# Chapter 124 – Acoustic Neuroma

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Acoustic neuroma (AN) is the most common benign tumor arising in the posterior cranial fossa. The term *acoustic neuroma* is a misnomer, in that the tumor typically arises from the vestibular rather than the auditory division of the eighth cranial nerve and is of Schwann's cell origin. Thus the proper nomenclature would be *vestibular schwannoma.* These tumors are thought to originate near Scarpa's ganglion where the density of Schwann's cells is greatest. The origin of the tumor is equally divided between the superior and the inferior divisions of the vestibular nerve. Typically, these tumors are benign and slow growing, increasing in size, on average, from 1 to 2 mm a year; however, more rapid or slower growth characteristics are also observed. The consistency can be soft, firm, or mixed, with cystic components as well.

## *HISTORY*

Surgery of AN was first described in the late 19th century. Early successful surgical resection was accomplished through a suboccipital craniotomy, removing the tumor by finger dissection.[1] Surgical mortality was unacceptably high owing to the fact that many patients were moribund preoperatively. Two of the early pioneers in AN surgery were Harvey Cushing and his protégé, Walter Dandy. During the first 3 decades of the 20th century, Cushing refined his philosophy of management of AN to recommend a bilateral suboccipital craniectomy approach and advocated unhurried resection and meticulous hemostasis. He also employed partial cerebellar resection when necessary. His techniques for hemostasis included the use of bone wax, silver clips, and electrocautery.[2,3] Unfortunately, he gutted only the core of the tumor; thus many patients subsequently died of tumor regrowth.

The concept of total tumor removal was advanced by Dandy, who reintroduced a unilateral suboccipital approach with gentle but complete resection of the tumor capsule.[4] The first translabyrinthine craniotomy was performed by F. H. Quix in 1911.[5] This approach was condemned by the neurosurgical community until the early 1960s when the translabyrinthine approach was perfected by William House in conjunction with his neurosurgical colleague, William Hitselberger. Their use of an operating drill and microscope to directly access the tumor with preservation of the facial nerve set the stage for the new era of surgery for AN.[6]

Methods for diagnosing AN have significantly improved over the past century. Tomography has enabled the identification of enlargement of the internal auditory canal (IAC). Myelography required injection of contrast material into the subarachnoid space; the contrast was floated into the IAC by patient positioning. Contrast-enhanced computed tomography (CT) eliminated much of the morbidity associated with myelography, reduced the amount of radiation exposure, and increased the sensitivity of diagnostic radiographic tests. Since the mid-1980s, magnetic resonance imaging (MRI) has become the state-of-the–art in diagnosing ANs. Tumors as small as 1 to 2 mm may be readily identified on MRI.

Audiometric tests have undergone similar sophisticated improvements over time. A battery of special tests, including Bekesy's audiometry, alternating binaural loudness balance test, short–increment sensitivity index, and tone decay, are now of only historical importance for use in categorizing cochlear or retrocochlear hearing loss. Identifying decay of the acoustic reflex or reduced word discrimination at higher presenta–tion levels (rollover) is suggestive of retrocochlear pathology. The auditory brain stem response (ABR) test is now the most specific and sensitive objective audiometric test for diagnosing AN. It had been reported that an abnormal ABR might be identified in 96% of tumors. Recent publications have shown that the ABR test may be normal (false–negative) in 31% of patients with tumors less than 1.0 cm.[7] The greater sensitivity of MRI testing now allows discovery of small tumors limited to the IAC.

## *PATIENT PRESENTATION*

Patients with a small tumor isolated to the IAC typically complain of unilateral hearing loss, tinnitus, and occasionally vestibular dysfunction. A few patients experience sudden hearing loss. Recurrent acute attacks of vertigo are an unlikely presentation for AN. However, disequilibrium with motion intolerance may be present. Patients may describe unilateral difficulty in discerning speech. This becomes more apparent when the telephone is used in the involved ear. Patients complaining of this problem should be evaluated with MRI. Facial nerve dysfunction is a rare presenting sign. Slow progressive weakness may occur with larger tumors. Patients complaining of headaches prompt the request for MRI, which may demonstrate an otherwise asymptomatic acoustic neuroma.

Very large tumors not only compromise hearing and facial function (paresis, synkinesis) but also may affect other cranial nerves causing hypesthesia, analgesia, dysesthesia, dysphagia, aspiration, and hoarseness. Coarse-beating nystagmus on ipsilateral gaze, fine–beating nystagmus on contralateral gaze (Brun's nystagmus), and ataxia with a broad–based gait are manifestations of compression of the brain stem and cerebellum.

## PATIENT SELECTION AND COUNSELING

Since the mid-1980s, MRI has evolved to be the state–of-the–art in identifying AN. Enhanced CT with thin cuts taken 0.6 mm apart through the IAC is also capable of identifying tumors as small as 3 to 5 mm, but this is less sensitive than MRI.

Management of posterior fossa tumors suspected of being an AN is dependent on numerous factors. Currently, there are three options for therapy: surgery, irradiation, and observation. In the first option (surgical resection), surgery can be performed through three main approaches along with their modifications—the middle fossa, translabyrinthine, and retrosigmoid approaches. It is assumed that complete resection will be accomplished, although on rare occasion, subtotal removal may be planned. In the second form of therapy (irradiation), methods for delivery include cobalt radiation by gamma knife surgery and photon beam radiation by a linear accelerator. Stereotactic radiation has traditionally been delivered by neurosurgeons; however, neurotologists are now actively participating in this treatment modality as well.[8] The third option for management is to perform no immediate intervention but to observe and monitor tumor growth with serial MRI.

Goals of treatment include either complete resection in the case of surgery, or prevention of growth in the case of radiation, while minimizing morbidity and mortality.[9] Preservation of facial nerve function and hearing function are secondary goals. Surgical mortality is typically less than 1% for acoustic neuroma resection, with an overall morbidity rate of 22%.[9] Recurrence following surgical resection is approximately 1.5%.[9] In their discussion, Kaylie and McMenomy conclude that microsurgery is the treatment of choice for acoustic neuroma due to higher growth rates following radiation versus surgery, comparable postoperative cranial nerve function, and the risk of radiation-induced malignancy.[9] However, the authors acknowledge that following radiation, the quality of life measures are better, and return to work occurs more quickly.

