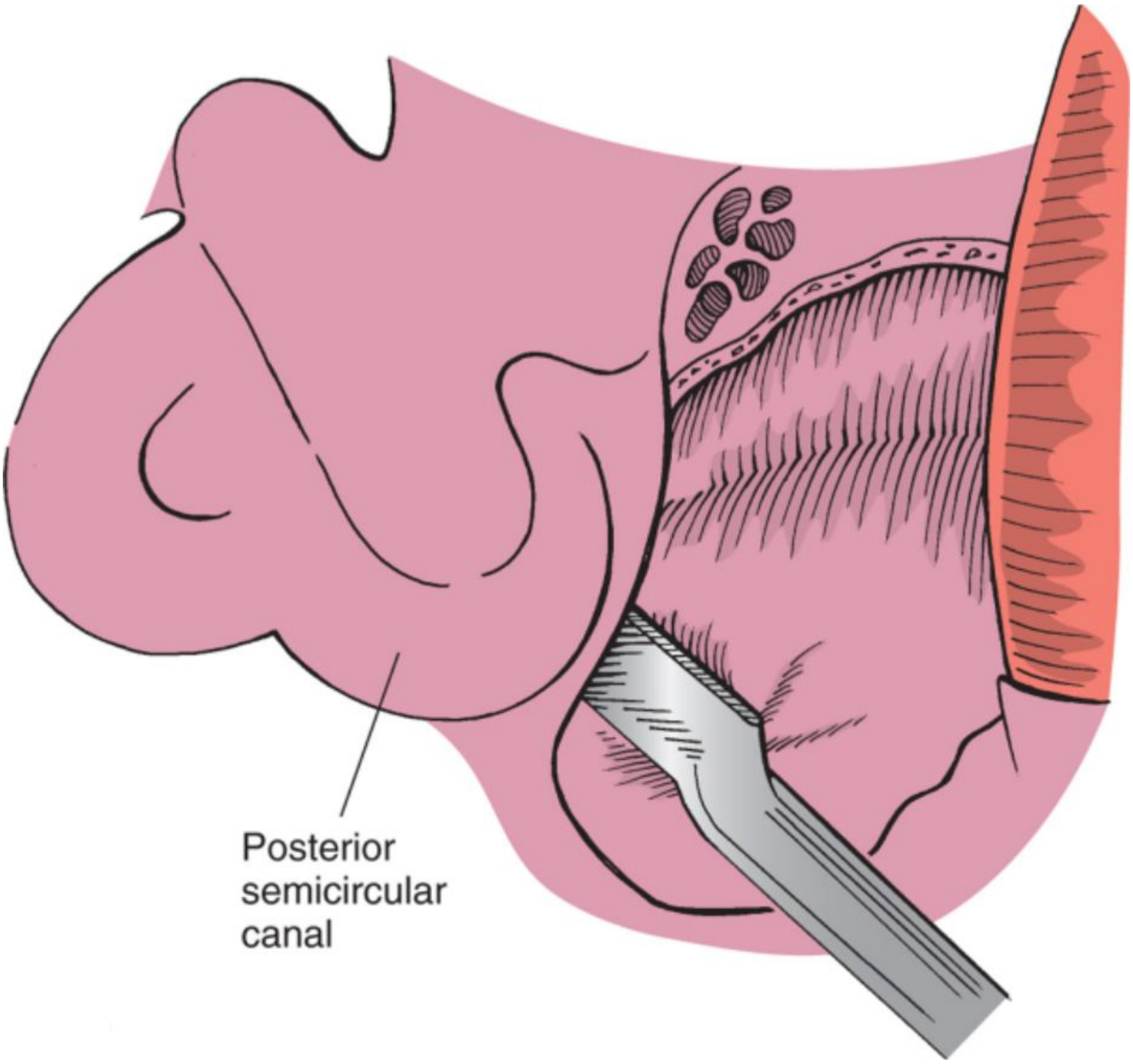


**Figure 131-7** The dura medial to the posterior semicircular canal is palpated to define the operculum and endolymphatic duct.

At this point, decompression of the sac is complete and if shunting is not planned, the surgical wound is closed in a standard layered fashion. To open the endolymphatic sac, the surgeon carefully incises the lateral wall of the sac in a radial direction using a Beaver no. 5940 blade from the sigmoid sinus toward the operculum (Fig. 131-8). The medial and lateral walls of the sac are bluntly separated using an annulus elevator (Fig. 131-9). To place a shunt, the surgeon inserts a small piece of 0.005-inch thick silastic sheeting into the lumen of the sac (Fig. 131-10). The wound is then closed in the standard layered fashion for mastoid surgery and a mastoid dressing is applied for 24 hours.

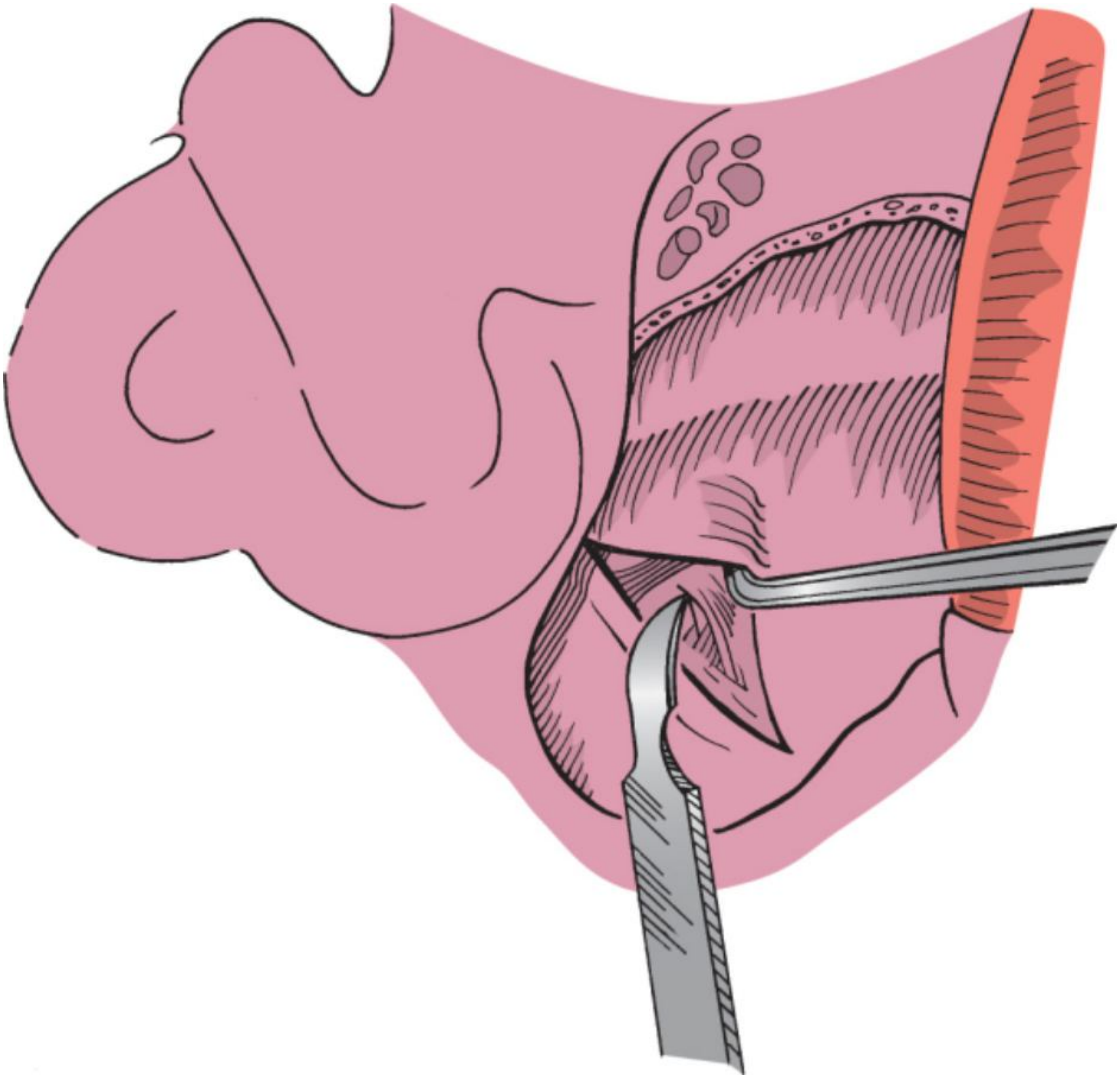

**Figure 131-8** The lateral wall of the endolymphatic sac is incised.

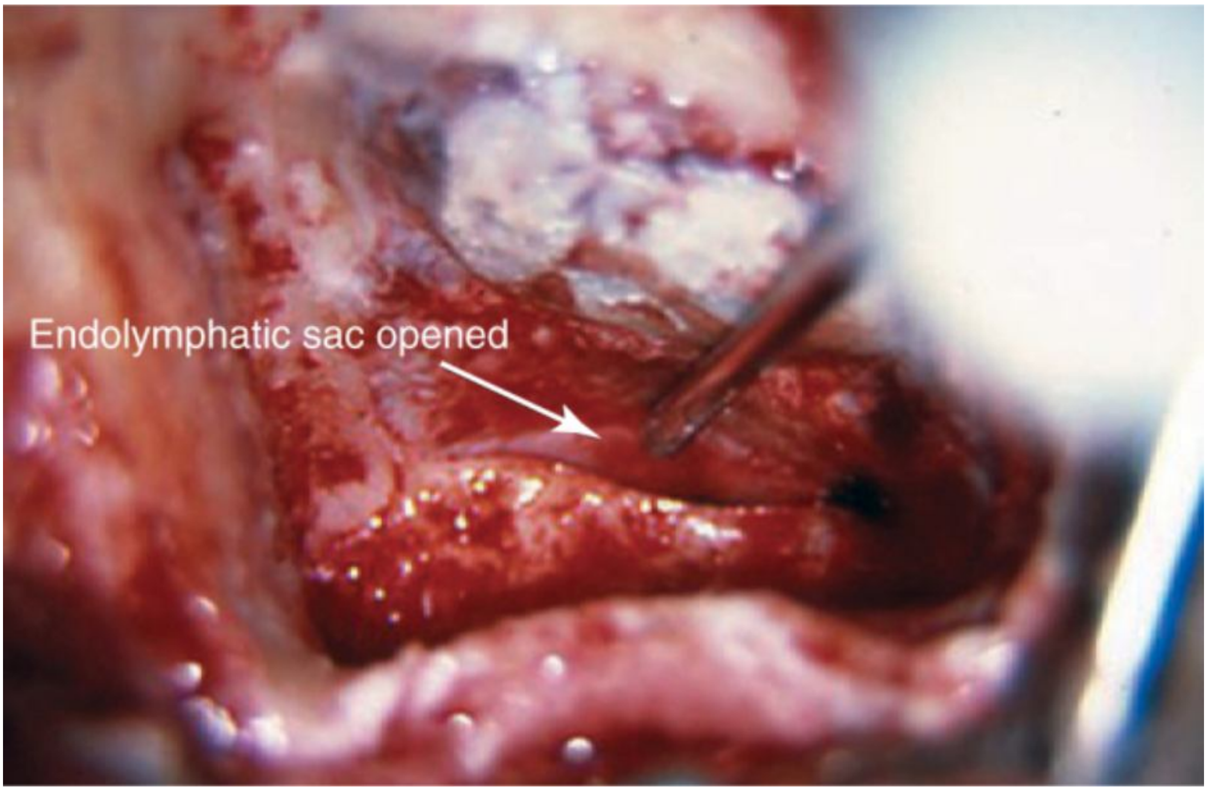


**Figure 131-9** The medial and lateral walls of the endolymphatic sac are bluntly separated.

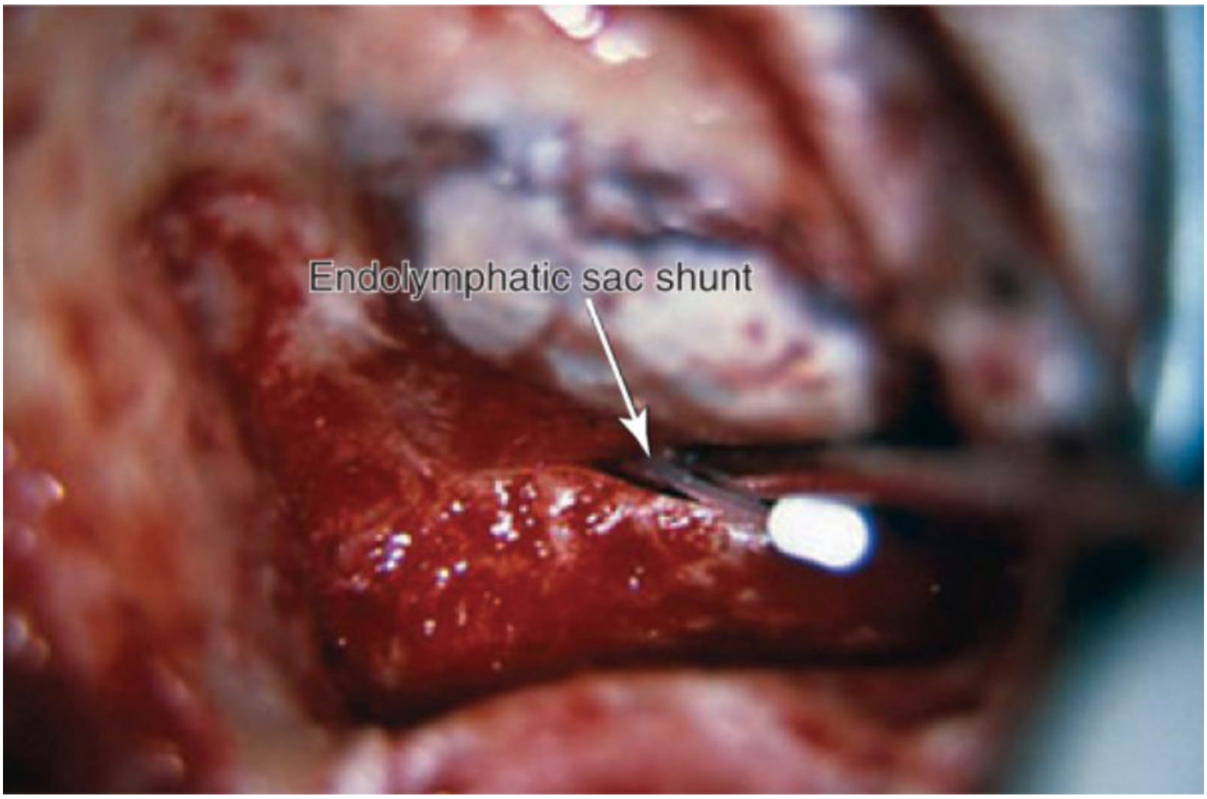


**Figure 131-10** A silastic shunt is inserted in the lumen of the endolymphatic sac.

## Surgical Labyrinthectomy

For the patient with disabling vertigo or disequilibrium resulting from a unilateral peripheral vestibulopathy and with no useful hearing in the affected ear, vestibular ablation is the treatment of choice. This may be done chemically using intratympanic gentamicin or surgically through a standard transmastoid approach. The neurosensory epithelium of the vestibular labyrinth is systematically and completely removed. This reliably controls vertigo in most patients, but moderate to severe postoperative disequilibrium may necessitate a course of vestibular rehabilitation therapy to facilitate central vestibular compensation.

A transmastoid labyrinthectomy begins with a complete mastoidectomy through a standard postauricular incision, with intraoperative facial nerve monitoring. Perioperative antibiotics are not routinely administered for this procedure. Once the mastoid antrum is entered medially, the LSC is identified and drilling is continued anteriorly into the epitympanum until the body of the incus is identified. The perilabyrinthine air cells are carefully removed to expose all three semicircular canals. The surgeon should identify the course of the tympanic and mastoid segments of the facial nerve, but need not skeletonize it.

The semicircular canals are then opened sequentially to maintain surgical orientation of the canals during the labyrinthectomy. Using a 3-mm cutting burr and copious suction irrigation, the LSC is fenestrated superiorly along its entire length, beginning at the ampullated end and progressing posteriorly toward the PSC (Fig. 131-11). The inferior wall of the LSC protects the second genu of the facial nerve and should be left intact. The PSC is then fenestrated using the same size drill burr. Dissection is continued inferiorly and anteriorly under the facial nerve to expose the ampulla of the PSC. The inferior wall of the PSC should be left intact because it protects a high-riding jugular bulb. The PSC is then followed superiorly to the common crus, which will lead to the SSC. The SSC lies perpendicular to both the LSC and the PSC, on a deeper plane, and is carefully dissected in a posterior to anterior direction toward the ampulla (Fig. 131-12). Care is taken not to violate the tegmen mastoideum and middle fossa dura during this portion of the bony dissection.

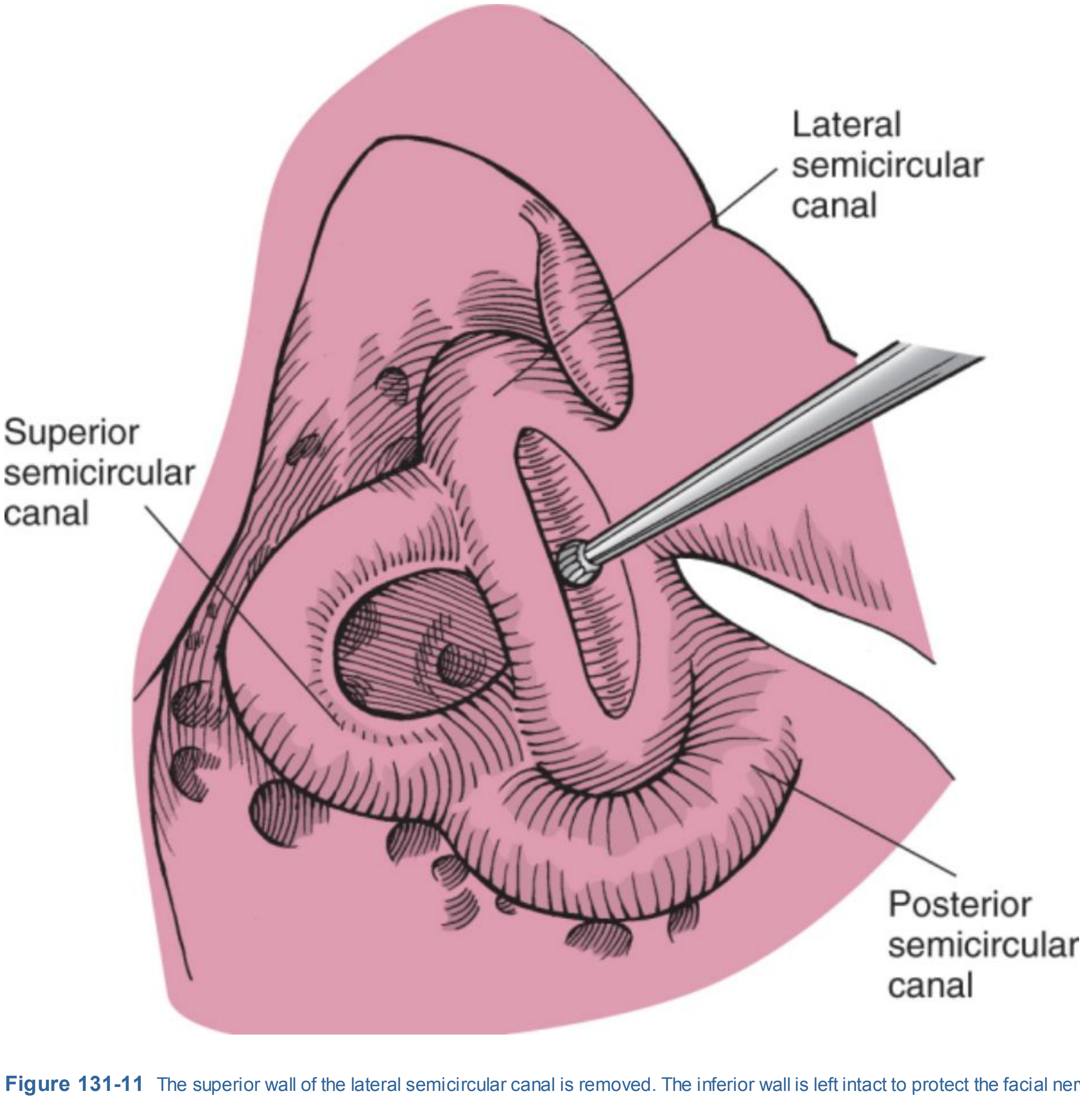


**Figure 131-11** The superior wall of the lateral semicircular canal is removed. The inferior wall is left intact to protect the facial nerve.