Many physicians agree that observation is often appropriate for older patients or those with small tumors. Patients opting for observation must be informed of the natural history of AN, particularly the risk of hearing deterioration or sudden hearing loss. A recent publication from Denmark found that 89% of tumors less than 1.5 centimeters that were observed for 3 to 4 years demonstrated tumor growth and/or further hearing loss.[10] However, a meta-analysis of 903 patients treated initially with observation found that only 20% ultimately required intervention.[11] It has also been reported that 50% of patients with class A or B hearing will lose useful hearing if observed.[12] Patients must be aware of potentially increased surgical risk if intervention becomes necessary at an older age.[13]

The best results of microsurgery are seen in centers with high patient volumes and experienced surgical teams.[13] Additionally, better results are seen in the later stages of a surgeon's career due to the learning curve.[14] The advantage of surgical resection is the ability to achieve complete tumor removal with very low rates of recurrence. However, recurrence rates of up to 20% can be seen in cases of subtotal resection.[11] Meta-analysis of 5005 patients undergoing microsurgery between 1972 and 1999 indicates a good facial nerve outcome (House–Brackmann Grade 1-2) in 87%, and a 36% rate of useful hearing preservation.[11] Potential complications include hearing loss, cerebrospinal fluid (CSF) leak, facial weakness, headaches, meningitis, cerebrovascular accident, and death. In the best case scenario, hearing may be preserved in approximately 50% of patients who have useful hearing preoperatively.[13,15] Hearing preservation rates vary by approach: 53% of patients had useful hearing preserved via the middle fossa approach, while this rate dropped to 30% with the retrosigmoid approach as reported by Harsha.[15] Therefore patients should be aware of the risk of hearing loss. Patients should be made aware of subsequent alternatives for aural rehabilitation including the CROS, BiCROS, and Baha hearing devices.

Facial nerve outcomes are affected by the size of the tumor, with tumors larger than 1.5 cm having an increased risk of facial weakness postoperatively. Facial nerve outcomes are better when surgery is performed in a center doing a high volume of such surgery. Rates of good facial nerve function are 93% for middle fossa, 97% for retrosigmoid, and 78% for translabyrinthine approaches in series of at least 100 patients.[15] However, it should be noted that patients' self-reports of facial nerve function are often worse than the surgeon's assessment.[16]

The case of a patient with good preoperative hearing but tumor located laterally in the IAC deserves special mention. When the tumor extends laterally into the fundus, particularly if it is of inferior vestibular nerve origin, the transverse crest will likely preclude total tumor resection via the middle fossa approach (Fig. 124-1). Additionally, it is difficult to achieve full tumor resection while preserving hearing through a retrosigmoid approach in this case as well. Therefore such patients may opt for a translabyrinthine approach, knowing that hearing loss will be traded for more complete tumor resection and possibly a lower chance of facial weakness.[13]

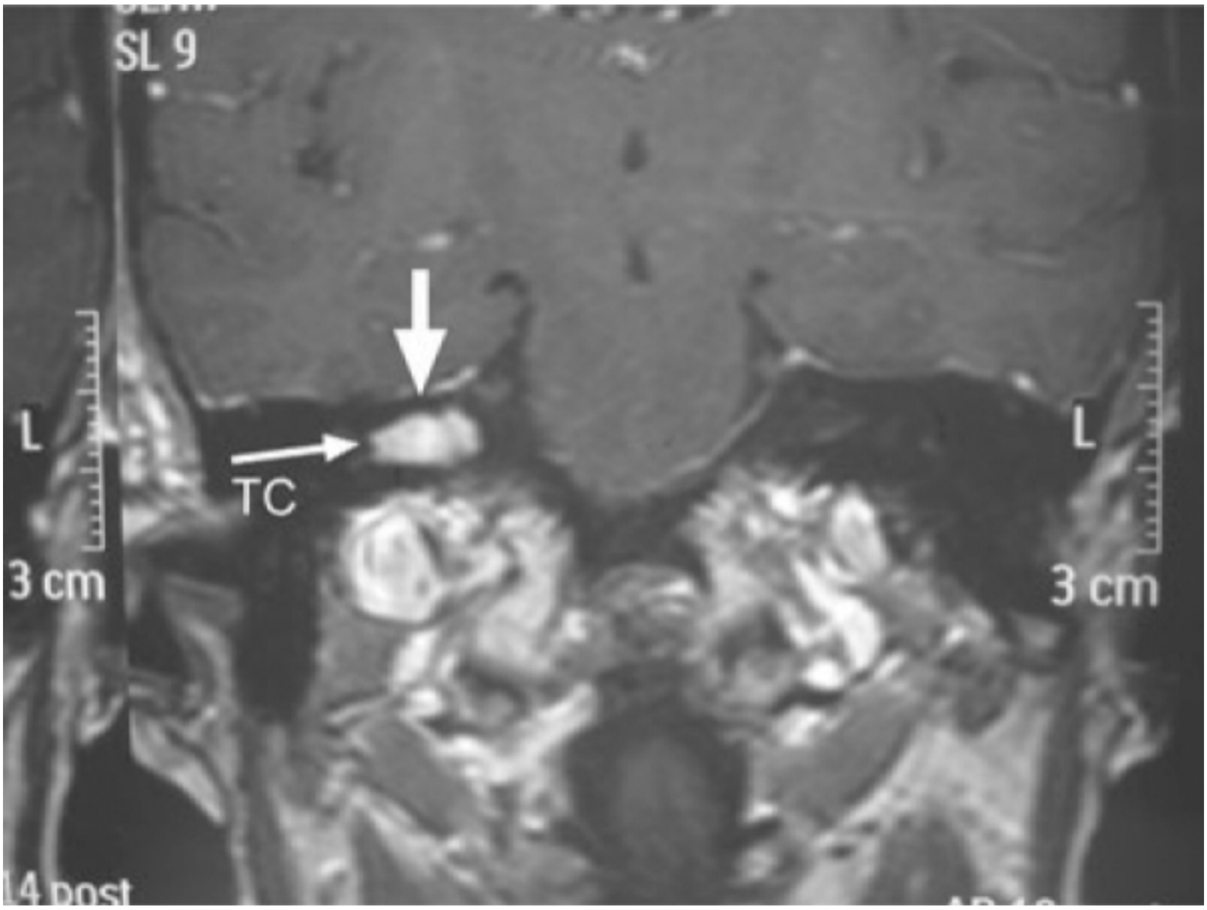


**Figure 124-1** T1-weighted magnetic resonance image with contrast showing a right internal auditory canal acoustic neuroma located laterally in the fundus *(arrow)*, above and below the transverse crest (TC).

Radiosurgery offers the advantage of outpatient treatment and minimal recovery time, and affords excellent tumor control with low rates of cranial nerve dysfunction.[17,18] Many reports indicate that improved hearing and facial nerve results are seen following stereotactic radiosurgery (SRS) compared with microsurgery.[19–21] In a series of patients treated at the University of Pittsburgh with gamma knife radiosurgery using a median dose of 13 Gy, a 97.1% rate of tumor control was achieved with 1.1% rate of facial weakness, 2.6% rate of trigeminal nerve dysfunction, and 71% rate of "hearing level preservation."[22] However, high-frequency hearing loss following SRS has been shown to correlate with maximal cochlear dose and transient evoked otoacoustic emissions (TEOAEs) worsened in 75% of patients who had measurable TEOAEs before treatment.[23] At the University of Florida, linear accelerator-based SRS results on 108 patients with AN treated after 1994 included a 93% rate of radiologic control, 5% rate of facial neuropathy, and 2% trigeminal neuropathy.[24] A meta-analysis of 1475 patients treated with gamma knife radiosurgery between 1969 and 2000 documented an 8% rate of tumor growth and an 8% rate of trigeminal or facial neuropathy, and 4.6% of patients ultimately required microsurgery.[25] Hydrocephalus may also develop following radiosurgery, requiring placement of a ventriculoperitoneal shunt.[26] Patients must be informed of the eight cases of possible malignant transformation reported in the literature, as well as the possibility that future surgical resection may be more difficult.[13,24,27] Some centers also offer conventionally fractionated radiotherapy for AN.[28] The principles and details regarding our use of CyberKnife SRS are provided in Chapter 125.

Recent investigations have addressed quality of life following treatment for AN. Several studies suggest that SRS offers improved posttreatment quality of life compared with microsurgery.[20,29] Myrseth and colleagues reported better facial nerve function, as well as better Glasgow Benefit Inventory and SF-36 scores, in patients treated with gamma knife versus microsurgery. A prospective trial conducted at the Mayo Clinic showed that patients undergoing microsurgery experienced a decline in several subscales of the Health Status Questionnaire postoperatively; this decline was not seen in patients treated with gamma knife radiosurgery.[20] Additionally, the Dizziness Handicap Inventory scores were better for the gamma knife group.[20]

Understanding the typical growth characteristics of AN facilitates the physician's decision regarding what treatment should be offered to the patient. Overall, we consider surgical resection to be the preferred method in the management of AN in young (younger than 65 years of age), healthy patients. An estimation of the patient's longevity must be considered. Patients who are otherwise healthy and have a family history of survival into their late ninth decade can be considered for surgical intervention. Patients between 65 and 70 years of age are evaluated on the basis of factors that include their health, neurologic examination, tumor size, tumor location, rate of growth, hearing status in each ear, and family medical history. We acknowledge that gamma, electron, or proton beam radiation should also be considered effective alternative methods for stopping tumor growth. In the face of documented growth of the tumor, we recommend radiation for patients older than 70 years of age or for patients who have tumors beyond the IAC who are medically unstable. We offer the option of photon beam or gamma radiation to patients who have a recurrence of a previously resected tumor. We also recommend radiation to patients who have had subtotal removal of a large tumor where total resection might have the potential to produce adverse surgical morbidity. In the elderly or medically compromised patient, a small tumor without associated neurologic symptoms other than unilateral hearing loss can be followed over time, observing for evidence of tumor growth. Repeat MRI is obtained in 6 months to compare tumor size. If tumor growth becomes manifest, radiation treatment is suggested, and if no growth has occurred, the MRI scan will be repeated in 6 months. The interval increases to yearly and then every 3 years if there is no change in the size of the tumor.

A treatment program must be individually tailored for each patient with bilateral ANs (neurofibromatosis-2 [NF-2]). NF-2 patients may have other associated intracranial tumors or tumors of the spinal cord and must be diligently examined and imaged to determine the tumor status as well as their medical stability for intracranial surgery. The size of the tumors and the hearing status must be accurately determined. Management options include surgical resection, surgical decompression to allow for tumor growth, radiation, and observation. Until recently, we considered radiation therapy to be a reasonable alternative in the management of bilateral tumors. However, the poor hearing results following gamma radiation do not justify this method as the preferred, exclusive treatment alternative when hearing is intact. Furthermore, the long-term outcome of irradiating NF-2 tumors is unknown at this time. Given that these tumors often present in young people, it may be necessary to follow them for periods up to 50 years. If tumor growth occurs despite radiation therapy, complete surgical removal may be technically more difficult because of the radiation therapy, with greater likelihood of neurologic consequences. We have had experience using an auditory brain stem implant inserted at the time of tumor removal for patients with bilateral ANs. The device provides sound awareness to an anacoustic ear but has not provided the excellent speech recognition achieved with cochlear implants. In summary, one must judiciously decide which patient would be ideally suited for radiation therapy.

Other than the exceptions noted previously, most patients are considered to be surgical candidates for excision of the tumor. Various factors must be evaluated in order to formulate a treatment plan. The status of the patient's hearing is the predominant issue that dictates the surgical approach. There is great controversy as to what is considered useful hearing. Patients with hearing thresholds better than 50-dB speech reception threshold (SRT) and 50% speech discrimination (DISC) (word recognition) are considered candidates for a hearing preservation procedure. However, the size and location of the tumor must be taken into account when attempting to save hearing. It can be argued that any hearing should be preserved in order to provide sound localization. Thus hearing levels of 70 dB SRT and 30% DISC may be considered usable hearing suitable for a hearing aid. Hearing in the contralateral side must also be considered. If hearing function is normal in the uninvolved ear, then preservation of poor hearing will not be psychoacoustically useful to the patient. Patients with tumors that extend greater than 2 cm into the cerebellopontine angle (CPA) are unlikely to have preservation of hearing regardless of the preoperative hearing status. However, if preoperative hearing is good, it is reasonable to attempt hearing preservation through a retrosigmoid approach if the tumor does not extend laterally to the fundus of the IAC.

The translabyrinthine approach is used to remove tumors in most patients with hearing levels greater than 50-dB SRT and less than 50% DISC. This approach may also be used in patients with good hearing, if the tumor extends past the transverse crest in the IAC and the patient is willing to sacrifice hearing for more complete tumor resection. The translabyrinthine approach is reported to have a 9% rate of postoperative CSF leak, and depending on the size of the tumor, a 73% rate of House–Brackmann Grade I–II facial function. This rate increases to 78% in high–volume centers.[15] The translabyrinthine approach is also used for NF-2 patients with poor hearing in whom an auditory brain stem implant is anticipated.

The retrosigmoid approach is useful for patients with serviceable hearing and greater than 0.5-cm tumor extension into the CPA. We also favor the retrosigmoid approach for removing very large tumors when the brain stem is compressed and shifted to the contralateral side. The disadvantage of this approach is its limited access to the lateral IAC. The retrosigmoid approach has been reported to have a 30% rate of hearing preservation overall, a 92% rate of House–Brackmann Grade I–II facial function at all centers, and an 11% rate of postoperative CSF leak. Notably, there is a 21% rate of postoperative headache following this approach.[15]

The middle fossa approach is useful for excising tumors that are contained within the IAC or that extend less than 0.5 cm into the CPA at the porus. Furthermore, caution must be observed for patients older than 60 years of age. The dura in these patients is often thin and subject to lacerations. This may be accompanied by annoying venous bleeding, making the middle fossa dissection challenging and making obtaining a watertight dural closure difficult. This approach offers a 53% rate of hearing preservation overall and an 89% rate of House–Brackmann Grade I–II facial function.[15] Rates of hearing preservation correlate with tumor size and vary by center, and may be improved with near field whole eighth nerve monitoring in small tumors.[30] For tumors with more than 10-mm extension into the CPA, there is a higher postoperative rate of hearing loss and facial weakness when the middle fossa approach is used.[31] There is a 6% rate of postoperative CSF leak and 8% incidence of postoperative headaches.[15]

## PREOPERATIVE PLANNING

A complete history is obtained regarding symptoms including hearing status and tinnitus. Patients are questioned regarding difficulty with ambulation, dysequilibrium, and vertigo. A history of headaches, facial twitching, hypesthesia, or difficulty with voice or swallowing is sought.