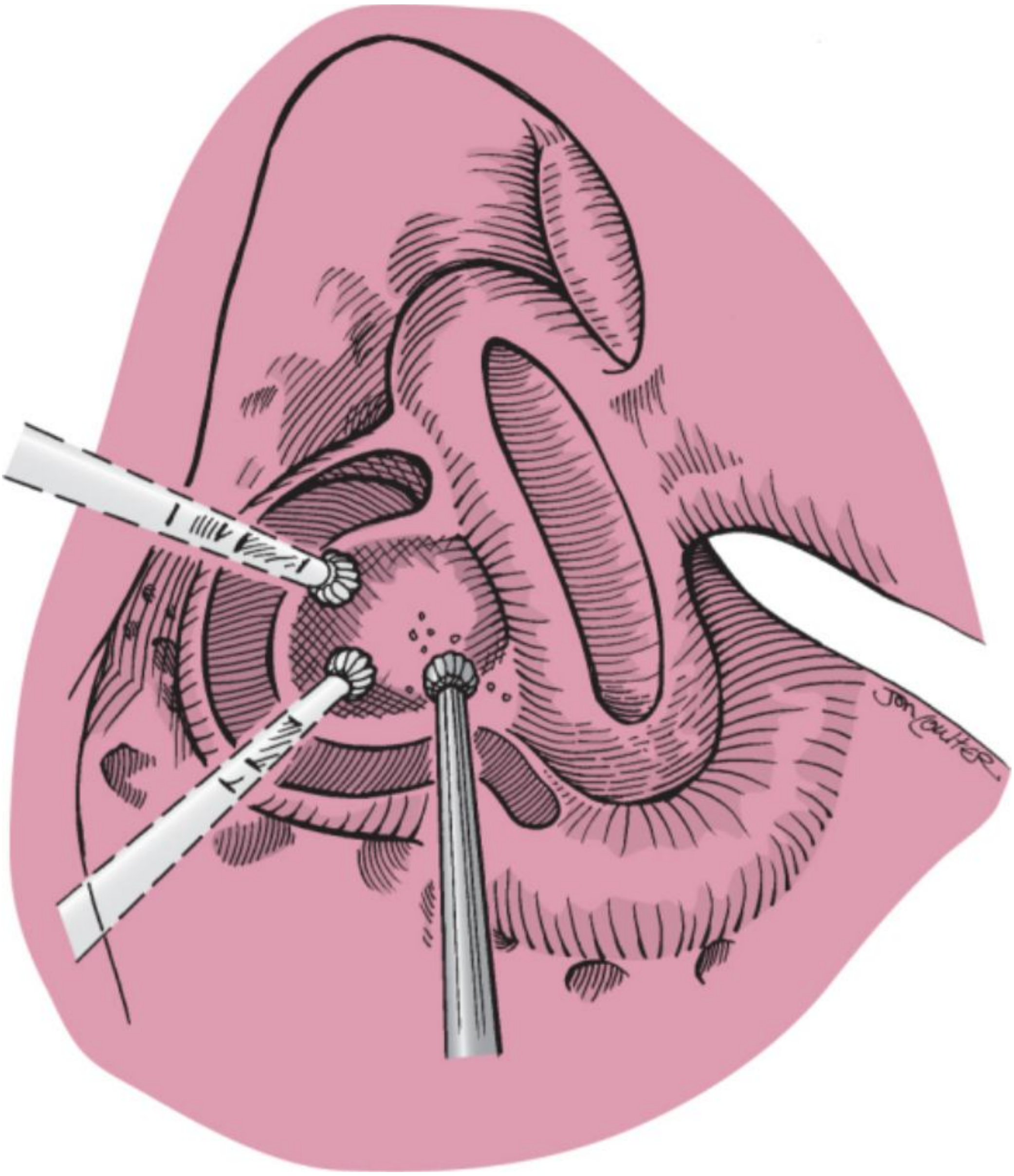

**Figure 131-12** The common crus and superior semicircular canal are fenestrated from a posterior to anterior direction toward the superior semicircular canal ampulla.

Anteriorly, the neurosensory epithelium of the superior and lateral ampullae is exposed and the vestibule is opened (Fig. 131-13). The medial wall of the superior and lateral ampullae should be left intact to prevent exposure of the internal auditory canal and facial nerve, cerebrospinal leak, and facial paralysis.

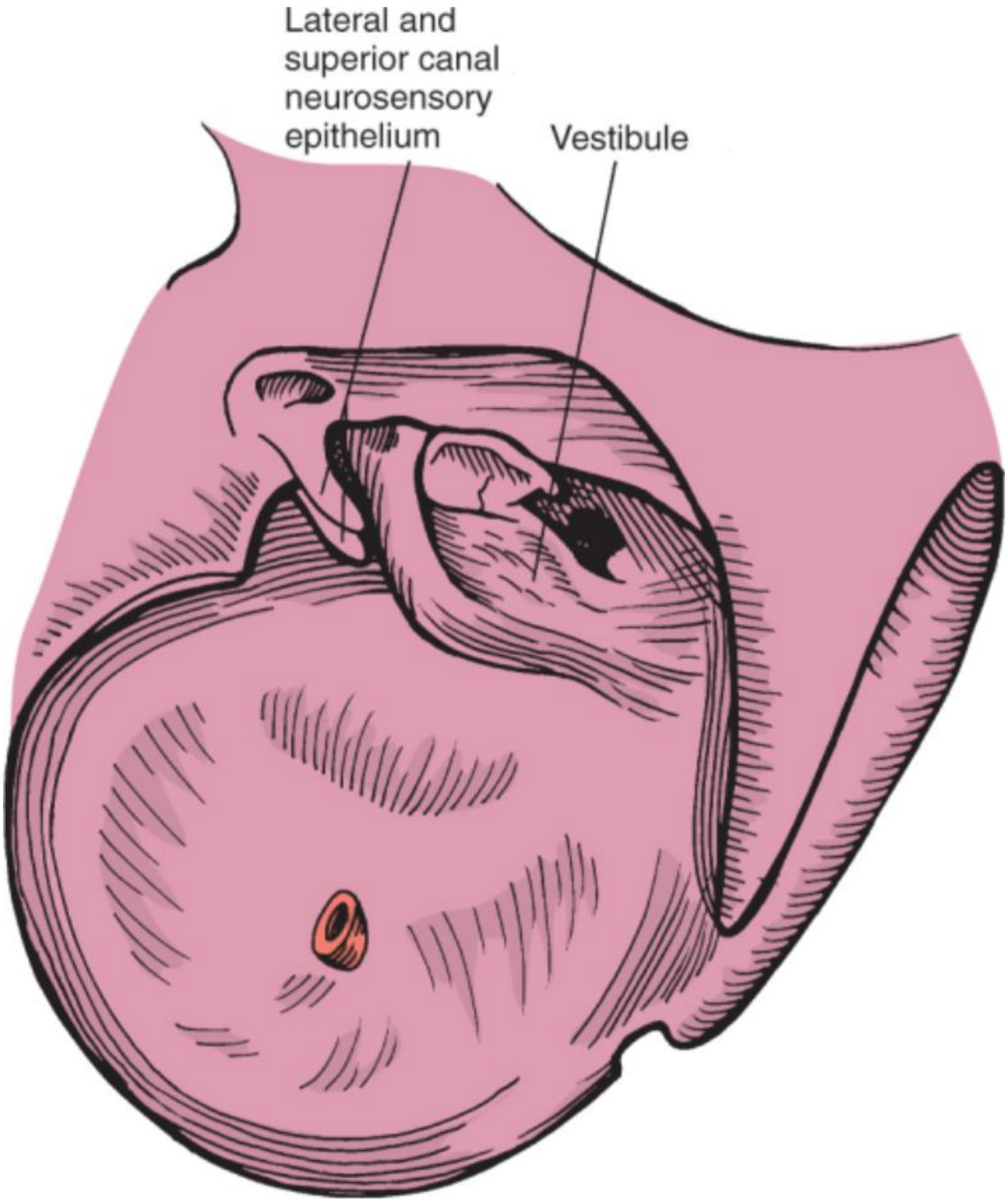


**Figure 131-13** The neurosensory epithelium of the superior and lateral semicircular canal ampullae is exposed, the vestibule is opened, and the posterior semicircular canal is followed inferiorly to expose its ampulla.

Once all five portions of neurosensory epithelium are exposed (the ampullae of the three semicircular canals, the utricle, and the saccule), each is removed systematically with a round knife or microcurette, taking care not to rupture the underlying bony cribrosa (Fig. 131-14). The area is inspected for cerebrospinal fluid leak. If there is no cerebrospinal fluid leak, closure of the surgical site proceeds in a layered fashion as for standard mastoid surgery. If a cerebrospinal fluid leak is detected, a free abdominal fat graft is used to obliterate the mastoid cavity. A mastoid dressing is applied over the ear for 24 hours.

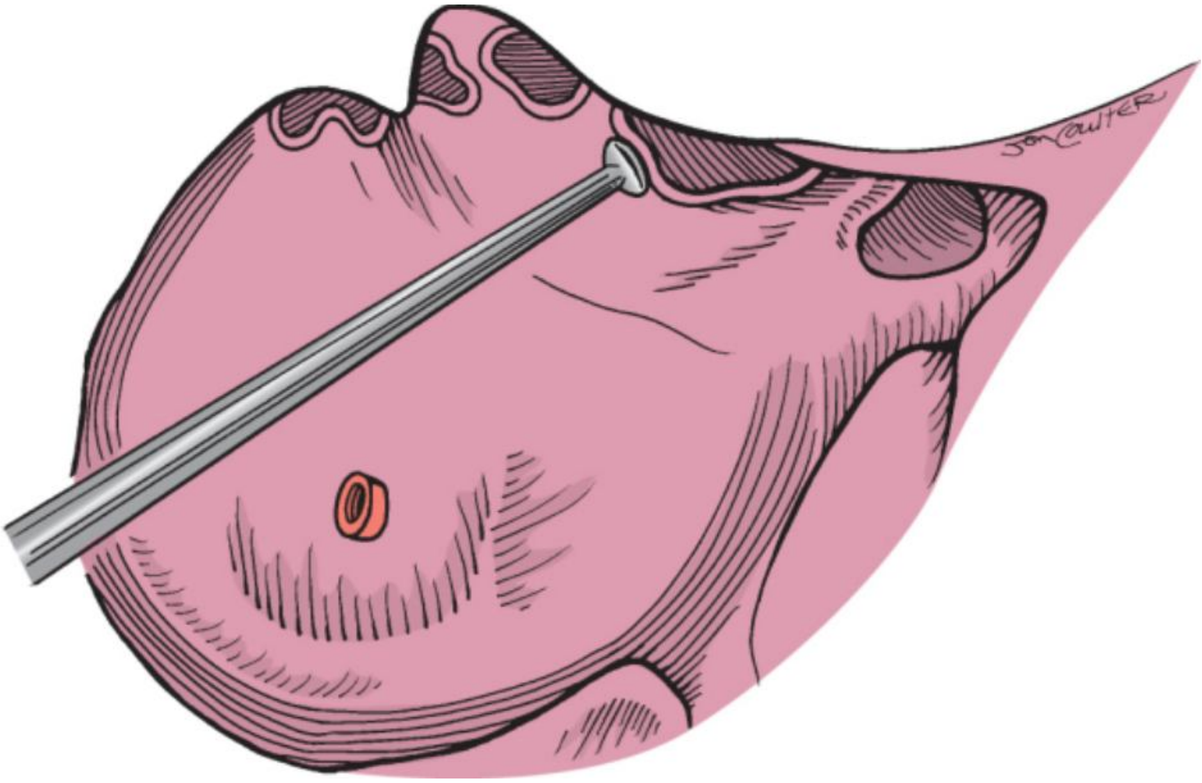

**Figure 131-14** The five areas of neurosensory epithelium are exposed and removed systematically using a round knife or microcurette.

## Translabyrinthine Approach for Vestibular Nerve Section

This procedure is reserved for the rare patient who continues to experience disabling vestibular symptoms following a surgical labyrinthectomy. The goal is to remove Scarpa's ganglion with additional exposure of the internal auditory canal after the labyrinthectomy has been completed. This procedure carries an increased risk of facial nerve injury and cerebrospinal fluid leak compared with labyrinthectomy alone.

The preparation and surgical exposure for this procedure are as described for a transmastoid labyrinthectomy. Intraoperative facial nerve monitoring is routinely employed. Broad-spectrum antibiotics are administered intravenously at the time of induction of general anesthesia. A labyrinthectomy is completed as described above. The lateral one half of the internal auditory canal is then skeletonized using medium-sized diamond burrs and copious suction irrigation. The superior limit of the internal auditory canal is marked by the ampulla of the SSC, which is innervated by the superior vestibular nerve. The dura of the lateral internal auditory canal is exposed and the facial nerve is identified and electrically stimulated anterosuperiorly as it exits the internal auditory canal into the labyrinthine segment. At the fundus of the internal auditory canal, a vertical crest of bone (Bill's bar) separates the facial nerve anteriorly from the superior vestibular nerve posteriorly, and a transverse crest separates the superior vestibular nerve from the inferior vestibular nerve.

Dura along the posterior aspect of the internal auditory canal is incised, and superior and inferior dural flaps are developed to expose the contents of the internal auditory canal (Fig. 131-15). The superior vestibular nerve is then separated from the facial nerve from a lateral to medial direction using a blunt dissector. A 3- to 5-mm length of the superior vestibular nerve is resected. Similarly, the inferior vestibular nerve is separated from the cochlear nerve anteriorly by gentle blunt dissection from a medial to lateral direction to minimize traction on the cochlear nerve. A short segment of the inferior vestibular nerve is also resected (Fig. 131-16). The singular nerve is specifically identified and divided.

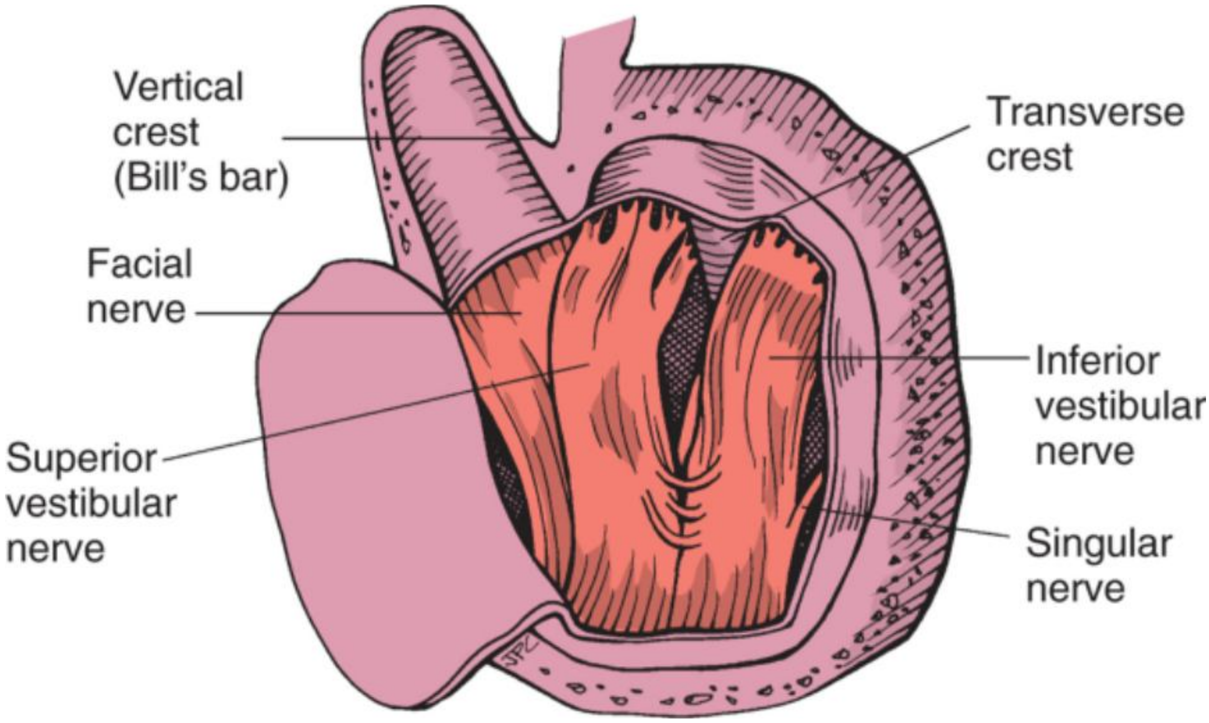


**Figure 131-15** The transverse crest and Bill's bar are exposed at the fundus of the internal auditory canal. The dura of the internal auditory canal is opened. The facial, superior vestibular, inferior vestibular, and singular nerves are identified.

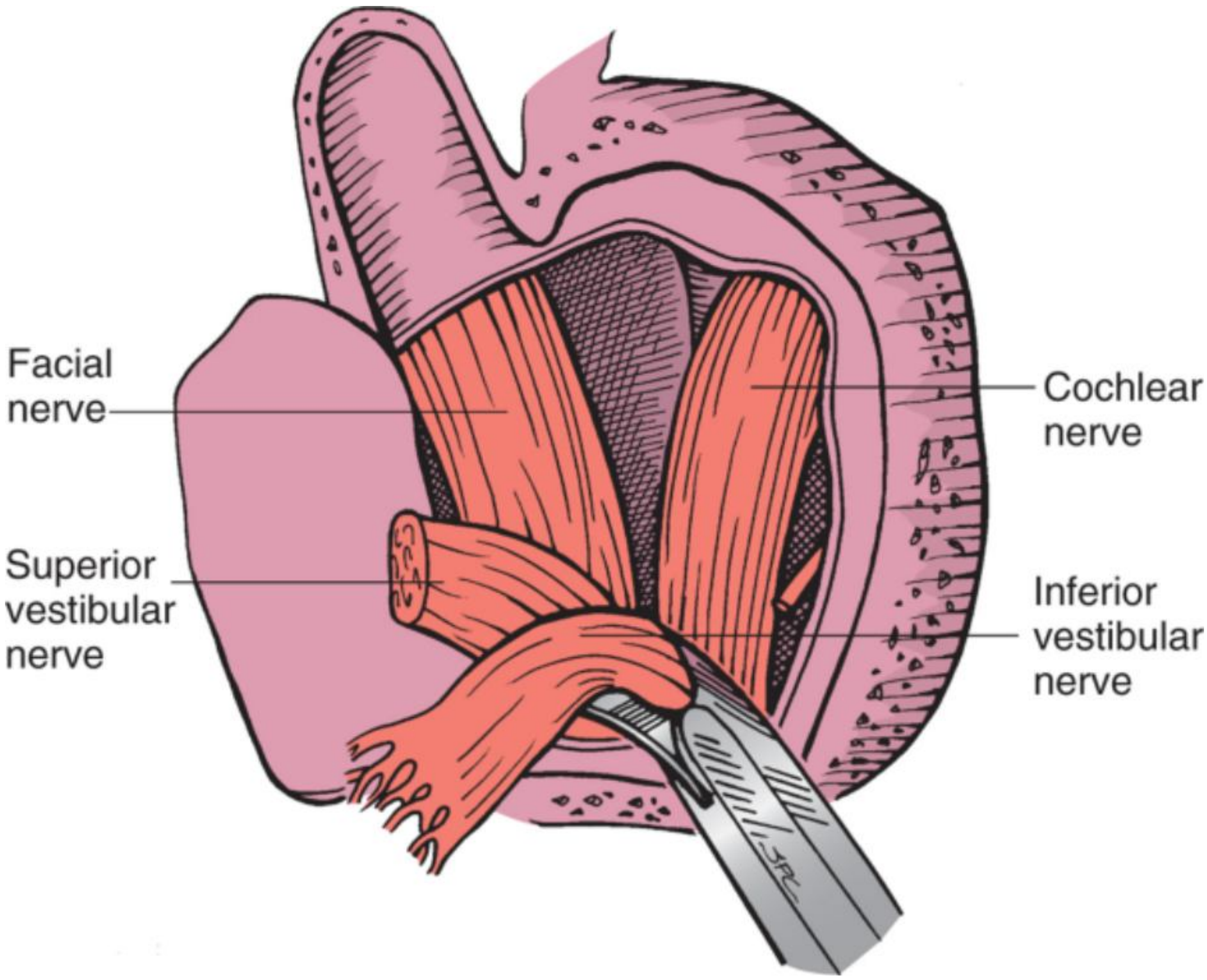


**Figure 131-16** A segment of the vestibular nerve is resected.

Once the nerve section is complete, the dura of the internal auditory canal is reopposed. In a well-aerated temporal bone with a large aditus ad antrum, the incus should be removed so that the eustachian tube and middle ear can be packed with temporalis muscle. The mastoid cavity is obliterated with free abdominal fat grafts. A watertight multilayer closure is then completed using a combination of absorbable and nonabsorbable sutures. A compressive mastoid dressing is applied for 3 days. The patient is discharged home on postoperative day 4 if no cerebrospinal fluid leak is apparent.

## Posterior Fossa Approaches for Vestibular Nerve Section

The vestibular nerve may be exposed within the posterior fossa with an approach through the mastoid (retrolabyrinthine/presigmoid) or through a retromastoid/retrosigmoid craniotomy (retrosigmoid approach). Both approaches preserve hearing in the operated ear.

The posterior fossa approaches for vestibular nerve section are popular because they provide consistent and direct exposure of the cerebellopontine angle and expose the cochleovestibular and facial nerves between the porus of the internal auditory canal and the brain stem. Using these approaches, the facial nerve is easily identified anterior to the cochleovestibular nerve, and inadvertent injury to the facial nerve is uncommon.

The primary disadvantage of these approaches is that the vestibular nerve is exposed where the vestibular portion of the cochleovestibular nerve is not anatomically separate from the cochlear portion. Thus, location and division of the vestibular nerve must be based on the surgeon's knowledge of the anatomy of the cochleovestibular nerve. The presence of small blood vessels, which tend to demarcate the cochlear and vestibular nerve fibers, and subtle color differences between the two types of nerve fibers aid the surgeon in determining the plane between the vestibular versus cochlear nerve. Although there is a possibility of leaving some vestibular fibers uncut, the high rates reported for the control of vertigo suggest that leaving a few vestibular fibers uncut may be of limited clinical significance.

## Retrolabyrinthine Approach for Vestibular Nerve Section

The patient is positioned supine with the head turned away from the surgeon. The ear is prepped and draped as for standard neuro-otologic surgery. Intraoperative facial nerve and evoked auditory brain stem responses are monitored routinely. A single dose of antibiotic is administered at the time of induction of general anesthesia. A wide C-shaped incision is made approximately 3 cm posterior to the postauricular crease and extended down to the temporalis fascia superiorly and mastoid periosteum inferiorly. Skin and subcutaneous tissue are then elevated in the subcutaneous plane anteriorly. The temporalis muscle and fascia and the periosteum are incised with an offset incision to allow for a good layered wound closure at the end of the proce- dure to prevent or contain cerebrospinal fluid leaks through the incision. An anteriorly based musculoperiosteal flap is then elevated to expose the mastoid cortex and secured in place with a large self-retaining retractor.

A complete mastoidectomy is performed and exposure down to the mastoid antrum allows for identification of the LSC. Bone overlying the middle fossa dura, sigmoid sinus, and posterior fossa dura is carefully removed using a large diamond burr. The vestibular labyrinth is exposed; particular attention is directed to fully skeletonizing the posterior semicircular canal (Fig. 131-17). Gelfoam is used to block the aditus ad antrum. The remaining bone over the posterior fossa dura between the sigmoid sinus and PSC is then removed with a Freer elevator or similar blunt dissector (Fig. 131-18). The endolymphatic sac and duct are preserved. The mastoid cavity is thoroughly irrigated with Bacitracin solution (Bacitracin 50,000 units/L of saline) once all bone dissection has been completed.

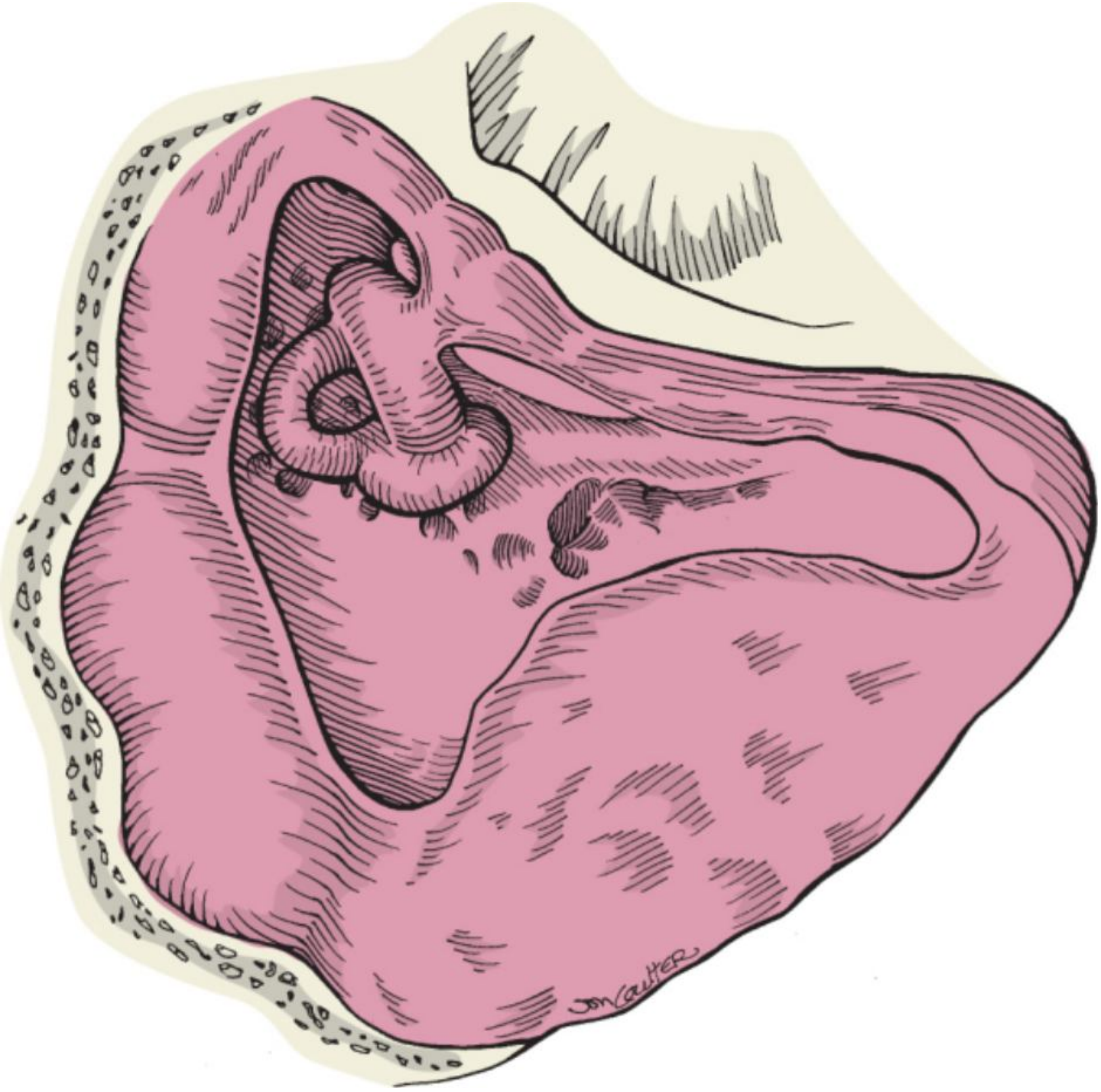

**Figure 131-17** The mastoidectomy is completed by skeletonizing the semicircular canals and the bony plate overlying the posterior fossa dura.

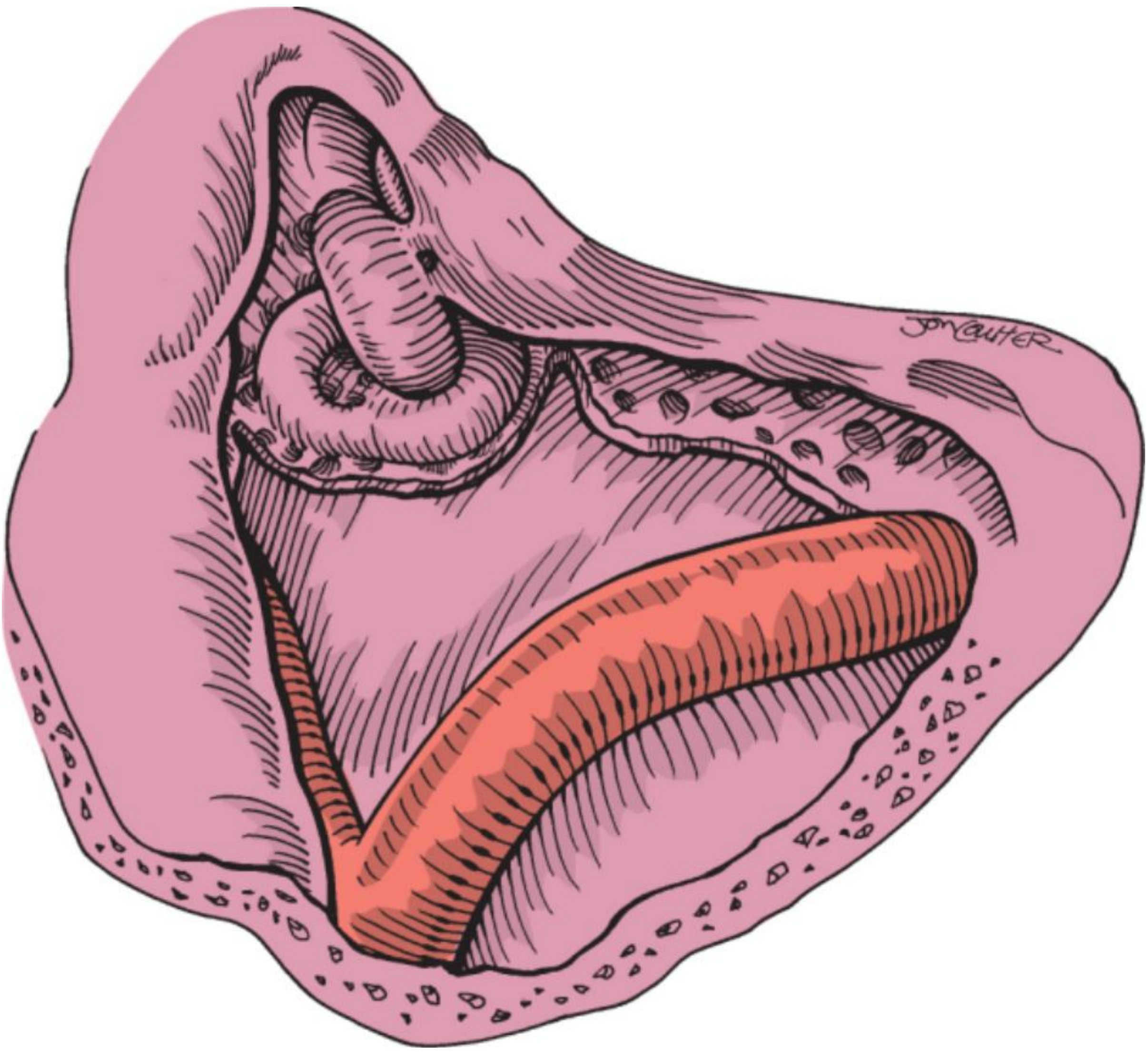


**Figure 131-18** Dura overlying the posterior fossa and sigmoid sinus is exposed.

The dura anterior to the sigmoid is incised, creating an anteriorly based C- or U-shaped dural flap (Fig. 131-19). A ½- × 3-cm neurosurgical cottonoid patty is placed over the cerebellum (Fig. 131-20). Cerebrospinal fluid is drained from the cerebellopontine cistern by opening the arachnoid in this location. The cerebellum falls away, allowing visualization of cranial nerves (CN) VII and VIII, centered within the field, with CN V anteromedially and CN IX, X, and XI laterally and inferiorly (Fig. 131-21).

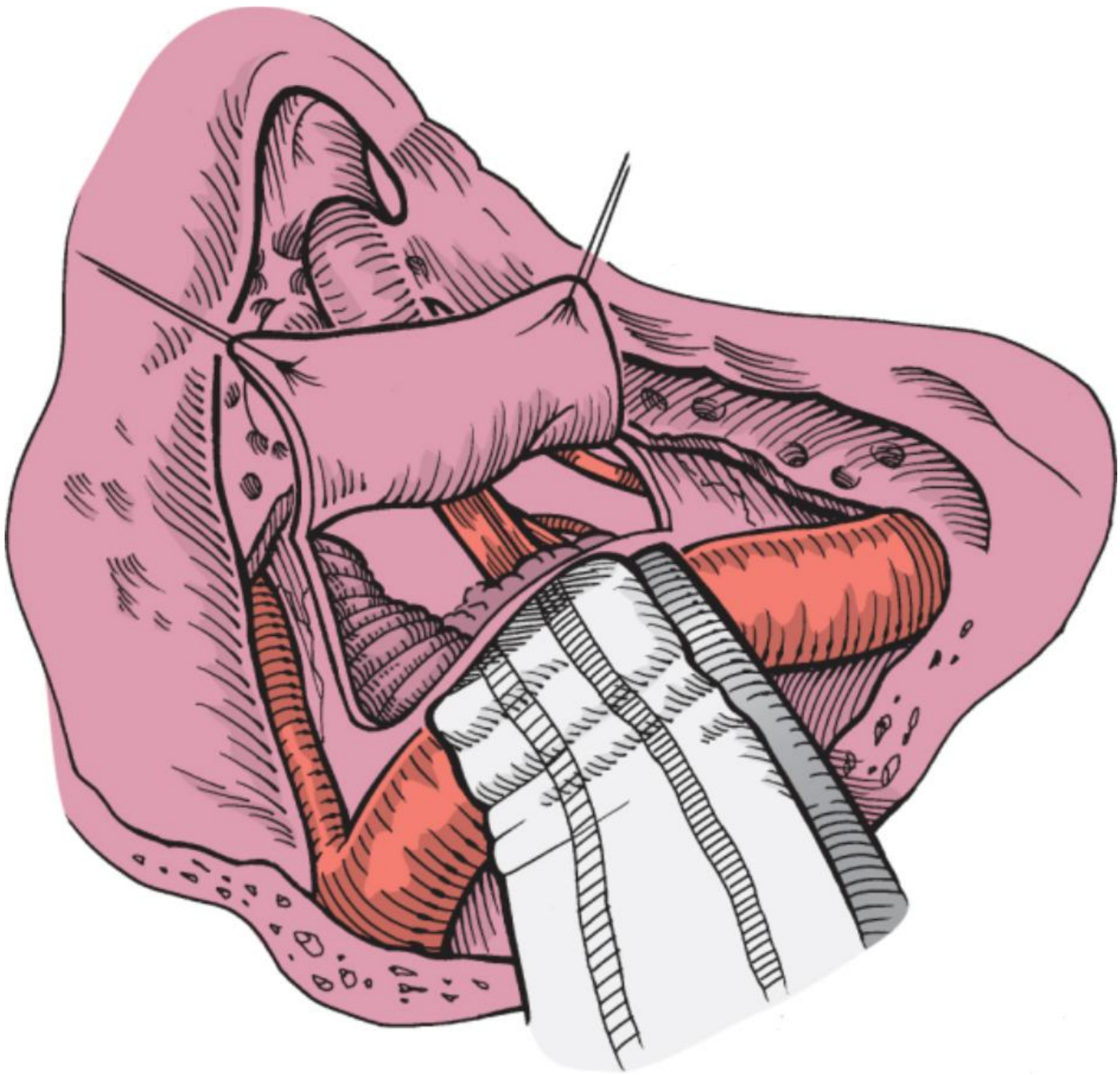

**Figure 131-19** An anteriorly based U-shaped dural flap is developed, and the contents of the posterior fossa are exposed.

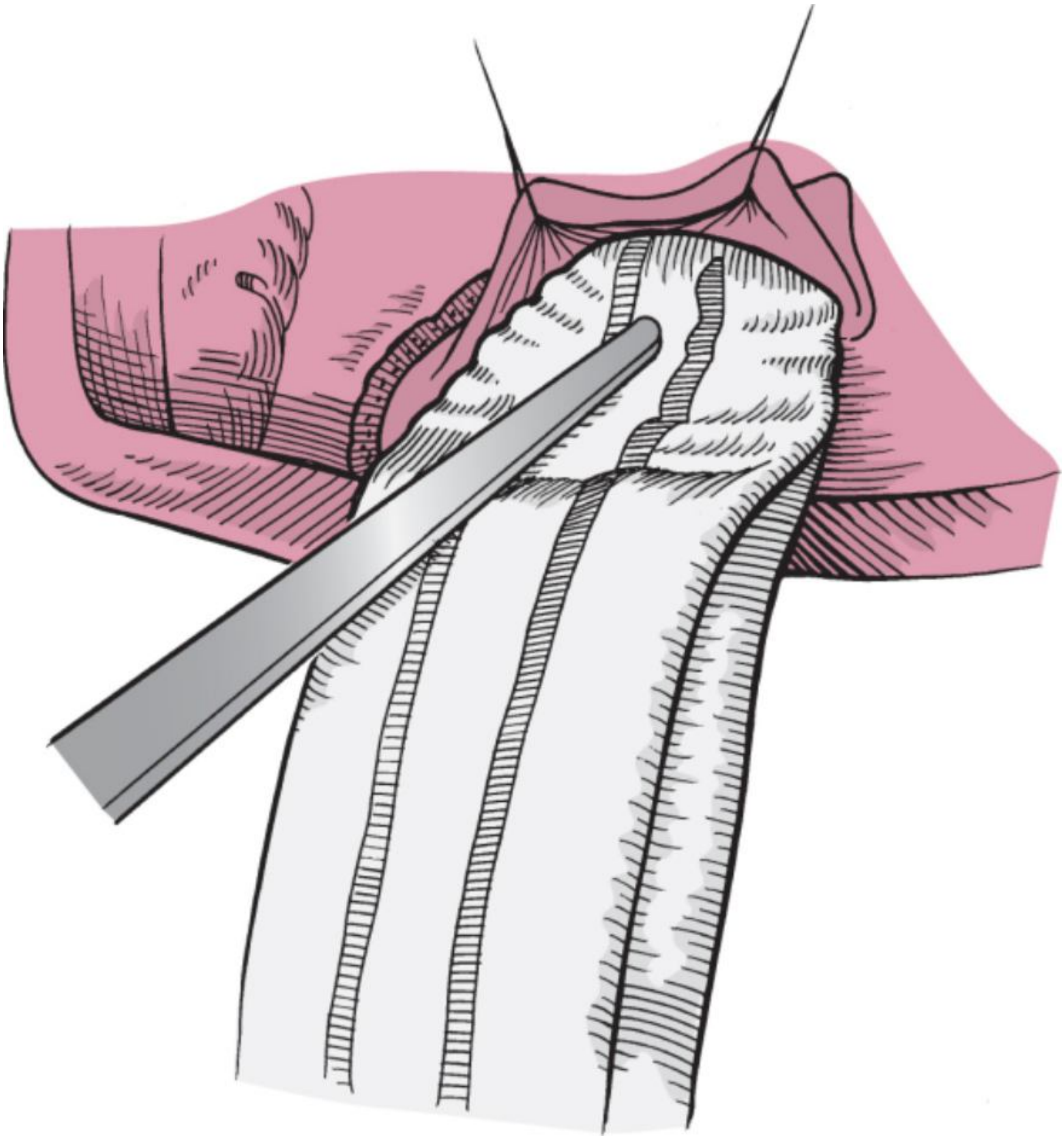

**Figure 131-20** A ½- × 3-cm neurosurgical cottonoid patty is advanced between the anterior edge of the dura and the surface of the cerebellum.