Physical examination is focused on cerebellar function and the cranial nerves of the posterior fossa. Extraocular movements are observed, looking for gaze–evoked nystagmus. Facial and corneal sensations are tested in order to evaluate the sensory distribution of the trigeminal nerve. Facial movements are observed, seeking evidence of weakness. The lower cranial nerves are assessed by testing oropharyngeal tactile sensation and vocal cord mobility. The patient's tandem gait is observed, and other evidence of cerebellar dysfunction, including dysmetria and dysdiadochokinesia, is sought.

A complete audiogram, consisting of air and bone pure–tone thresholds and speech audiometry, is obtained. Identifying rollover (worsening word recognition with increased presentation levels) further supports a retrocochlear lesion. Despite knowing that a patient has a posterior fossa tumor suggestive of an AN, ABR is frequently obtained, especially when hearing function is present. Evidence of interpeak latency shifts or change in waveform morphology is investigated. Furthermore, if good waveforms are readily identifiable, the ABR test provides a useful baseline for intraoperative auditory monitoring if a hearing preservation procedure is undertaken (Fig. 124-2).

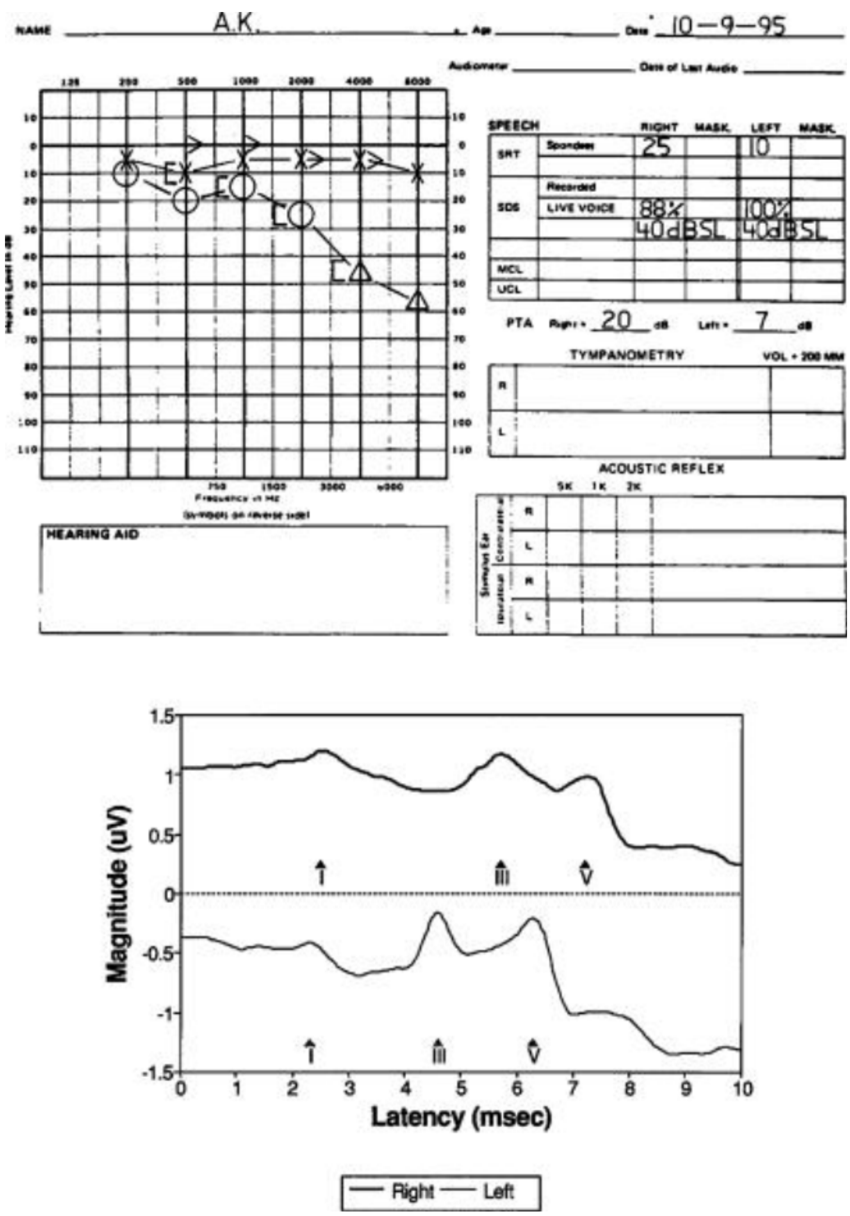


Figure 124-2 **A,** Audiogram of a 24-year-old patient complaining of right hearing loss. Note high–frequency sensorineural loss with reduced word recognition score. **B,** Auditory brain stem response of the same patient demonstrating a right interpeak latency shift of I–III and I–V intervals consistent with retrocochlear pathology.

Once a presumed diagnosis of AN is made, vestibular testing may be obtained. The findings on caloric stimulation provide information regarding the degree of vestibular loss owing to the tumor. A significantly reduced vestibular response informs the surgeon and patient that postoperative vertigo and dizziness should be at a minimum. The findings of reduced responses on caloric stimulation are considered to be indicative of superior vestibular nerve function. This information may be useful when planning a middle fossa approach. Normal residual caloric responses imply sparing of the superior vestibular nerve and the tumor originating from the inferior vestibular nerve. Unfortunately, the finding of a reduced vestibular response to caloric stimulation is not diagnostic of superior vestibular nerve tumor origin. It has been shown that a reduced caloric response can be demonstrated in 60% of tumors arising from the inferior division (Fig. 124-3).[32] In summary, we do not routinely obtain vestibular testing in diagnosing or planning treatment for patients suspected of having an AN.