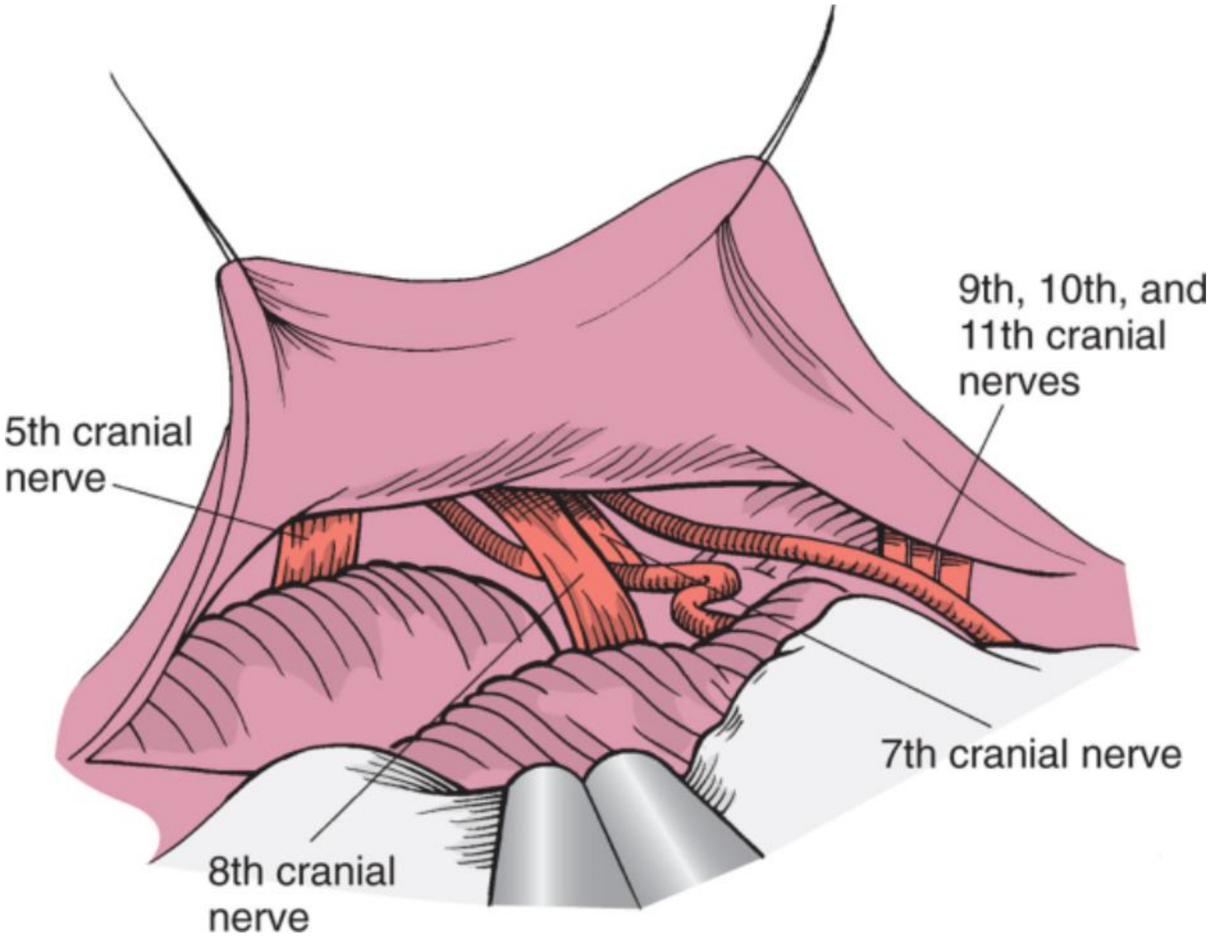


**Figure 131-21** Retrolabyrinthine exposure of the posterior fossa.

Under high magnification, the courses of CN VII and CN VIII are examined and confirmed using electrical stimulation of CN VII (Fig. 131-22). Any small vessels intimately associated with CN VIII are gently dissected off the nerve. A surgical plane is then developed between the cochlear and vestibular portions of CN VIII. A recent cadaver study found that in an average of 75% of cases, the surgeon could visually identify a cleavage plane within the vestibulocochlear nerve near the porus acusticus, or develop it near that point with a ball-tipped dissector.[21] The vestibular division of CN VIII typically appears grayer than the cochlear division, which appears whiter. Often a minute blood vessel lies along this cleavage plane (Fig. 131-23). The vestibulocochlear nerve also rotates approximately 90 degrees as it passes from the lateral internal auditory canal back toward the porus and brain stem, in a counterclockwise direction on the right side as viewed from the medial porus, and correspondingly clockwise on the left side.[22] Near the brain stem, the vestibular portion of CN VIII is usually more superior (closer to the tentorium); near the porus, it is usually superior or dorsal.

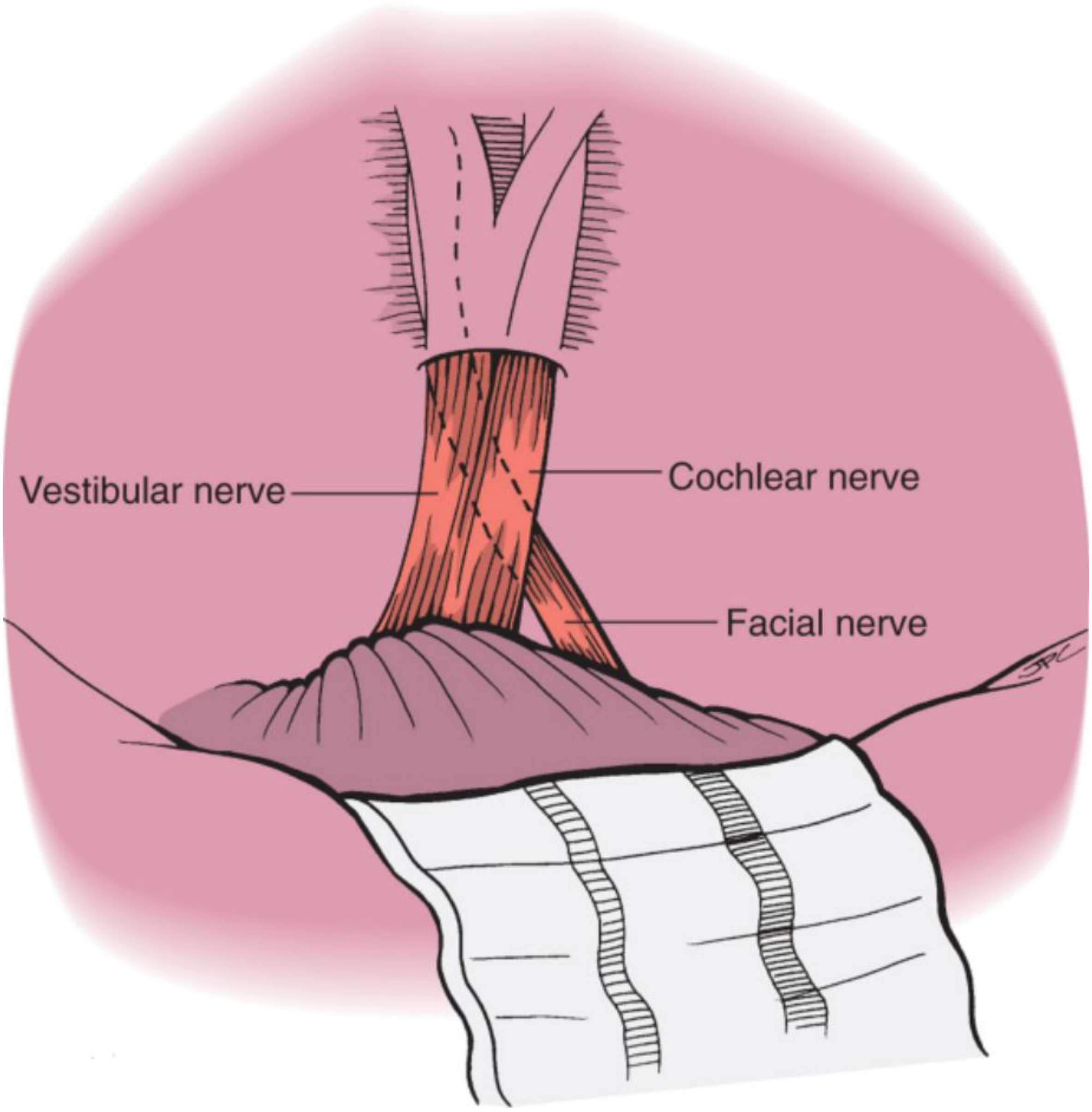


**Figure 131-22** Anatomic relationships of the vestibular nerve, cochlear nerve, and facial nerve.

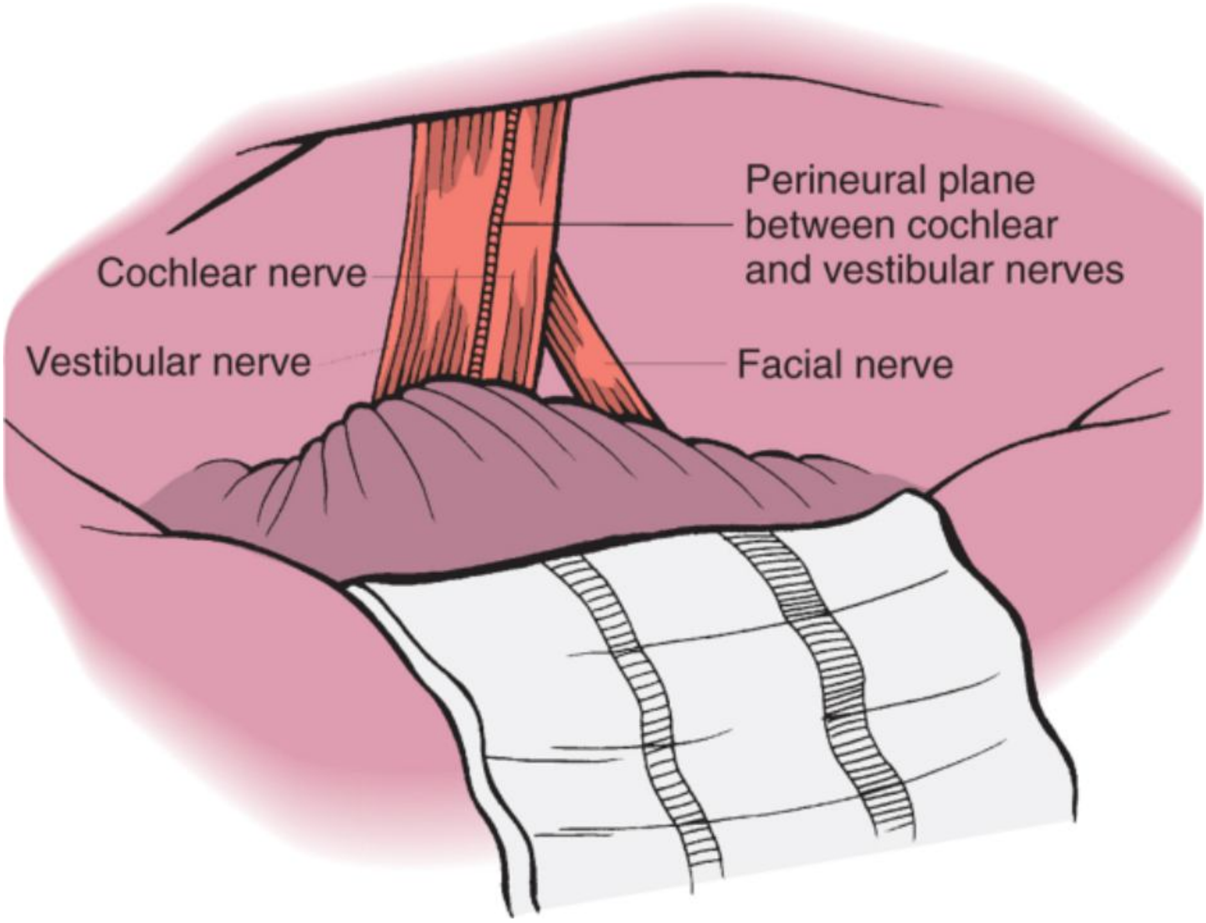


**Figure 131-23** A perineural plane between the cochlear and vestibular nerves is frequently demonstrated by a small vessel or a slight depression in the nerve running longitudinally on the dorsal surface of the nerve.

If a clear plane of demarcation can be identified, a no. 1 Roton dissector is used to separate the cochlear and vestibular divisions along this plane (Fig. 131-24). A bayoneted curved microscissors is then used to cut the vestibular division of the eighth nerve starting from the superior-dorsal surface of the nerve (Fig. 131-25). The nervus intermedius commonly adheres to the ventral surface of the eighth nerve near the junction of the vestibular and cochlear divisions. The nervus intermedius is identified by its whiter appearance and can be traced back to the brain stem coursing between the seventh and eighth cranial nerves. Electrical stimulation of the nervus intermedius will excite the facial nerve but at a higher threshold than will direct stimula- tion of the facial nerve. To complete sectioning of the vestibular division, the eighth nerve is sectioned to the level of the nervus intermedius. The surgeon completes the neurectomy with removal of a 5- to 10-mm segment of nerve (Fig. 131-26).

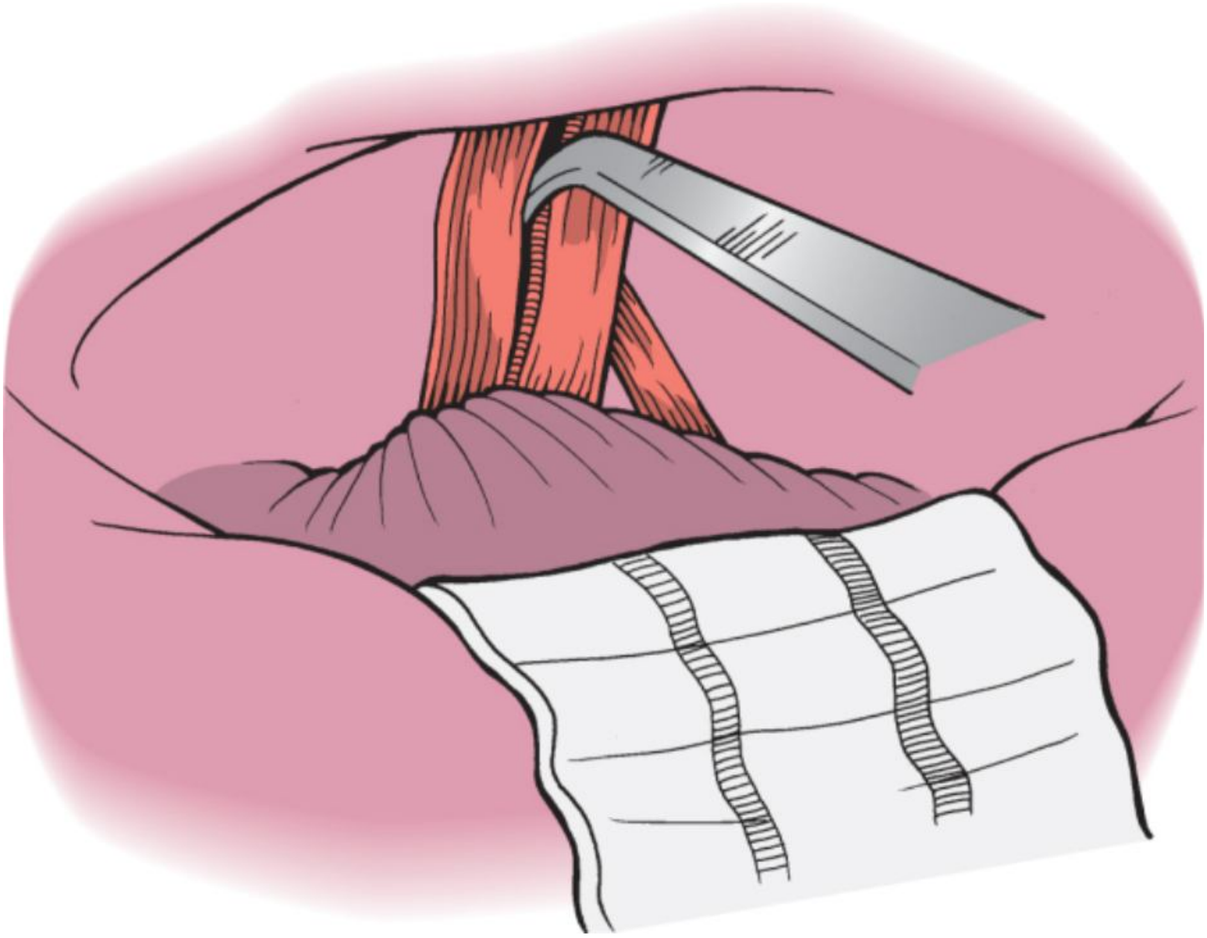

**Figure 131-24** Separation of the cochlear and vestibular nerves.

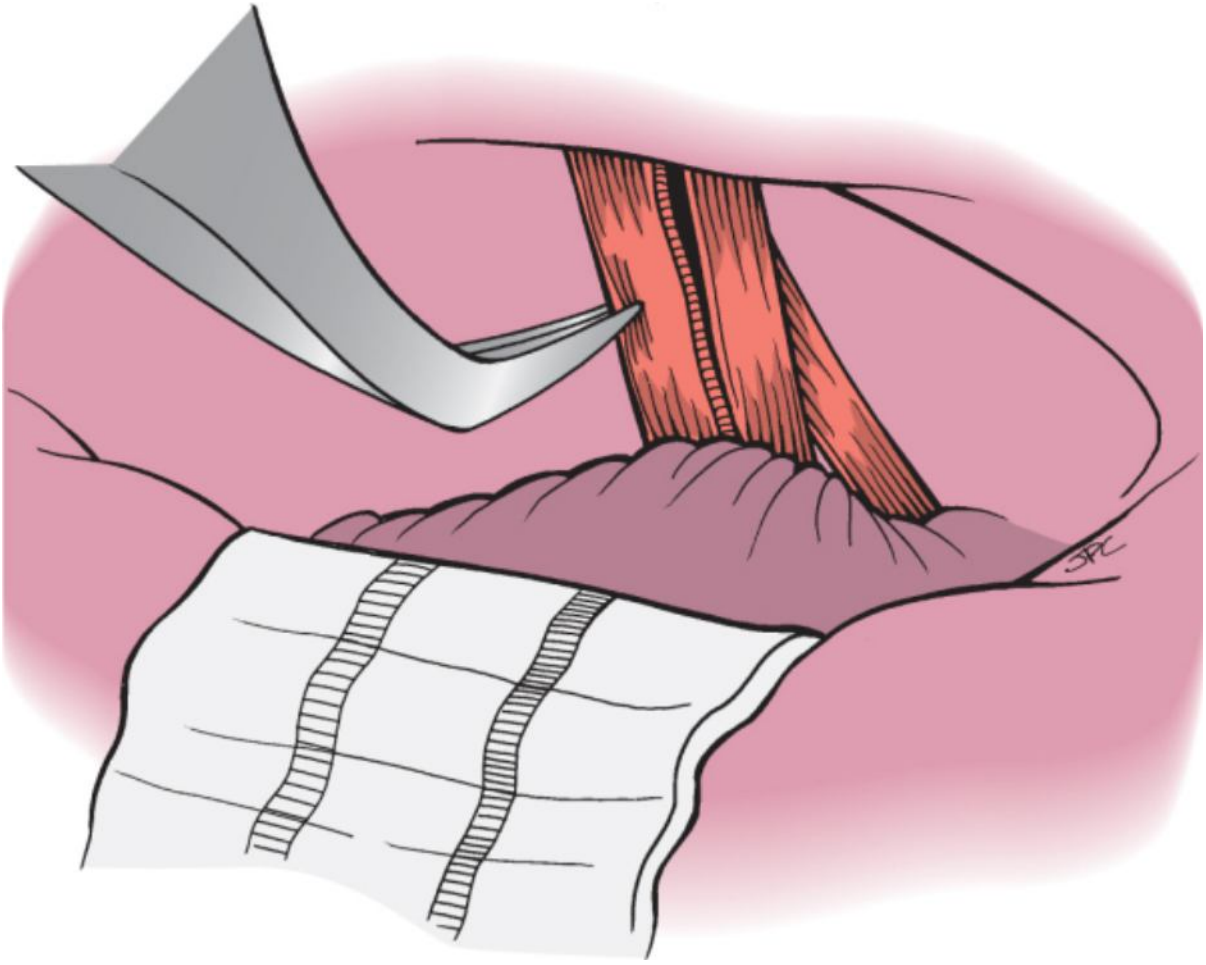

**Figure 131-25** The vestibular nerve is divided starting from the superior-dorsal surface of the eighth cranial nerve.

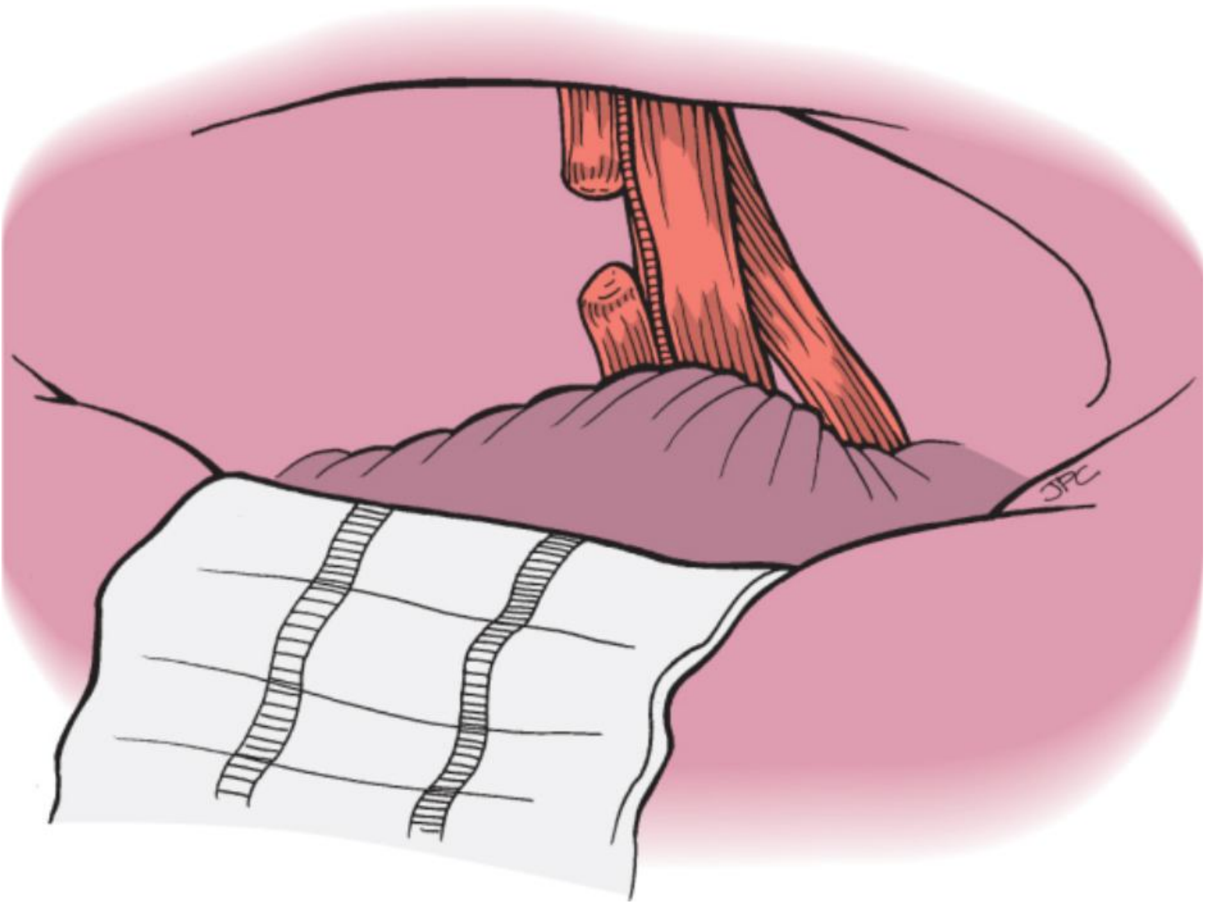

**Figure 131-26** The completed vestibular nerve section.

If the plane of demarcation is not clear, the vestibular division probably has rotated from a superior to a more dorsal relationship to the cochlear division (Fig. 131-27). In this situation, a bayoneted, curved microscissors is used to begin the nerve section starting from the superior-dorsal margin of the nerve. A no. 3 Roton dissector is then used to dissect the cut fibers toward the brain stem. Additional fibers are then divided with microscissors and dissected medially. This technique is continued until the cochlear division and nervus intermedius are identified by color changes and perineural tissue planes appear.

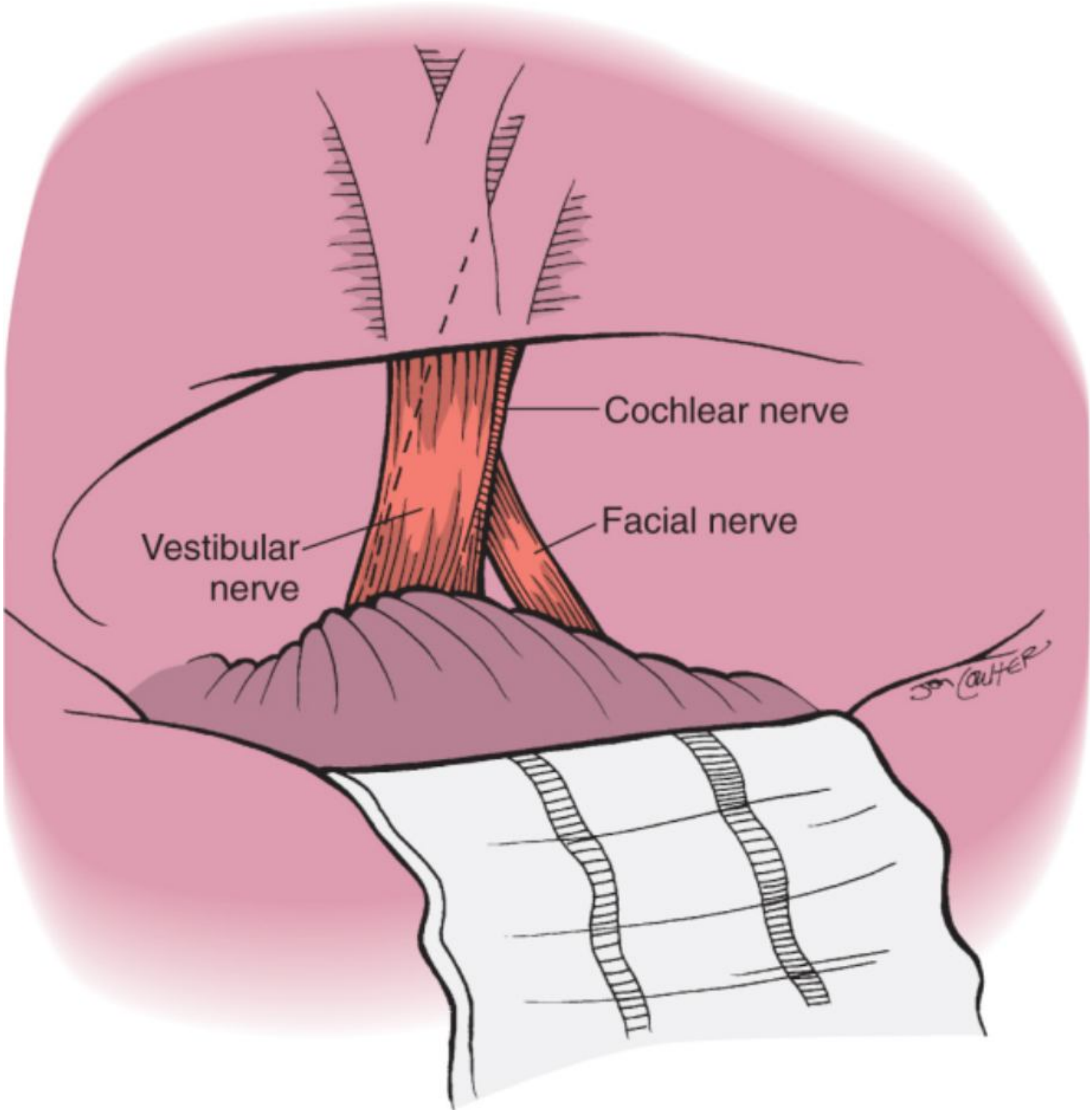


**Figure 131-27** If a clear plane is not observed between the vestibular and cochlear nerves, the vestibular nerve is usually dorsal to the cochlear nerve.

After completion of the neurectomy, the neurosurgical patty is removed and hemostasis is secured. Dura is reapproximated with interrupted 4-0 Surgilon. Postoperative cerebrospinal fluid leak is prevented by packing the aditus ad antrum with a temporalis muscle graft and the mastoid cavity with free abdominal fat grafts. Layered wound closure is accomplished in the standard fashion, with additional skin closure using 4-0 nylon. A compressive mastoid dressing is then applied for 72 hours.

## Retrosigmoid Approach for Vestibular Nerve Section

For a retrosigmoid vestibular nerve section, the patient is placed in a supine position, and a Mayfield head holder and pins are used to secure the head. A soft roll is placed under the ipsilateral shoulder, and the head is positioned in a 45-degree contralateral rotation and slight downward inclination. The bed is further rotated away to the contralateral side to optimize the angle of exposure of the posterior fossa (Fig. 131-28).

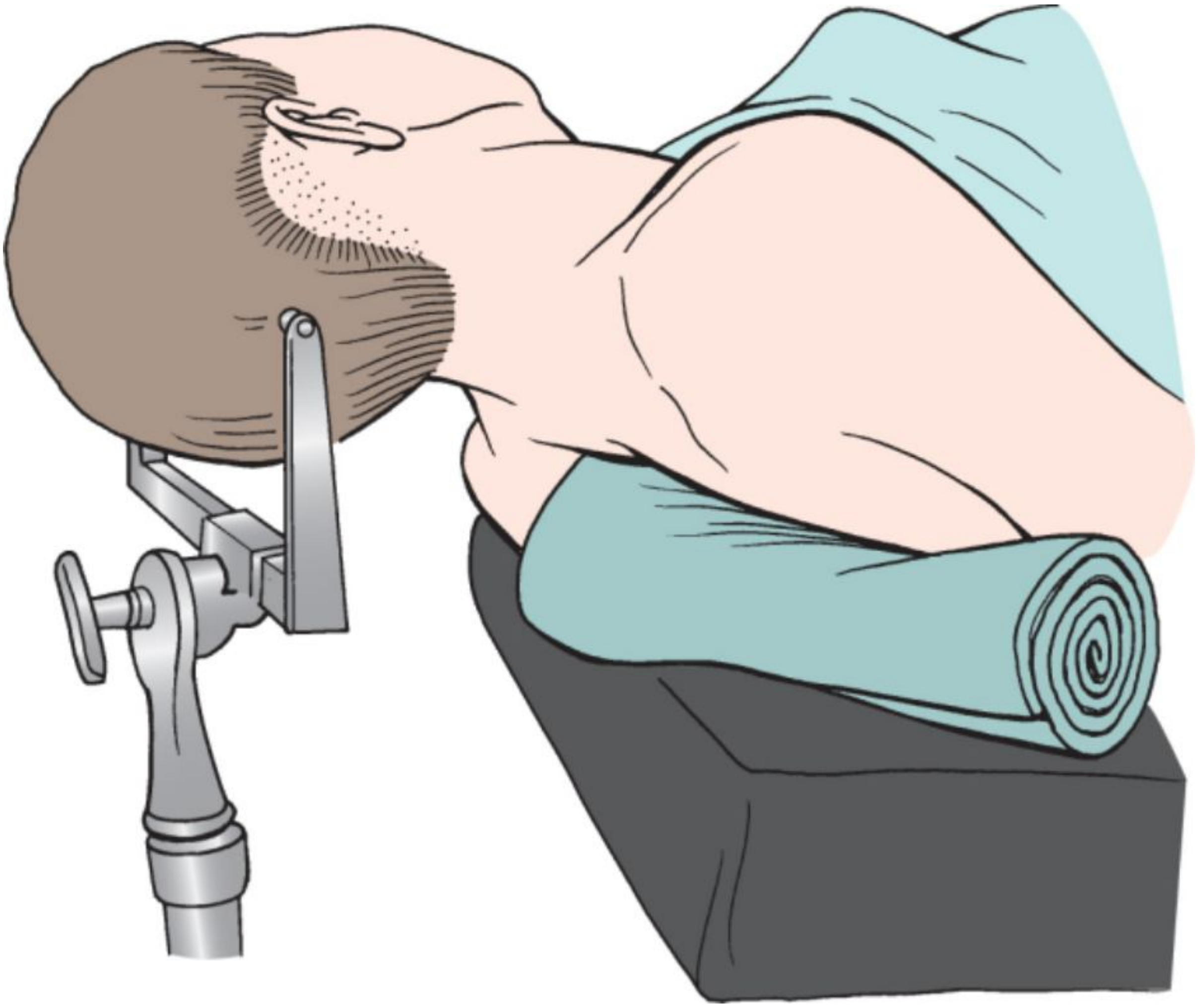

**Figure 131-28** Positioning of the patient for a retrosigmoid vestibular nerve section.

Intraoperative facial nerve and evoked brain stem audiometry monitoring is always used. Perioperative antibiotics are used for 24 hours, and dexamethasone (Decadron 10 mg) is given at the time of surgery. The anesthetist is instructed to keep the patient's $P_{CO_2}$ below 30 mm Hg and to infuse 0.3 to 0.5 g/kg of mannitol at the beginning of the case to lower intracranial pressure.

An oblique linear skin incision is made approximately 4 cm behind the mastoid tip and angled anteriorly and superiorly for 5 cm (Fig. 131-29). Typically, the epidermis is incised with a knife, and cutting cautery is used to divide the dermis and subcutaneous tissues. The subcutaneous dissection is carried first posteriorly then medially down to the bony cranium. The subcutaneous tissues and deep musculature overlying the retromastoid cranium are elevated forward via a combination of blunt dissection and electrocautery. The mastoid emissary vein is isolated and divided, and the bony foramen of the vein is occluded with bone wax. The dissection is carried inferiorly until the cranium curves medially near the margin of the foramen magnum. Anteriorly, the posterior insertions of the digastric muscle are released, and superiorly the inferior margin of the temporalis muscle is exposed. Self-retaining retractors are positioned and hemostasis secured.

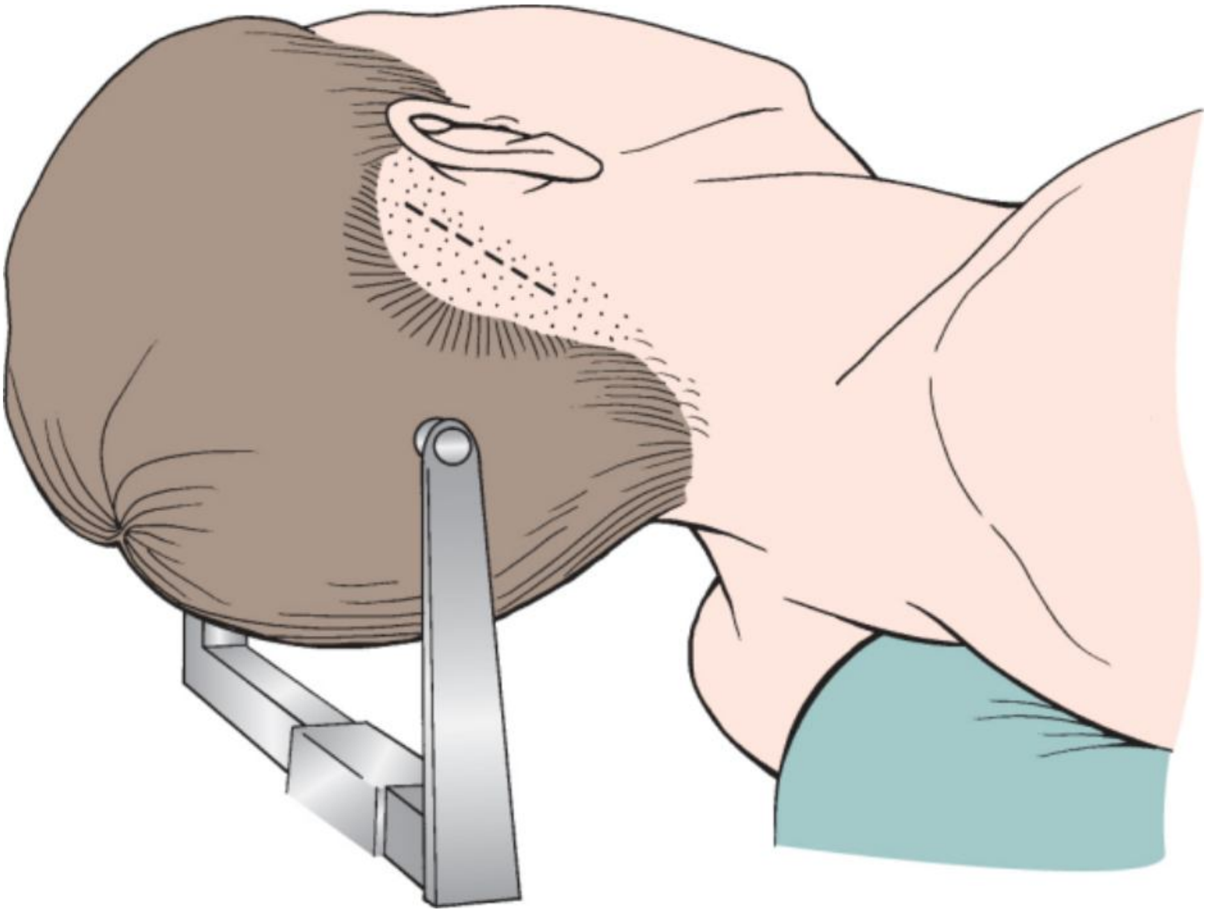

**Figure 131-29** The skin incision for a retrosigmoid vestibular nerve section.

The courses of the sigmoid and transverse sinuses are estimated by examining the surface anatomy of the mastoid and retromastoid cranium (Fig. 131-30). A high-speed cutting burr is used to outline the posterior margin of the sigmoid sinus and inferior margin of the transverse sinus under magnification. A retrosigmoid craniotomy measuring approximately 2.5 × 2.5 cm (Fig. 131-31) is performed using a combination of high-speed drills and rongeurs. Before opening the dura, hemostasis is secured and all exposed mastoid air cells are occluded with bone wax. The dura is incised in a manner creating an anteriorly based U-shaped dural flap (Fig. 131-32). Bipolar electrocautery is used for hemostasis. Surgilon 4-0 sutures are placed through the dural flap and used to retract the flap anteriorly.