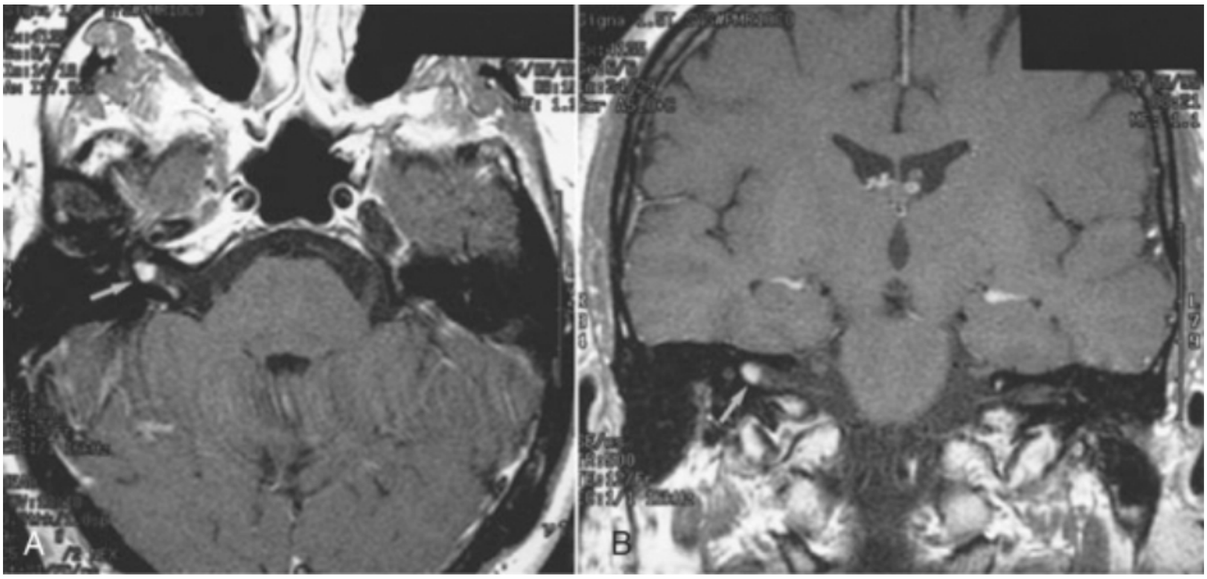


**Figure 124-3** T1-weighted contrast-enhanced axial **(A)** and coronal **(B)** magnetic resonance imaging scans. Note the right inferior vestibular nerve schwannoma *(arrows)* located in the posteroinferior fundus of the internal auditory canal (IAC).

Radiologic imaging is critical in diagnosing and managing a tumor in the posterior fossa. A presumptive diagnosis of an AN is determined by the location and shape of the tumor along with its signal characteristics without and with contrast. The tumor size has an inverse relation to the likelihood of preserving preoperative hearing. The larger the tumor, the less likely that the cochlear nerve and function can be maintained. As tumors get larger than 2 cm, hearing preservation is rarely successful. The same concern exists for the facial nerve. The removal of large tumors is more likely to produce postoperative facial paresis or paralysis. Also, facial nerve outcomes in cystic tumors have been reported to be worse than in solid tumors.[33]

The MRI scan demonstrates the relationship of the tumor to the surrounding brain. Brain stem compression may obstruct the fourth ventricle with resultant hydrocephalus. The scan is also reviewed to determine whether the tumor impinges on the fifth or lower cranial nerves. Removal of large tumors may produce postoperative corneal and facial hypesthesia from manipulation of the trigeminal nerve. Similarly, tumor extending inferiorly low in the posterior fossa can affect cranial nerves IX, X, and XI (Fig. 124-4). The surgeon and patient must both be prepared for a possible postoperative swallowing and laryngeal dysfunction.

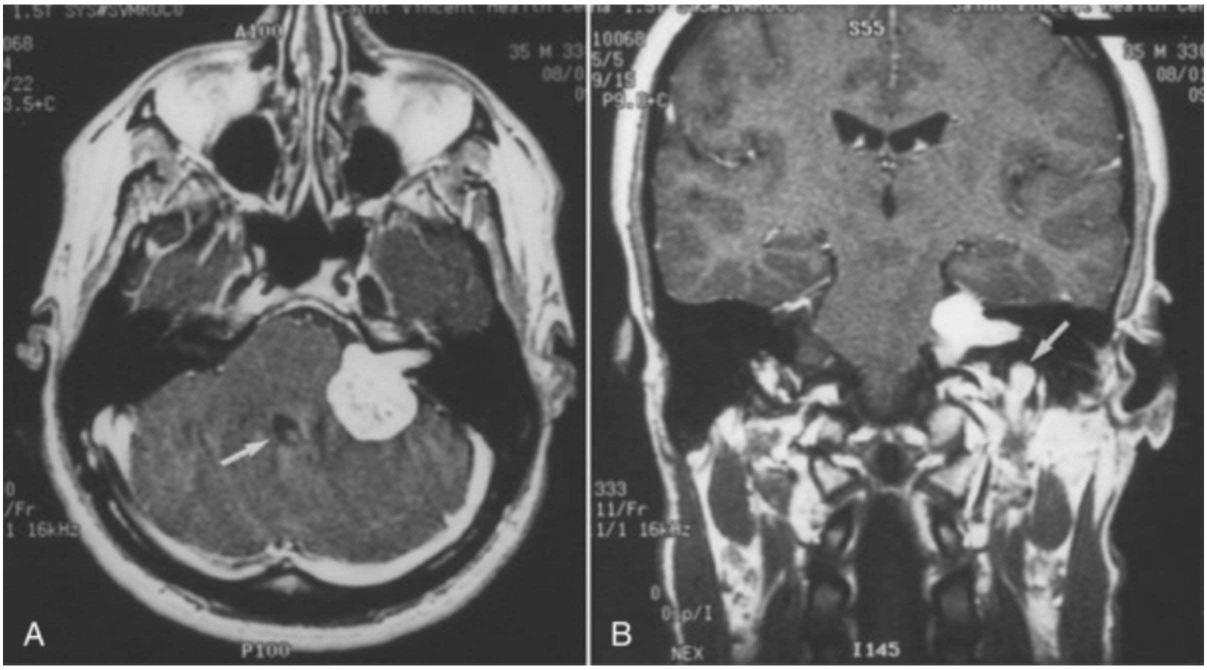


**Figure 124-4** T1-weighted contrast–enhanced magnetic resonance imaging scan of a left acoustic neuroma. **A,** Axial image showing a 3-cm tumor with compression of the brain stem. The fourth ventricle is patent *(arrow)*. **B,** Coronal image demonstrating the inferior extent of the tumor. Note the relationship to the jugular fossa (*arrow*).

The MRI scan is also reviewed in order to determine the lateral extent of the tumor. Patients with good hearing and tumor limited to the IAC and extending to the fundus are candidates for a middle fossa approach (Fig. 124-5). Patients with good hearing and tumor 0.5 cm beyond the IAC into the CPA should undergo a retrosigmoid approach if hearing is to be preserved. However, tumor extending and filling the fundus cannot be removed under direct microscopic vision. Owing to limitations posed by the otic capsule, the posterior wall of the IAC cannot be completely drilled laterally, exposing the fundus. Identifying tumor within the fundus on MRI requires thorough evaluation of this area at the time of surgery.

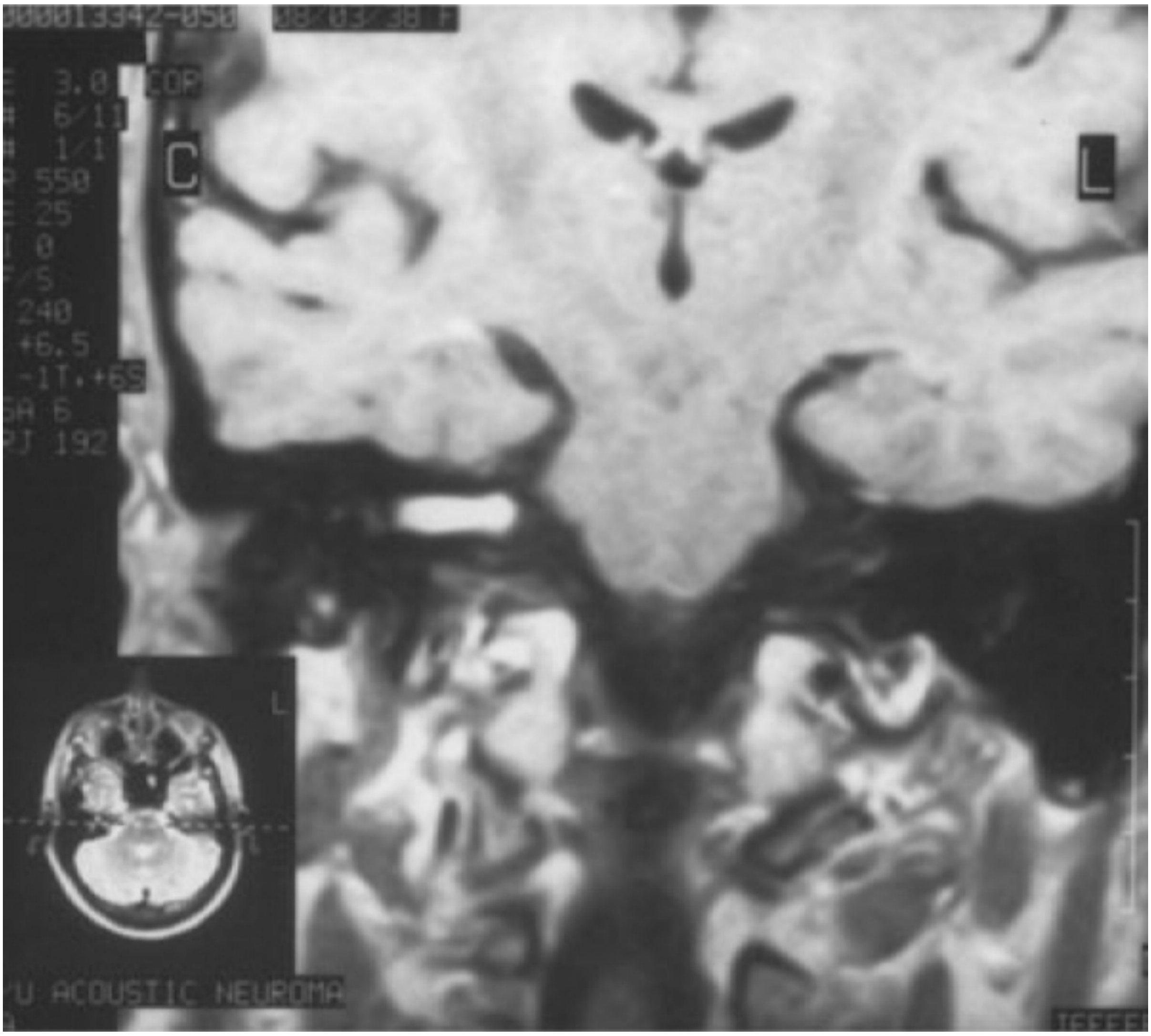


**Figure 124-5** T1-weighted contrast–enhanced magnetic resonance imaging scan of a right acoustic neuroma extending toward the fundus, filling the internal auditory canal. The transverse crest is not well outlined.

The location of the jugular bulb can be determined from the MRI scan. Blood and flow signal can be seen on T1- and T2-weighted images. However, a more accurate assessment of the bony and vascular anatomy of the temporal bone is obtained with a CT scan. We frequently obtain a thin-cut bone–windowed CT scan when a hearing preservation procedure is planned or when the jugular bulb is suspected on MRI of creating an anatomic obstacle. The noncontrast bone–windowed study shows the pneumatization of the temporal bone relative to the IAC (Fig. 124-6). Knowing preoperatively that the petrous bone is well pneumatized provides additional landmarks when drilling around the IAC via a middle fossa or retrosigmoid approach.