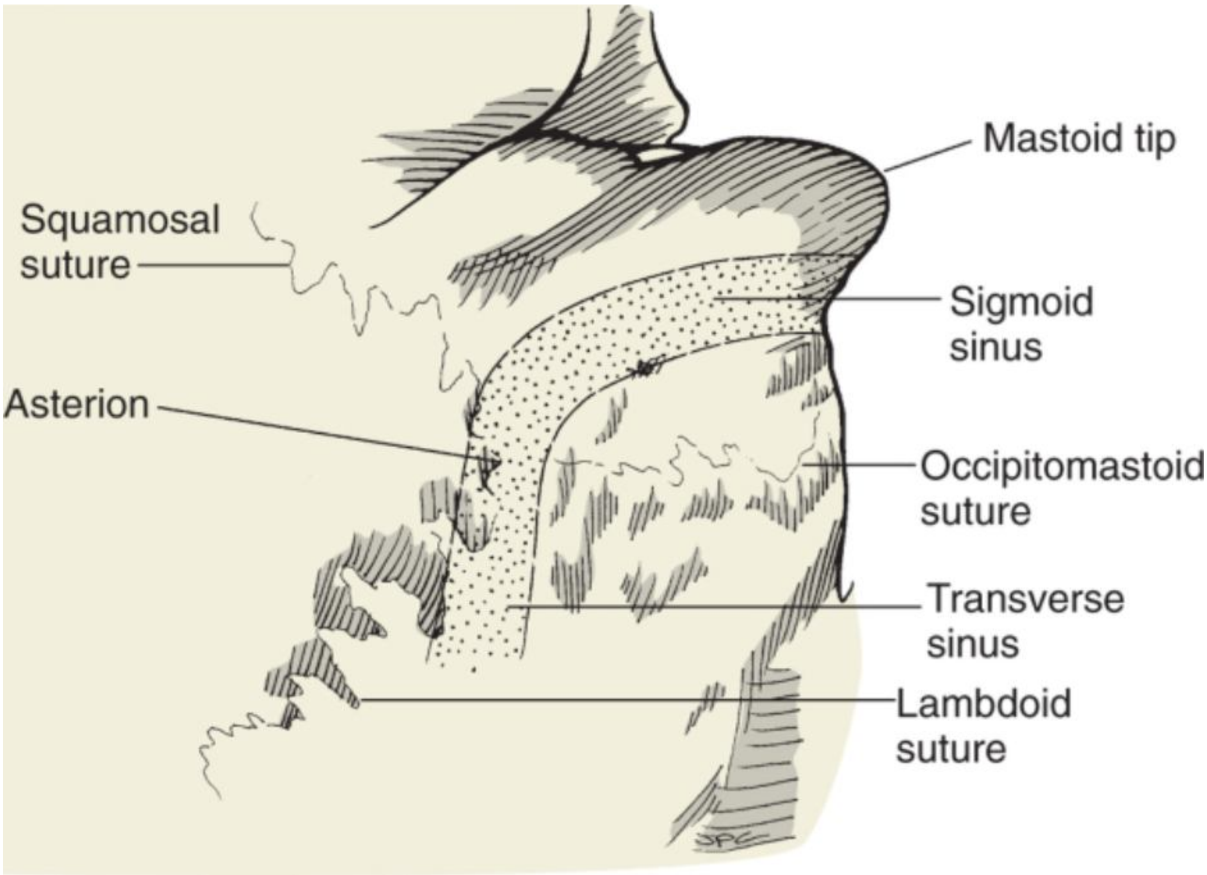


**Figure 131-30** The surface anatomy of the mastoid and retrosigmoid cranium, and the estimated course of the transverse and sigmoid sinuses.

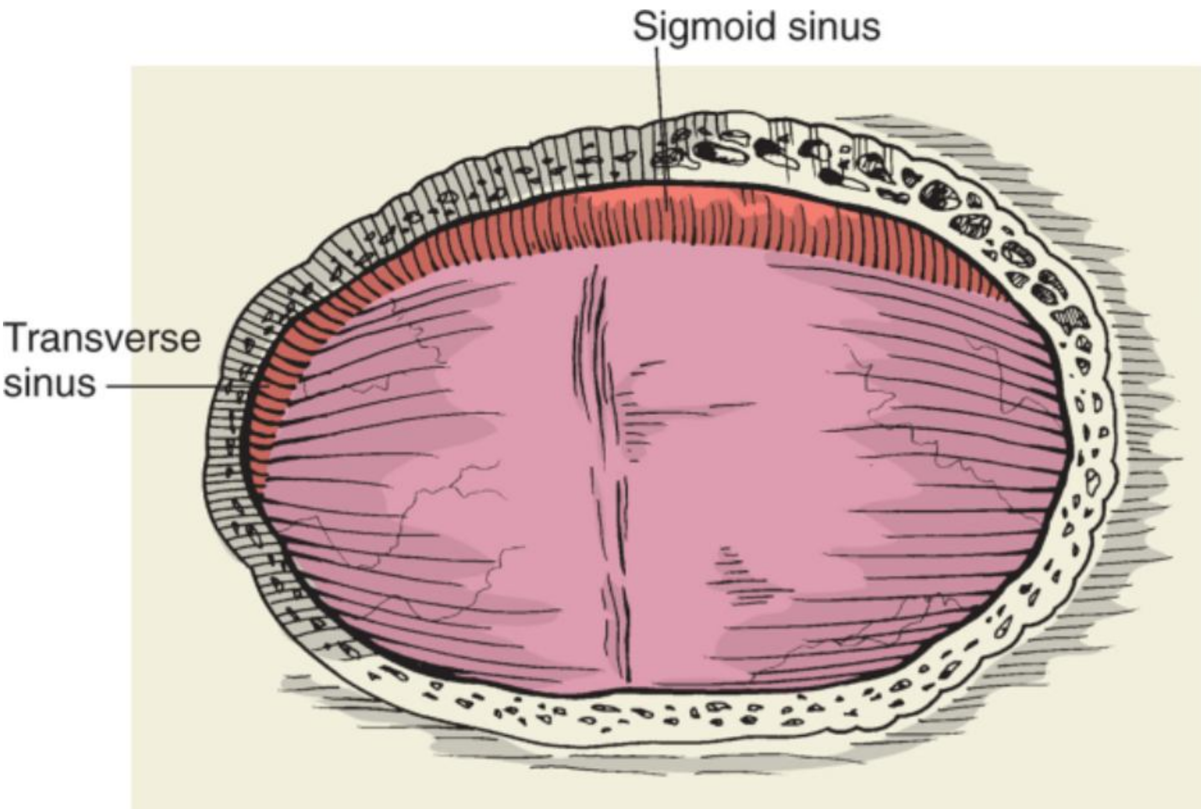


**Figure 131-31** The retrosigmoid craniotomy bordered by the sigmoid and transverse sinuses.

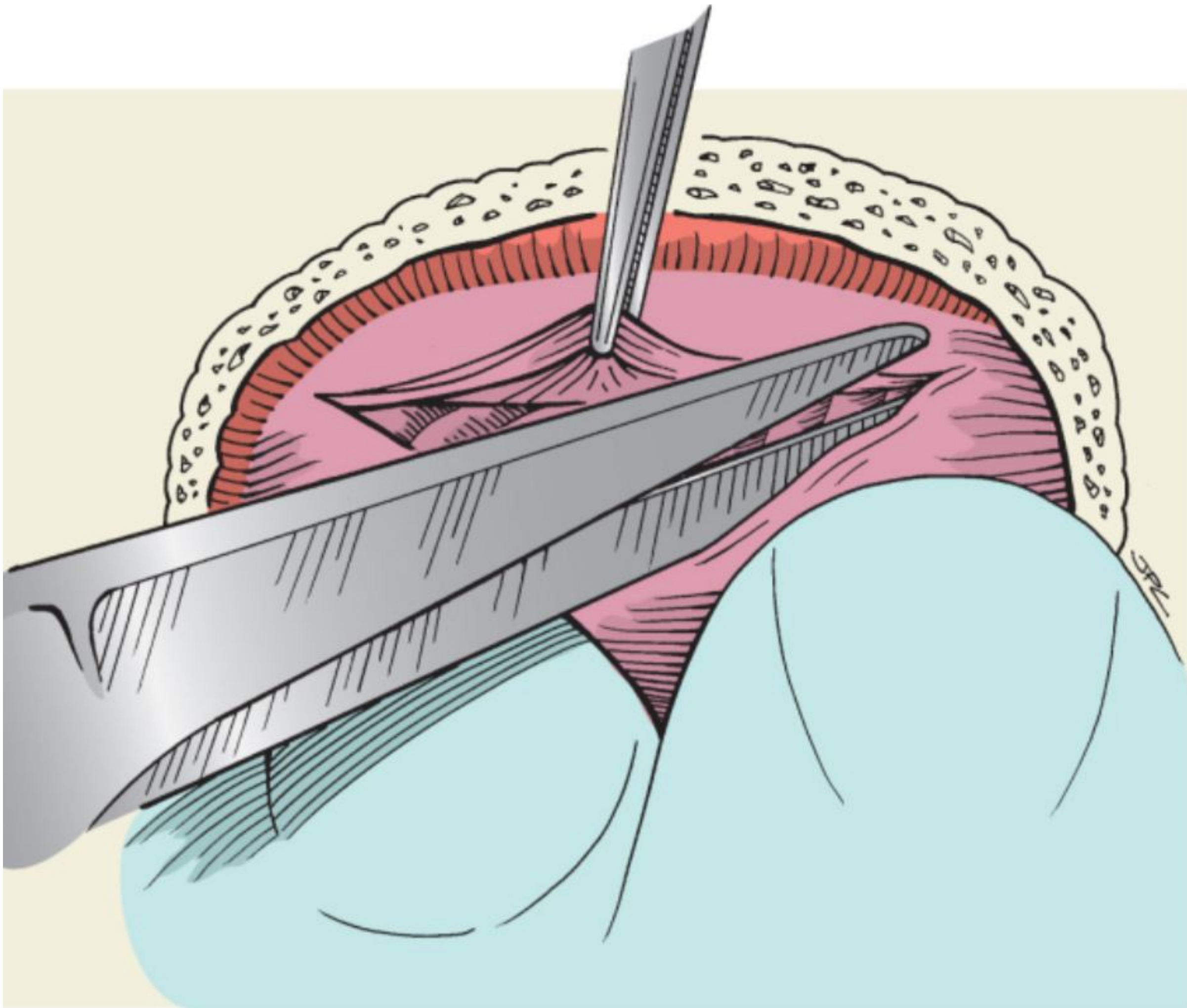

**Figure 131-32** Creation of an anteriorly based dural flap with gentle pressure applied on the lateral surface of the cerebellum.

Exposure of the posterior fossa contents, and identification of and section of the vestibular nerve are then completed in the manner described for the retrolabyrinthine approach. The dura is then closed with 4-0 Surgilon sutures. Small pieces of free abdominal fat graft are placed over the dura in the craniotomy site. The craniotomy is reconstructed by securing the craniotomy flap in place using surgical plates or mesh. The incision is then closed in three layers with a deep layer of 2-0 Vicryl reapproximating the musculoperiosteal tissue over the cranium. The deep cutaneous tissues are closed with 2-0 Vicryl. The skin incision is closed with a running 4-0 nylon stitch, and a light dressing is applied for 24 hours.

## Middle Fossa Approach for Vestibular Nerve Section

When hearing is present and the patient suffers from persistent vertigo after a retrolabyrinthine vestibular neurectomy, a middle fossa nerve section may be indicated to divide the vestibular components of CN VIII more distally and maintain hearing in the operated ear. This procedure is rarely used as the primary approach for vestibular nerve section. The advantage of this approach is that it enables visualization of the vestibular nerve where the superior, inferior, and singular nerves have separated from the cochleovestibular trunk, thus increasing the likelihood of a complete nerve section. This approach is more technically demanding and of necessity involves some retraction of the temporal lobe for an extended period. The risk of facial nerve injury and SNHL is greater than that incurred using the posterior fossa approaches.

The patient is positioned supine with the head turned to the contralateral side so that the operated ear faces up. Intraoperative facial nerve and brain stem evoked audiometry responses are monitored routinely. Broad-spectrum antibiotics are administered intravenously at induction of general anesthesia. Diuretics and steroids are also used to reduce cerebrospinal fluid pressure. An incision is made in the preauricular crease, starting at the level of the lower border of the zygoma and extending superiorly above, behind the auricle to form a reverse-question mark (Fig. 131-33). Anterior and posterior skin flaps lateral to the temporalis fascia are elevated to expose the temporalis muscle. An anteroinferiorly based temporalis muscle flap is created by incising the muscle along the linea temporalis using Bovie electrocautery. A 5- × 5-cm craniotomy, centered two-thirds anterior and one-third posterior to the external auditory canal, and inferiorly based at the root of the zygoma is created using a 4-mm cutting burr (Fig. 131-34). The bone flap is carefully elevated from underlying dura using a dural elevator and soaked in Bacitracin solution until the end of the case. Any bleeding from the dura may be controlled with bipolar electrocautery. The inferior border of the craniotomy is then lowered to the level of the middle fossa floor. Dura is carefully elevated off the middle fossa floor in a posterior to anterior direction to expose the anatomy of the floor of the middle fossa (Fig. 131-35). The limits of exposure are the middle meningeal artery anteriorly, the sulcus of the superior petrosal sinus medially, and the arcuate eminence overlying the dome of the superior semicircular canal posteriorly. Dura over the greater superior petrosal nerve (GSPN) tends to be densely adherent to the nerve. Therefore, great care is needed in dissection at this point due to the possibility of a dehiscent geniculate ganglion. The dura is elevated in a posterior to anterior direction to minimize injury to the GSPN and geniculate ganglion. Once exposure of the middle fossa floor is complete, the tongue of the middle fossa self-retaining retractor is secured at the sulcus of the superior petrosal sinus to retract the temporal lobe.