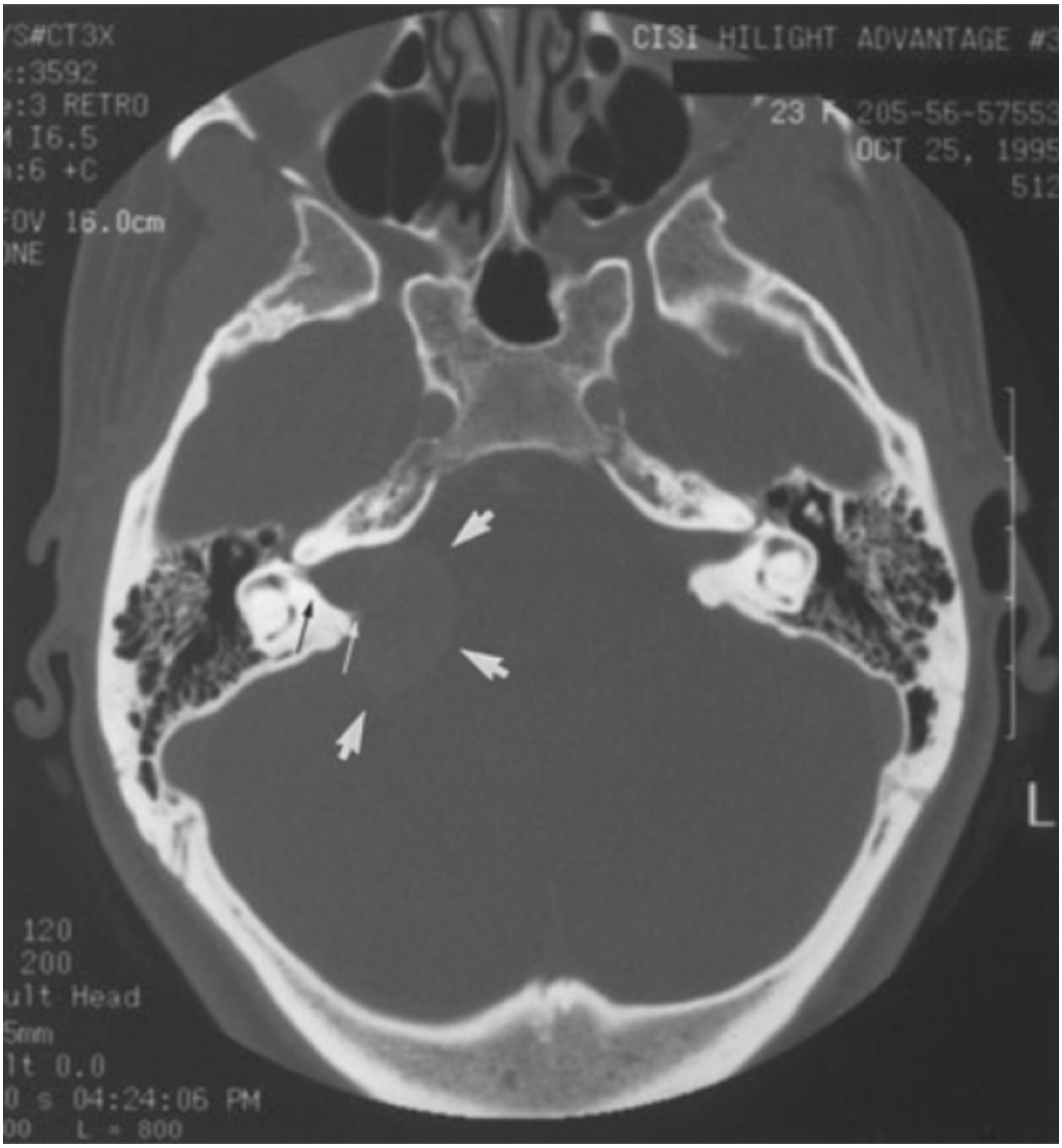

**Figure 124-6** Bone algorithm computed tomography scan of a right acoustic neuroma. Note widening of the internal auditory canal. Approximately 7 mm of bone from the posterior lip of the porus acusticus can be drilled safely before the posterior semicircular canal is entered *(small arrows)*. *Large arrows* outline the margin of the tumor.

Collating the data presented previously helps determine which surgical approach is most appropriate and provides information that may be predictive of successful preservation of hearing. Negative predictive factors include tumor size greater than 2.0 cm, evidence of widening of the IAC, tumor extension laterally to the fundus, and poor waveform morphology on ABR testing.[34,35]

## Informed Consent

An excellent discussion of informed consent in acoustic neuroma treatment was published in 2005.[13] The author stressed the importance of a balanced and unbiased discussion of treatment options, which is most easily afforded by a multidisciplinary team having experience with both radiation and surgical modalities of treatment. The decision process must be individualized for each patient. There are numerous factors that must be considered when formulating a treatment plan, both in the mind of the physician and in what is proposed to the patient. These factors include the chronologic and physiologic age and health of the patient; characteristics of the tumor such as size, location, and rate of growth; a family history or presence of multiple intracranial tumors (NF-2); hearing status of the ipsilateral and contralateral ear, ABR waveform morphology, if obtained; and the functional status of their vestibular system. Surgeons should be aware that patients make their treatment choices using information given to them by physicians, patient education pamphlets, Internet searches, discussions with other patients, and published data.[36] The inclination of the patient regarding their preference for surgical or radiation treatment influences their thought process. Some patients wish to avoid surgery at any cost; other people are distressed with the realization that tumor is present within their head and prefer surgical excision. The importance of a comprehensive and understandable informed consent cannot be overemphasized. It is most important to discuss with the patient and family the location of the tumor and its relationship to the surrounding vascular, dural, and neural structures. The treatment options of observation, surgical removal, or radiation therapy are reviewed. The risks, benefits, and outcomes are explained. Although the physician may influence the patient's thinking, the final decision for treatment rests with the patient.

## SURGICAL TECHNIQUE

### Anesthesia

Removal of an AN is performed with the patient under general endotracheal anesthesia. Long-acting muscle relaxants are avoided in order to permit monitoring of the facial nerve. Short-acting muscle relaxants are employed at the start of the procedure during induction and intubation and following completion of tumor removal when final facial nerve thresholds are determined. Anesthesia is maintained with inhalation agents, narcotics, and barbiturates. Neurophysiologic monitoring is conducted for all procedures. This consists of electrode placed to monitor cranial nerves V, VI, VII, VIII, and X. Even if hearing is absent or to be sacrificed with a translabyrinthine approach, the contralateral ear is monitored because it provides feedback regarding the status of the contralateral brain stem. Somatosensory potentials are also evaluated during the case, reflecting the integrity of the lower brain stem and peripheral nervous system (Fig. 124-7). A urinary catheter is inserted, and antithrombotic stockings with sequential compression devices are placed. The infraumbilical area of the abdomen is shaved and prepared for potential removal of an adipose tissue graft.