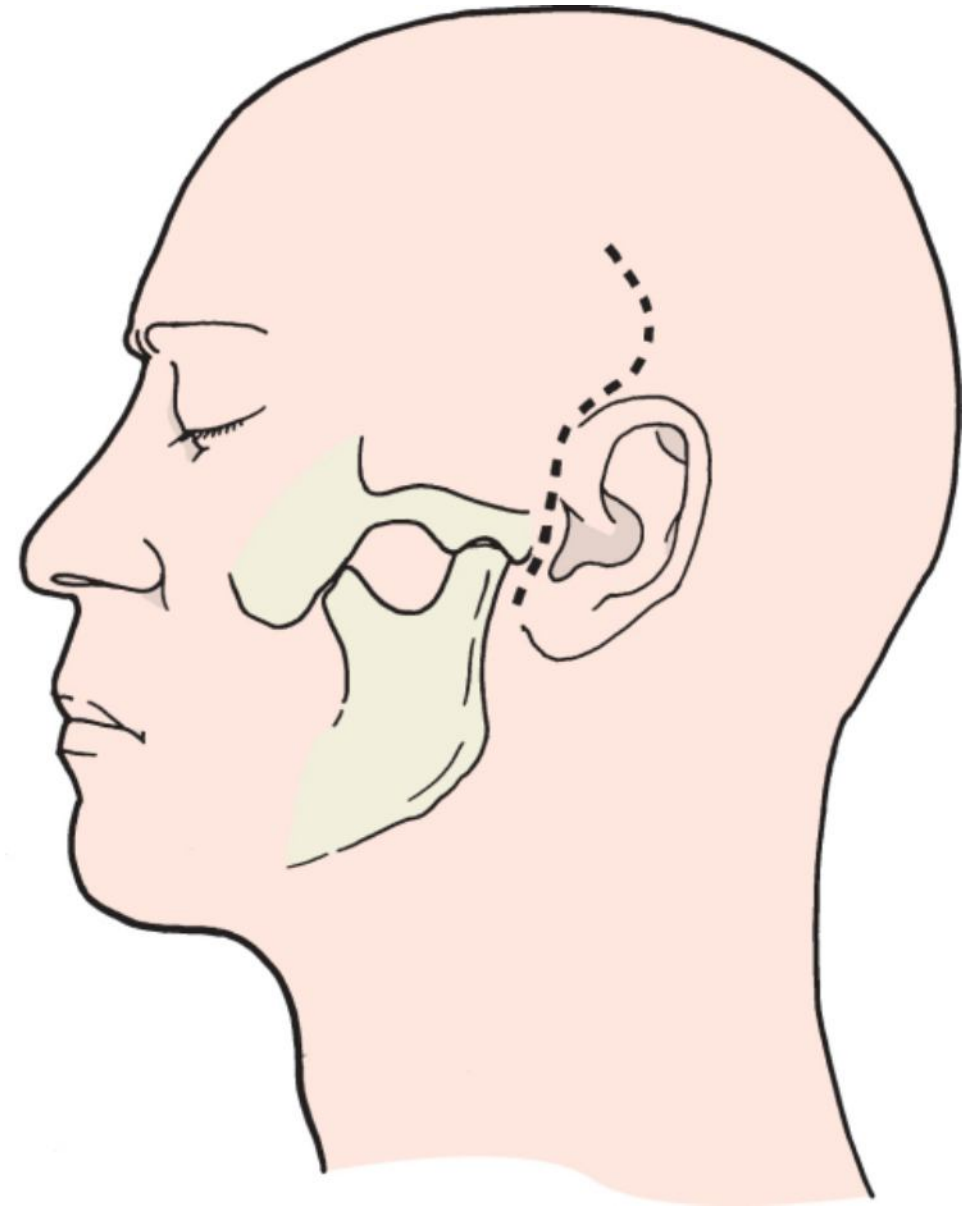

**Figure 131-33** Skin incision for a middle fossa craniotomy.

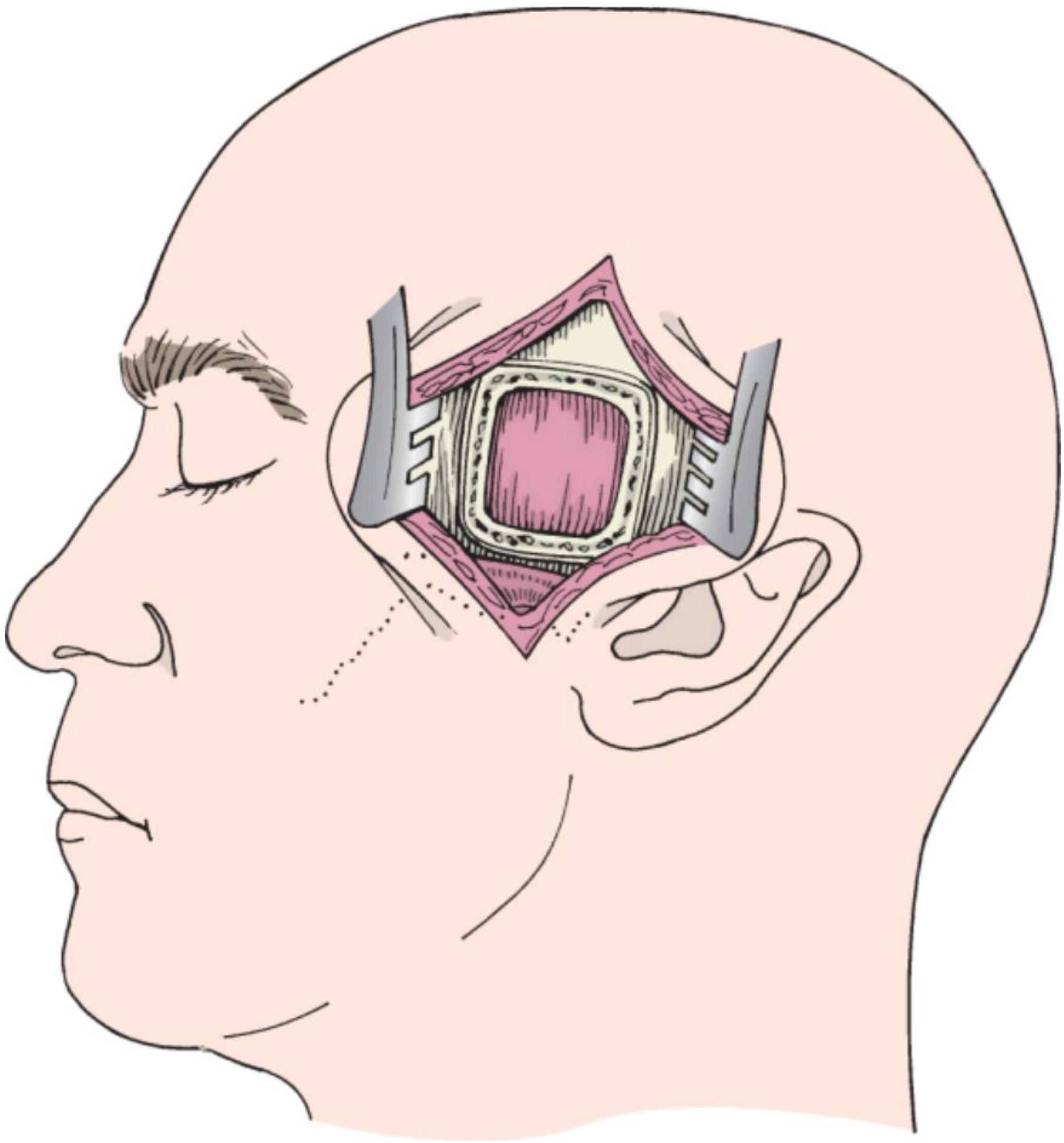

**Figure 131-34** Middle fossa craniotomy.

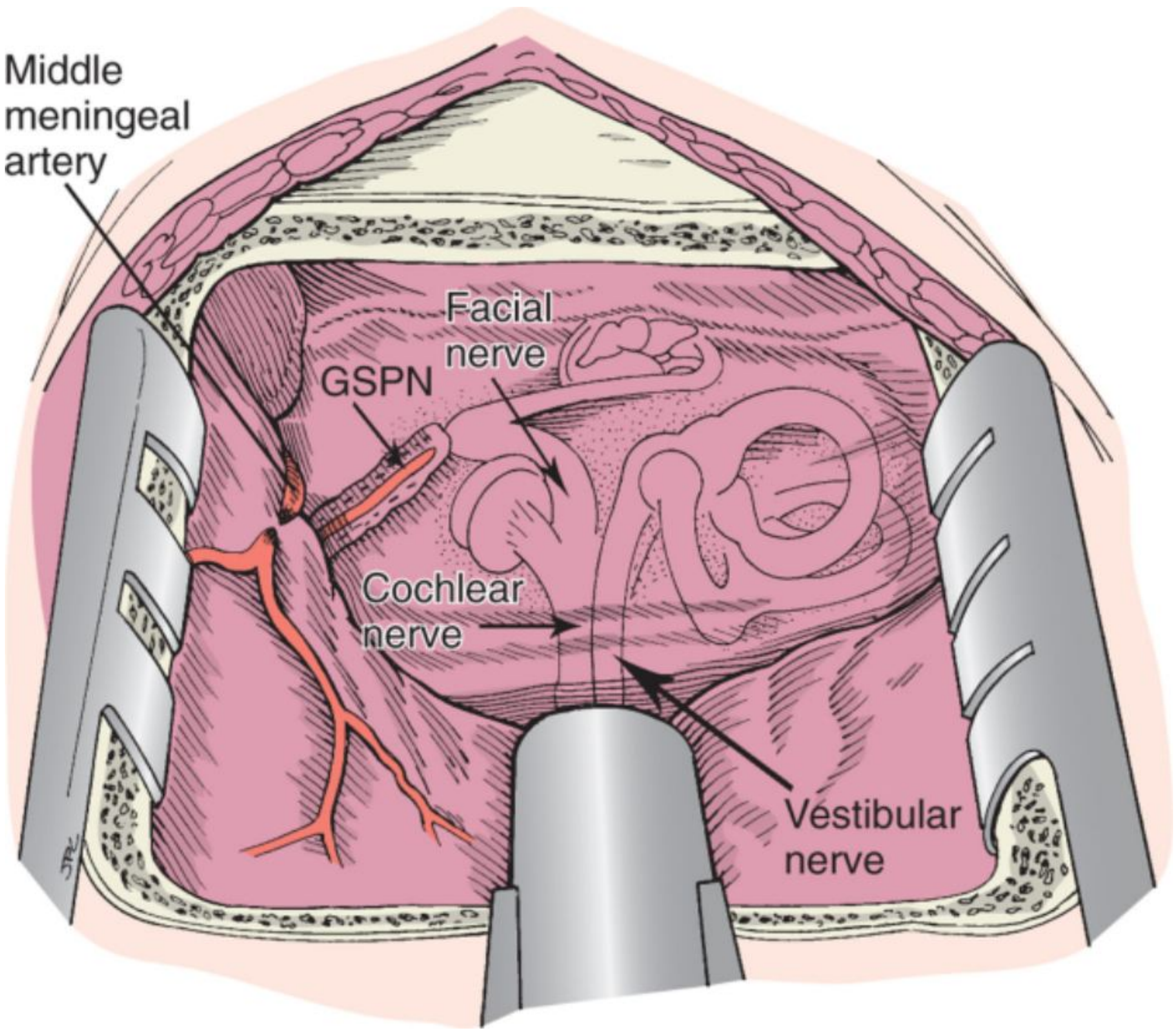


**Figure 131-35** Anatomy of the middle fossa floor. GSPN, Greater superficial petrosal nerve.

The floor of the middle fossa is then inspected. Anatomic landmarks to be identified include the GSPN, the geniculate ganglion, and the arcuate eminence overlying the dome of the superior semicircular canal. The location of the internal auditory canal is determined by bisecting the angle formed by the GSPN and arcuate eminence (Fig. 131-36). The roof of the internal auditory canal is first skeletonized over the medial half of the canal. Once the canal has been definitively identified, it may be followed out laterally to the fundus using progressively smaller diamond burrs. At the fundus of the internal auditory canal, the proximity of the basal turn of the cochlea and the ampulla of the SSC limit bony exposure to a 90-degree circumference over the roof of the canal (Fig. 131-37). Bill's bar at the lateral end of the internal auditory canal separates the facial nerve anteriorly from the superior vestibular nerve posteriorly.

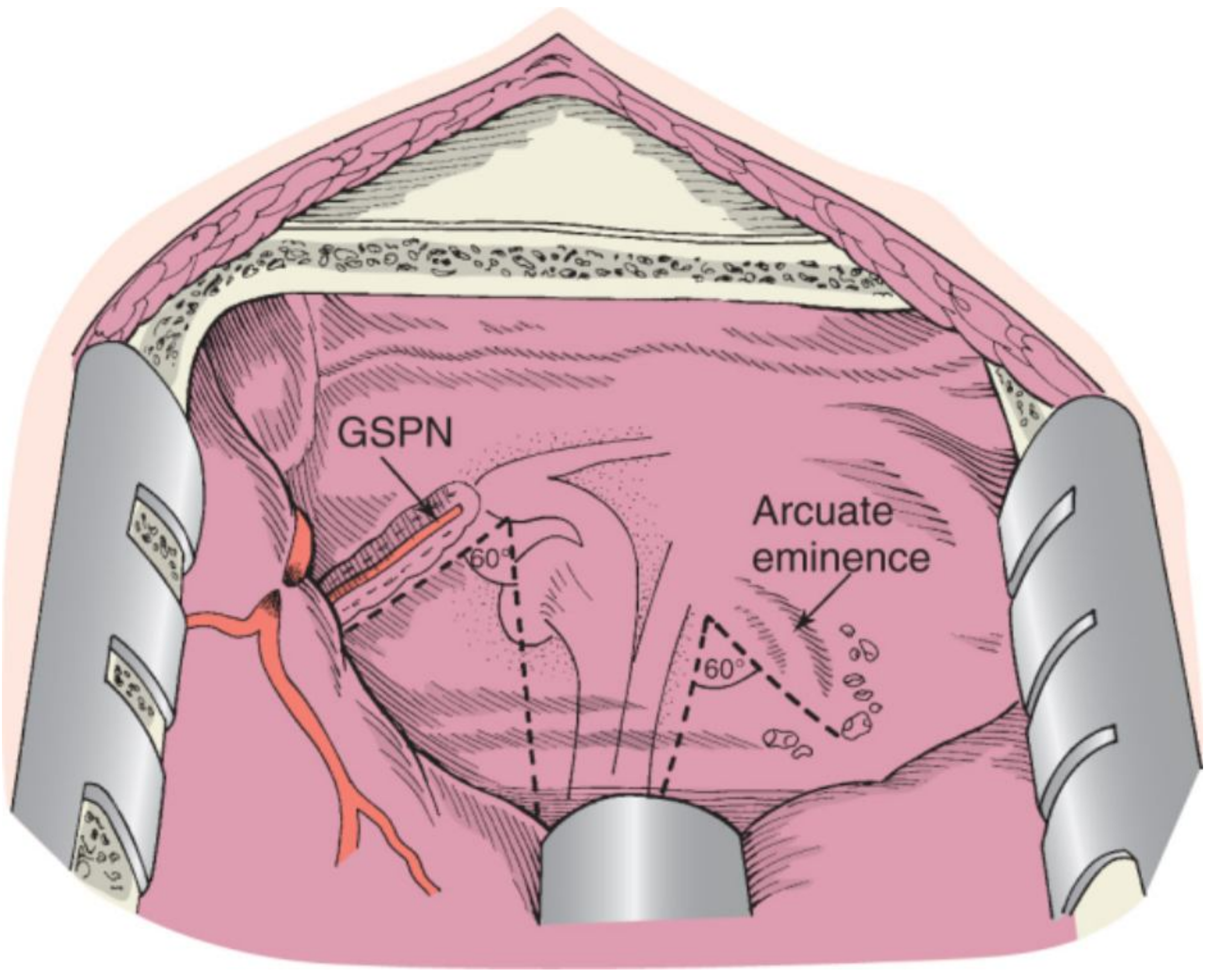


**Figure 131-36** Locating the internal auditory canal. GSPN, Greater superficial petrosal nerve.

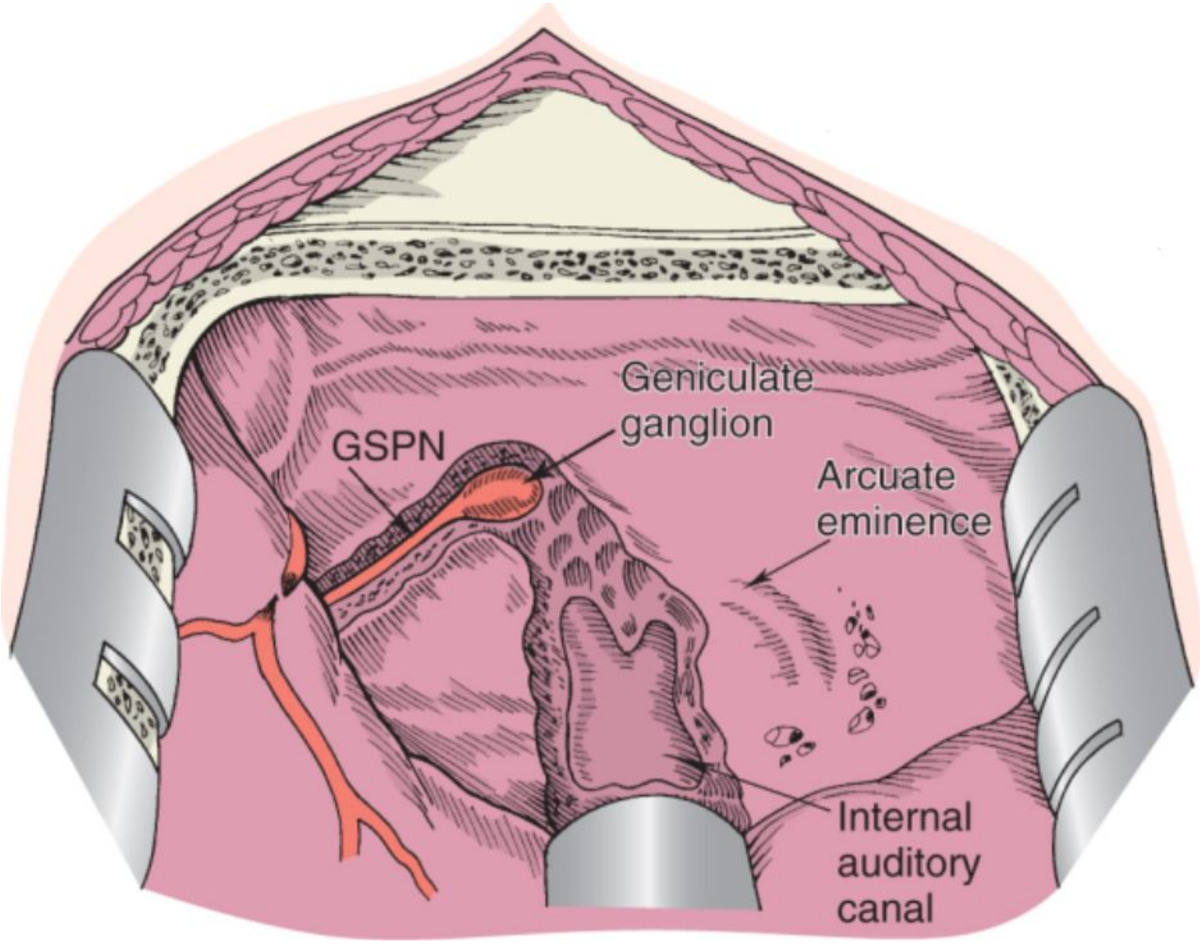


**Figure 131-37** Exposure of the internal auditory canal. GSPN, Greater superficial petrosal nerve.

Once the dura of the internal auditory canal is exposed, it is incised along the posterior one half of the internal auditory canal (Fig. 131-38). The contents of the canal are identified and the facial nerve course is confirmed using electrical stimulation. Vestibulofacial anastomotic fibers are divided (Fig. 131-39). The superior vestibular nerve is divided laterally and retracted medially to expose the inferior vestibular nerve (Fig. 131-40). The inferior vestibular nerve and the singular nerve are divided (Fig. 131-41). Finally, a segment of nerve containing Scarpa's ganglion is removed with microscissors. Care must be taken not to disrupt any blood vessels in the distal internal auditory canal, or else profound SNHL and facial paralysis can occur.

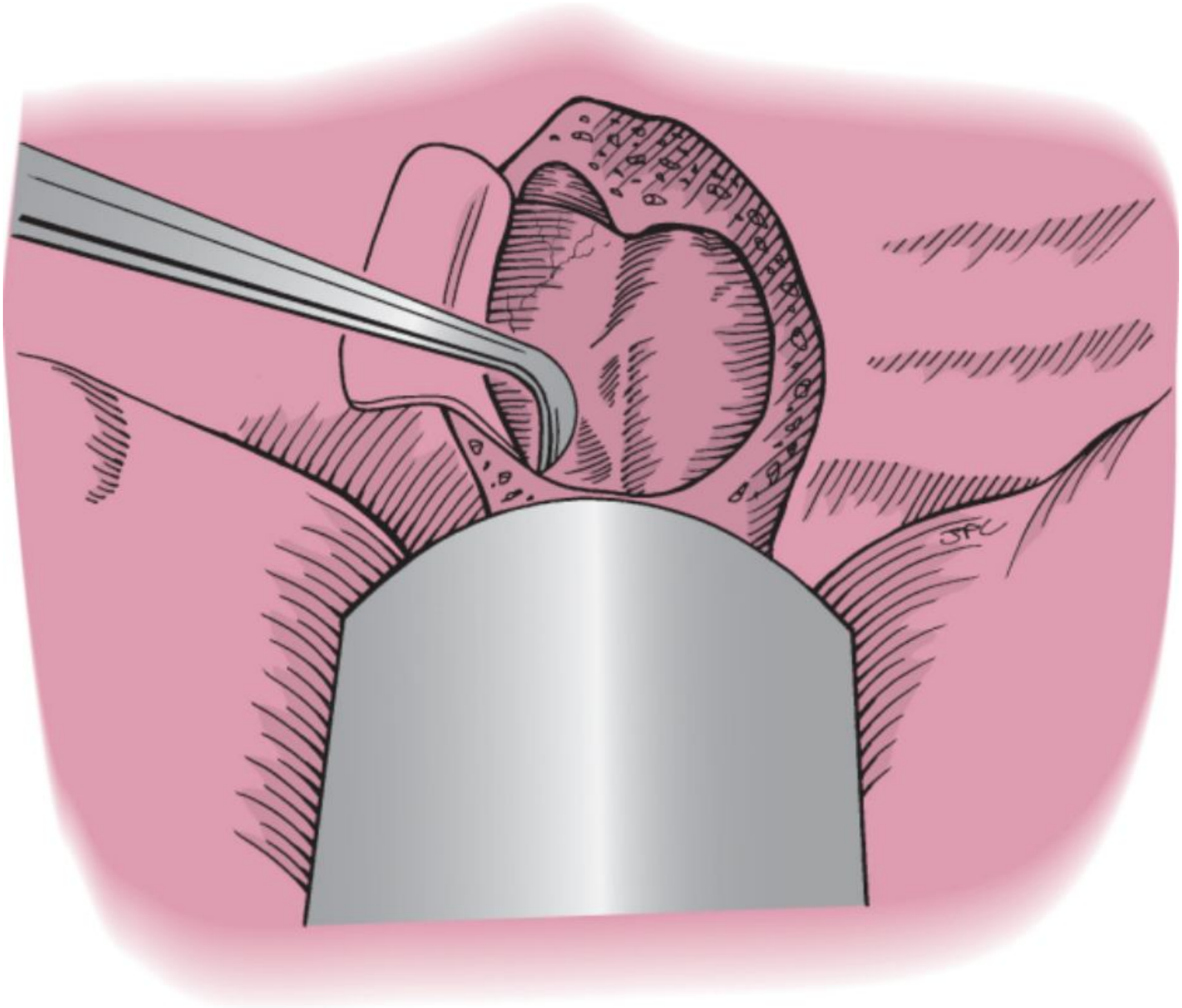

**Figure 131-38** The dura of the internal auditory canal is incised.

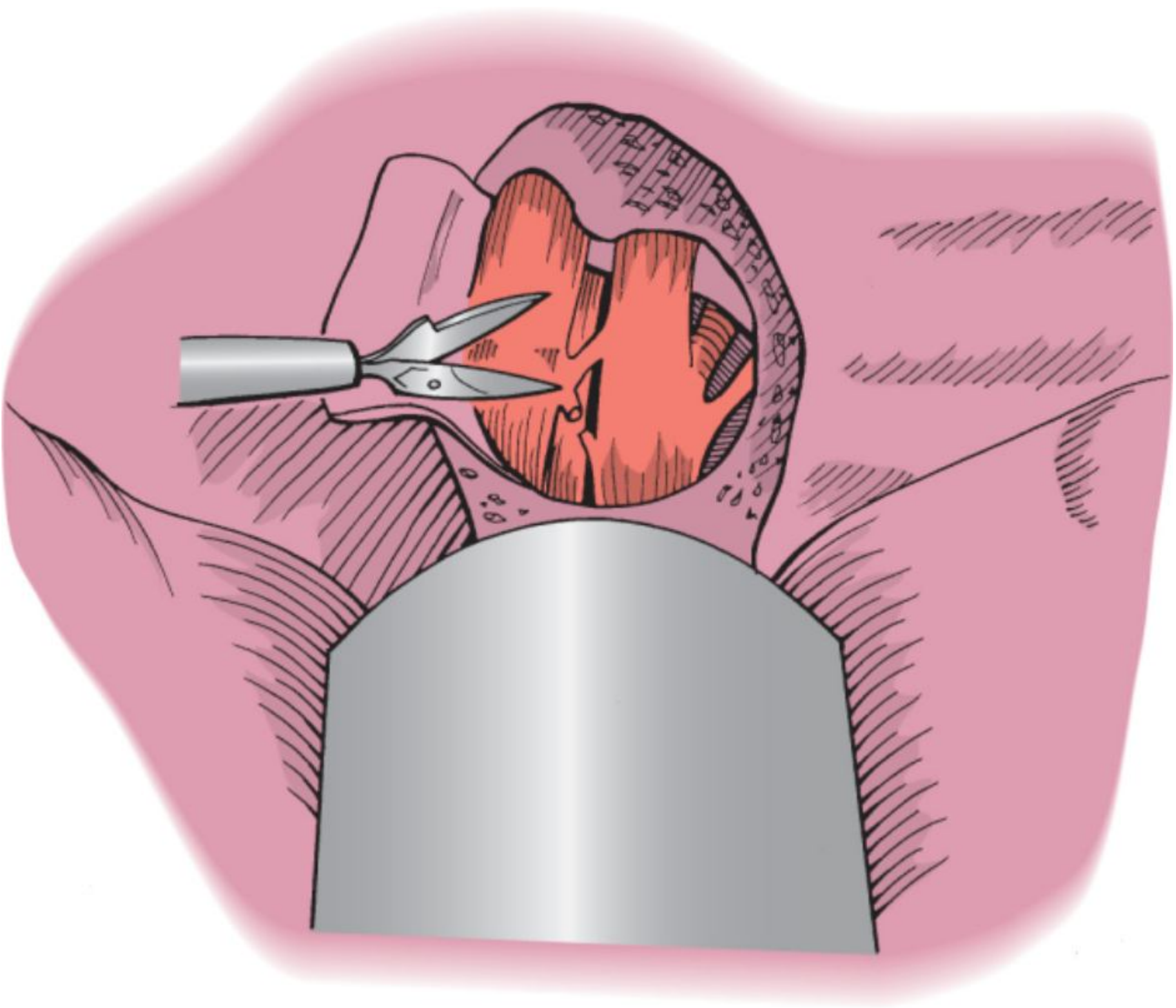

**Figure 131-39** Vestibulofacial anastomotic fibers are divided.

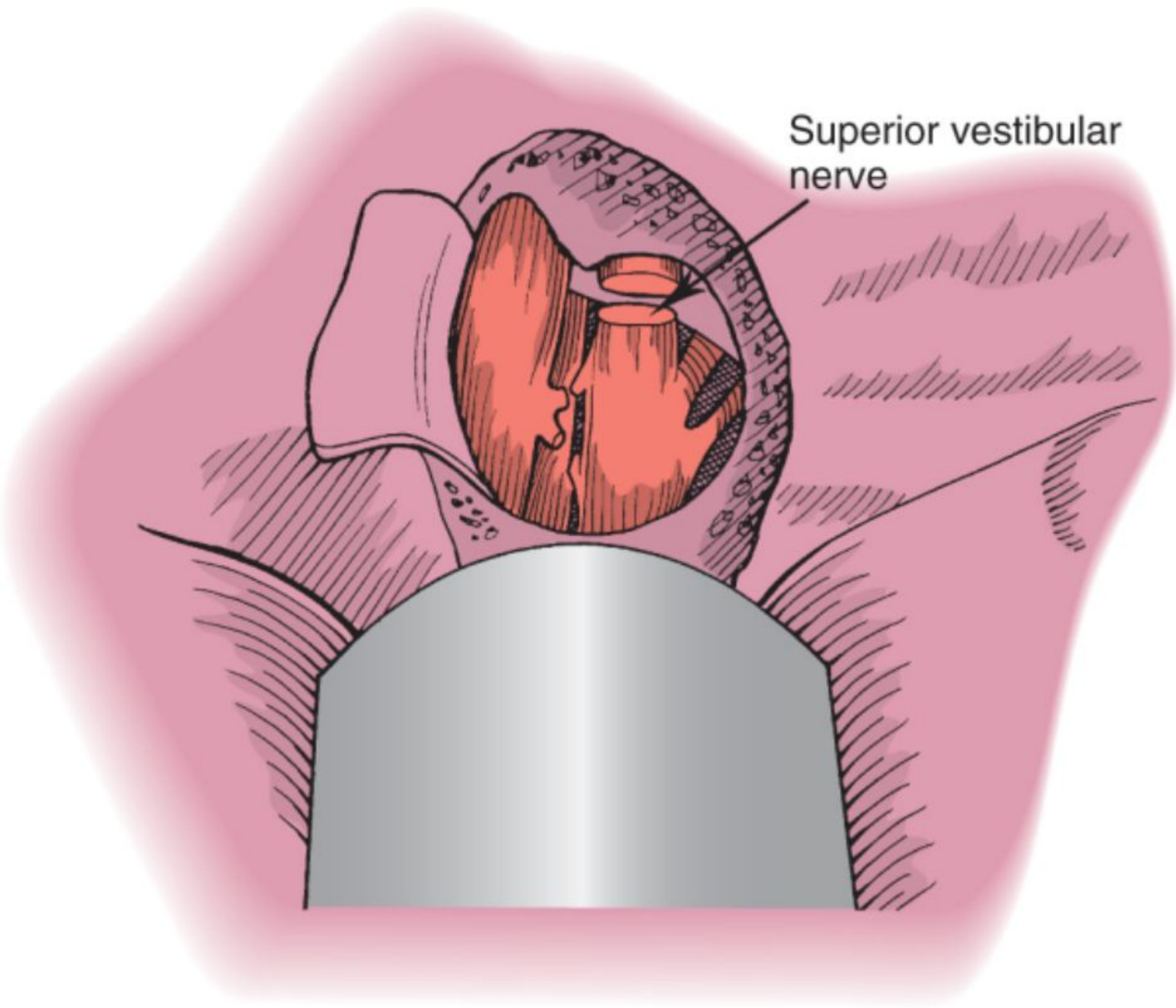


**Figure 131-40** The superior vestibular nerve is divided distally.

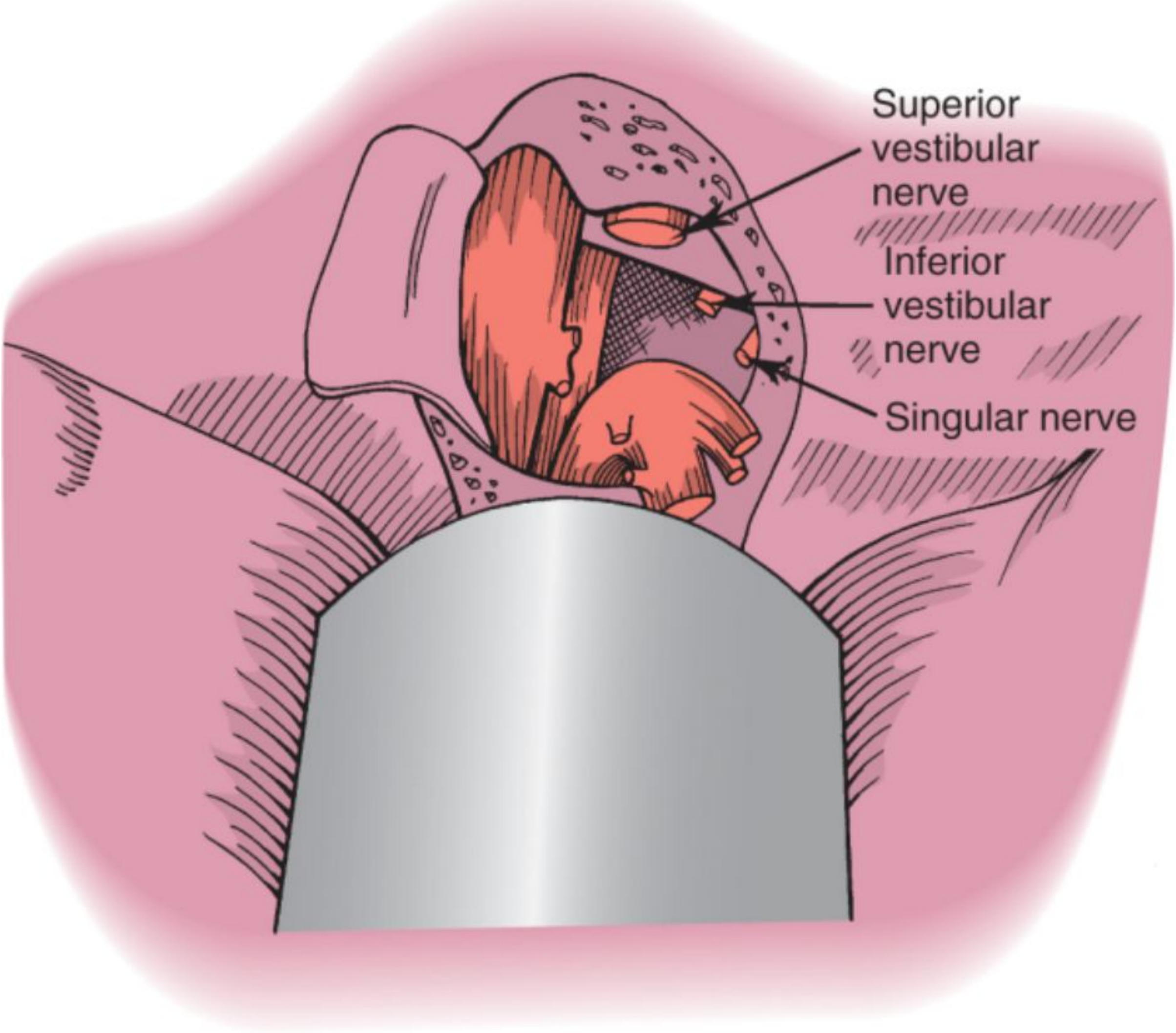


**Figure 131-41** The inferior vestibular nerve and the singular nerve are divided distally.

Once the nerve section is complete, the dural flaps are reopposed and the roof of the internal auditory canal is plugged with a free fat or muscle graft. The temporal lobe is allowed to reexpand over the middle fossa floor. The craniotomy bone plate is replaced. The surgical site is closed in layers to achieve a watertight seal. A light mastoid dressing is placed over the operated ear and kept in place for 24 to 72 hours. The patient is observed in the hospital for 3 to 4 days. Perioperative antibiotics are administered for 24 hours.

### Repair of Superior Semicircular Canal Dehiscence Syndrome

Surgical repair of a symptomatic dehiscent SSC is performed using a middle fossa approach, as described above for middle fossa vestibular nerve section. Once the middle fossa floor is exposed and the self-retaining middle fossa retractor placed under the bony petrous ridge, the arcuate eminence is identified. The arcuate eminence corresponds to the SSC in most cases. The dehiscent segment of the SSC is identified and inspected.

We have adopted the practice of both plugging and capping the SSC in each case. A bone paste is made from bone dust from the craniotomy and bone wax, and compressed into the defect to occlude the membranous labyrinth. A split-thickness calvarial bone graft is then fashioned from the middle fossa craniotomy bone flap and placed over the bony defect in the floor of the middle fossa. Any defects laterally along the tegmen should also be either occluded with bone wax or covered with fascia. The temporal lobe is allowed to reexpand over the middle fossa floor after removal of the self-retaining retractor. The craniotomy flap is replaced, and temporalis muscle and skin incision are closed in multiple layers to achieve a watertight seal. A light mastoid dressing is placed over the operated ear and kept in place for 24 to 72 hours. The patient is observed in the hospital for 3 to 4 days. Perioperative antibiotics are administered for 24 hours.

## *POSTOPERATIVE MANAGEMENT*

Most surgical procedures for vertigo will result in varying degrees of postoperative disequilibrium. Vestibular rehabilitation and physical therapy should be instituted early if symptoms are moderate to severe. Additional supportive care during this time includes antiemetic medications, pain control, and intravenous fluids. Nonablative procedures such as endolymphatic sac surgery and PSCO may also result in mild postoperative disequilibrium necessitating overnight observation in the hospital.

All patients undergoing intracranial surgery should receive broad-spectrum antibiotics intravenously for 24 hours. These patients are closely monitored in the postoperative period for potential complications including cerebrospinal fluid leak, meningitis, and intracranial bleeding.

## COMPLICATIONS

Complications specific to surgery for vertigo include cerebrospinal fluid leak, meningitis, facial nerve injury, and further hearing loss. Management of postoperative cerebrospinal fluid leaks and iatrogenic facial nerve injuries are discussed elsewhere in this text. Potential risks and complications of each surgical procedure should be discussed with patients during the process of obtaining informed consent for surgery.

### Posterior Semicircular Canal Occlusion

SNHL may occur if the vestibule is violated during skeletonization of the PSC. This usually occurs if the PSC is fenestrated too close to its ampulla, rather than midway between the ampulla and the common crus. Suctioning should be avoided in and around the fenestrated PSC because this may disrupt the membranous labyrinth. Temporary SNHL may result from a serous labyrinthitis. Postoperative SNHL, dizziness, and vertigo may be reduced by minimizing the size of the PSC fenestration and administering perioperative steroids.

### Endolymphatic Sac Surgery

Risks specific to this procedure include hearing loss, facial nerve injury, inadvertent fenestration of the PSC, bleeding resulting from trauma to the sigmoid sinus, and cerebrospinal fluid leak resulting from a dural tear. If the PSC is inadvertently fenestrated, the surgeon should avoid suctioning near the membranous labyrinth and immediately plug the defect with bone wax. The facial nerve is at risk for injury in the mastoid segment when skeletonizing the PSC and opening retrofacial air cells. Hearing loss resulting from endolymphatic sac surgery may be conductive or sensorineural in nature. Conductive hearing loss usually occurs as a result of blood in the middle ear after surgery. Delayed conductive hearing loss may occur if trapped bone dust in the middle ear causes bony ankylosis of the ossicular chain. This is prevented by plugging the aditus ad antrum with Gelfoam during the procedure. The posterior fossa dura may be violated when thinning the overlying bone at the time of initial exposure. Additionally, if the endolymphatic sac is not clearly identified, the posterior fossa dura may be mistakenly incised, resulting in cerebrospinal fluid leak. If the dural defect is small, it may be plugged with a small piece of muscle sutured in place with 4-0 Surgilon. A larger dural defect should be repaired with autologous tissue, and the middle ear and mastoid should be obliterated with muscle and fat, respectively, to prevent postoperative cerebrospinal fluid leak. Antibiotics are administered if a leak is detected at the time of surgery.

### Labyrinthectomy

Facial nerve injury and cerebrospinal fluid leak may occur during a labyrinthectomy. Knowledge of the normal intratemporal course of the facial nerve is critical in avoiding iatrogenic trauma to the nerve. When the LSC is fenestrated, the inferior wall of the canal should be preserved to protect the second genu of the facial nerve. The ampulla of the PSC is found deep to and under the facial nerve. Drilling should proceed cautiously in this area to expose the neuroepithelial contents of the ampulla without violating the facial nerve. The labyrinthine facial nerve is protected by preserving the medial wall of the SSC and LSC ampullae.

Cerebrospinal fluid leak may occur if the lateral portion of the internal auditory canal is inadvertently opened at the level of the vestibule or if the dura of the posterior or middle fossa are violated. Cerebrospinal fluid leak can be avoided by preserving the medial wall of the vestibule. In addition, the neurosensory epithelium of the inner ear must be removed carefully, or the underlying bony cribrosa that transmits the vestibular nerve axons can be disrupted, causing a cerebrospinal fluid leak. If a cerebrospinal fluid leak occurs, the remaining labyrinthine capsule and mastoid should be obliterated with a free abdominal fat graft. Intravenous antibiotics are started intraoperatively and continued for 24 hours if a leak occurs.

### Translabyrinthine Vestibular Nerve Section

Complications of translabyrinthine vestibular nerve section include facial nerve injury and cerebrospinal fluid leak. The risk of facial nerve injury is greater for translabyrinthine vestibular neurectomy than for labyrinthectomy because of the additional risk of facial nerve injury in the internal auditory canal and proximal labyrinthine segment. The facial nerve may be injured during bony exposure of the proximal fallopian canal and dissection of the nerve within the internal auditory canal.

The anterior inferior cerebellar artery may loop deep into the internal auditory canal and can be injured during dissection of the contents of the canal. If bleeding is encountered within the internal auditory canal, the source of bleeding should be clearly identified. Electrocautery should not be generally used within the internal auditory canal because spread of current may injure the facial nerve or anterior inferior cerebellar artery. In this situation, bleeding may be controlled with Surgicel.

### Retrolabyrinthine and Retrosigmoid Vestibular Nerve Sections

Potential complications of both approaches include bleeding from a dural sinus, cerebellar edema, facial nerve injury, cochlear nerve injury, intracranial vascular injury, postoperative headache, and cerebrospinal fluid leak.

Trauma to the dural sinuses is best avoided by use of a gentle and patient technique when drilling near the sinuses. Rongeurs are used only after the dura has been freed from the overlying bone with dural elevators. The tip of the rongeur can easily tear a dural sinus if the tip is extended past the area of dura that has been elevated. A tear in the sigmoid sinus or mastoid emissary vein is usually managed by covering the area with Surgicel and applying light pressure. Larger tears may need to be repaired with 4-0 silk, with or without the addition of a small muscle plug.

Injury to the facial nerve is a rare but potential complication because of its proximity to the eighth nerve complex. Injury to the facial nerve is best avoided by clear identification of the nerve before the vestibular nerve section is performed. Electrical stimulation of the facial nerve is recommended to confirm the location and course of the nerve. Occasionally, the facial nerve is adherent to the ventral surface of the eighth nerve and will need to be separated from it before sectioning of the vestibular nerve. The facial nerve should be electrically stimulated at the end of the procedure to confirm its functional integrity. If the nerve does not respond to electrical stimulation, anatomic continuity should be confirmed by direct visualization of the course of the nerve. A transected nerve should be repaired primarily.

Trauma to the cochlear nerve is best avoided by using meticulous surgical technique. The arterial blood supply to the nerve must be maintained. Bipolar cautery near the eighth nerve should be used judiciously.

Headache in the immediate postoperative period may occur from sterile arachnoiditis, elevated intracranial pressure, or meningitis. To reduce the occurrence of sterile arachnoiditis and elevated intracranial pressure, one should use meticulous hemostasis. Dexamethasone is used perioperatively to reduce the severity of early postoperative headache. Retrosigmoid craniotomies should be reconstructed by replacing and securing the bone flap to avoid the development of chronic headaches. If headaches occur and persist, secondary reconstruction of the craniotomy defect, sensory nerve anesthetic block, or sensory nerve section may be required.

### Middle Fossa Vestibular Nerve Section

Additional complications encountered with the middle fossa approach include SNHL, vertigo, facial paralysis, intracranial bleeding, and cerebrospinal fluid leak. A thorough knowledge of temporal bone anatomy as visualized from the middle fossa floor is helpful in avoiding iatrogenic trauma to the facial nerve, cochlea, and vestibular labyrinth.

Facial paralysis occurs more frequently with the middle cranial approach than with any other approach for vestibular nerve section. The facial nerve is primarily at risk while one is exposing and working within the internal auditory canal. The dura of the internal auditory should be opened posteriorly, over the superior vestibular nerve. The vestibulofacial anastomoses must be sharply divided to avoid traction injury to the facial nerve.

Temporal lobe edema, contusion, or subdural hematoma may occur from direct injury during the craniotomy or from retraction injury during elevation of the dura overlying the middle cranial fossa. These complications are avoided by taking steps to reduce intracranial pressure at the start of surgery (i.e., reducing $P_{CO_2}$, intravenous mannitol, and dexamethasone). If the temporal lobe is tight, a small incision in the dura can be made to release cerebrospinal fluid before retraction of the temporal lobe. If temporal lobe injury is suspected, a head CT scan should be performed postoperatively to assess the degree of edema of the temporal lobe, and a neurosurgical colleague should be consulted.

### Superior Semicircular Canal Dehiscence Repair

This procedure poses risks similar to those incurred with middle fossa vestibular nerve section. Because the surgeon is intentionally occluding the SSC, there is a risk of SNHL as well, just as in the PSC occlusion procedure.[23]

**PEARLS**

- Surgery is indicated only for control of disabling vestibular symptoms in patients with peripheral vestibulopathy who have failed medical treatment and vestibular rehabilitation.
- Vestibular ablation is contraindicated in those with bilateral peripheral or central vestibulopathy.
- Chemical vestibular ablation using intratympanic gentamicin has become the preferred primary treatment modality for disabling unilateral peripheral vestibulopathy because the risks of treatment are significantly lower than those incurred with surgical ablation.
- The retrosigmoid and retromastoid approaches are the preferred approaches for vestibular nerve section in patients with aidable hearing in the affected ear.
- The posterior semicircular canal should be fenestrated midway between its ampulla and the common crus for PSCO to minimize the risk of violating the vestibule and causing sensorineural hearing loss.

**PITFALLS**

- Vestibular ablation in the presence of bilateral peripheral vestibulopathy will result in disabling oscillopsia.
- Suctioning in the vicinity of a fenestrated or dehiscent semicircular canal may result in disruption of the membranous labyrinth and postoperative sensorineural hearing loss.
- Incomplete removal of the sensory neuroepithelium within the posterior semicircular canal ampulla is the most common cause of persistent vertigo following a labyrinthectomy.
- The absence of consistent clear demarcation between the cochlear and vestibular nerves in the cerebellopontine cistern increases the risk of inadvertent injury to the cochlear nerve in posterior fossa approaches for vestibular nerve section.
- Middle fossa approaches necessitate temporal lobe retraction for exposure of the middle fossa floor, which is poorly tolerated in older individuals.