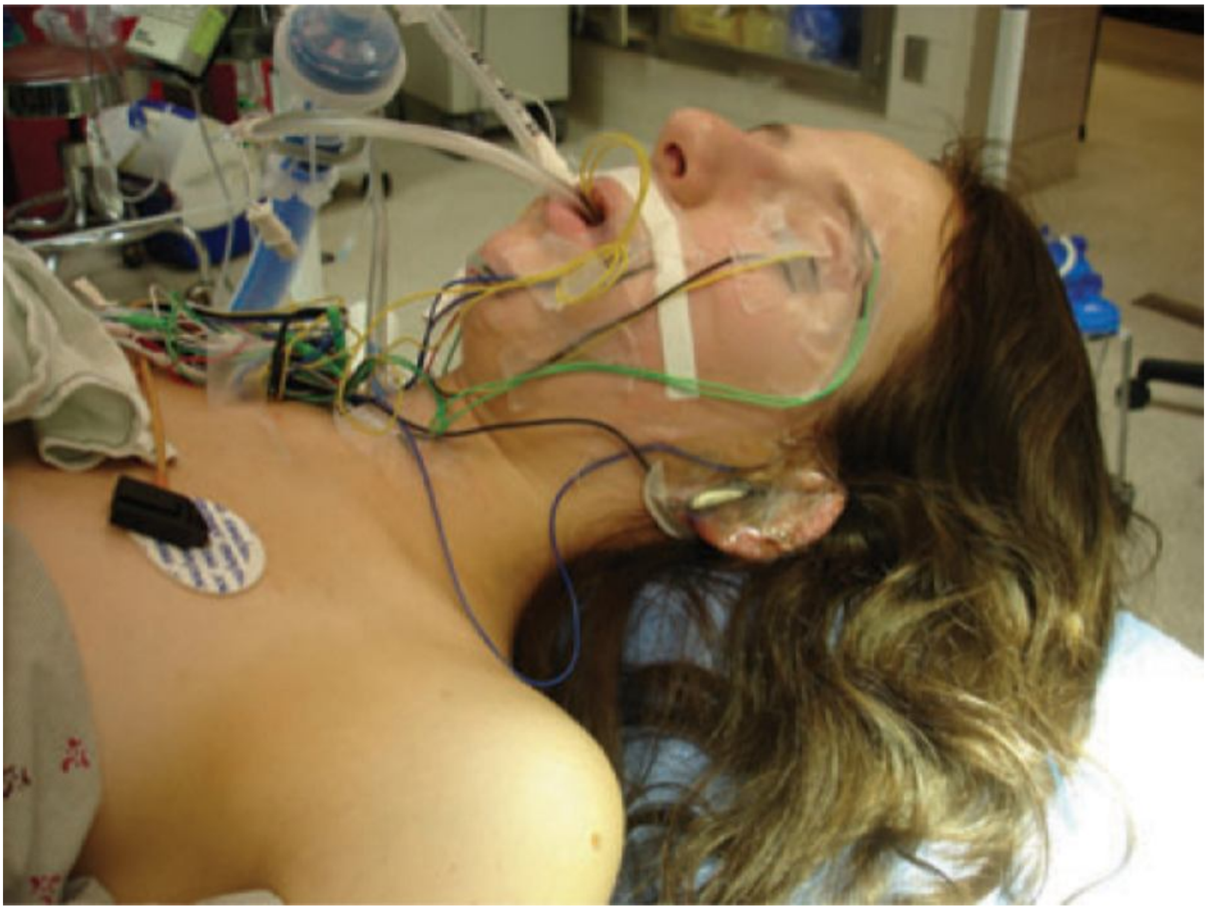

**Figure 124-7** Before turning the patient into the appropriate position for the procedure, electrodes are inserted for monitoring the cranial nerves and somatosensory potentials.

### Translabyrinthine Approach

A postauricular C-shaped incision begins 2 cm supe–rior to the root of the auricle. The incision extends posteriorly and inferiorly 4 cm posterior to the postauricular sulcus. It continues inferior and anterior to the mastoid tip (Fig. 124-8). Superiorly, the skin incision extends to the depth of the temporalis fascia. An anterior-based skin flap is developed superficial to the temporal fascia and fibroperiosteum overlying the mastoid cortex. A second or more medial anterior–based flap is created, consisting of incised temporalis fascia and muscle and mastoid fibroperiosteum. This is developed just anterior to the posterior edge of the skin incision (Fig. 124-9). A small piece of temporalis muscle deep to the temporalis fascia is harvested from the superior limit of this flap.

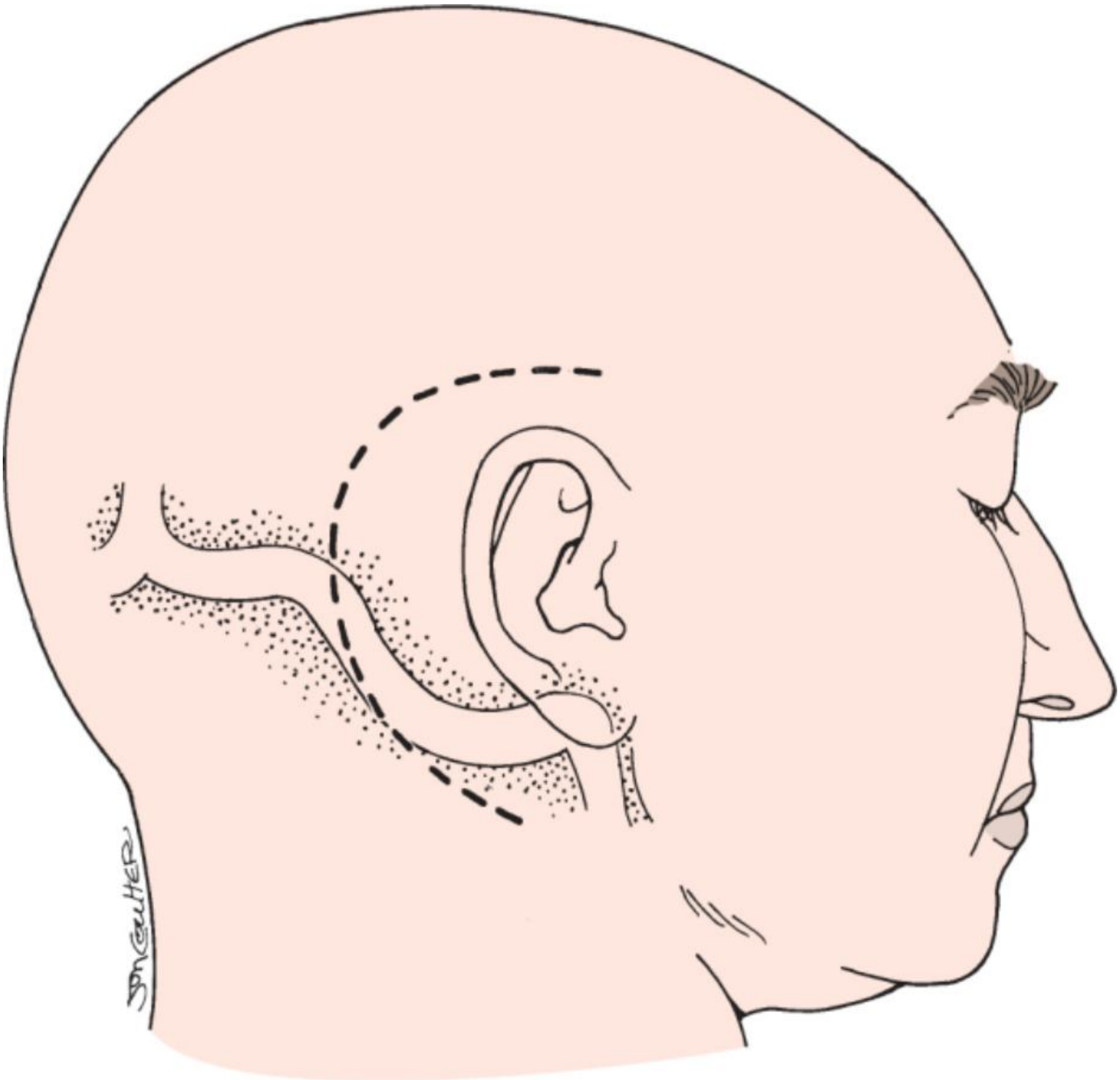

**Figure 124-8** Incision for a translabyrinthine approach. The transverse and sigmoid sinuses are illustrated.

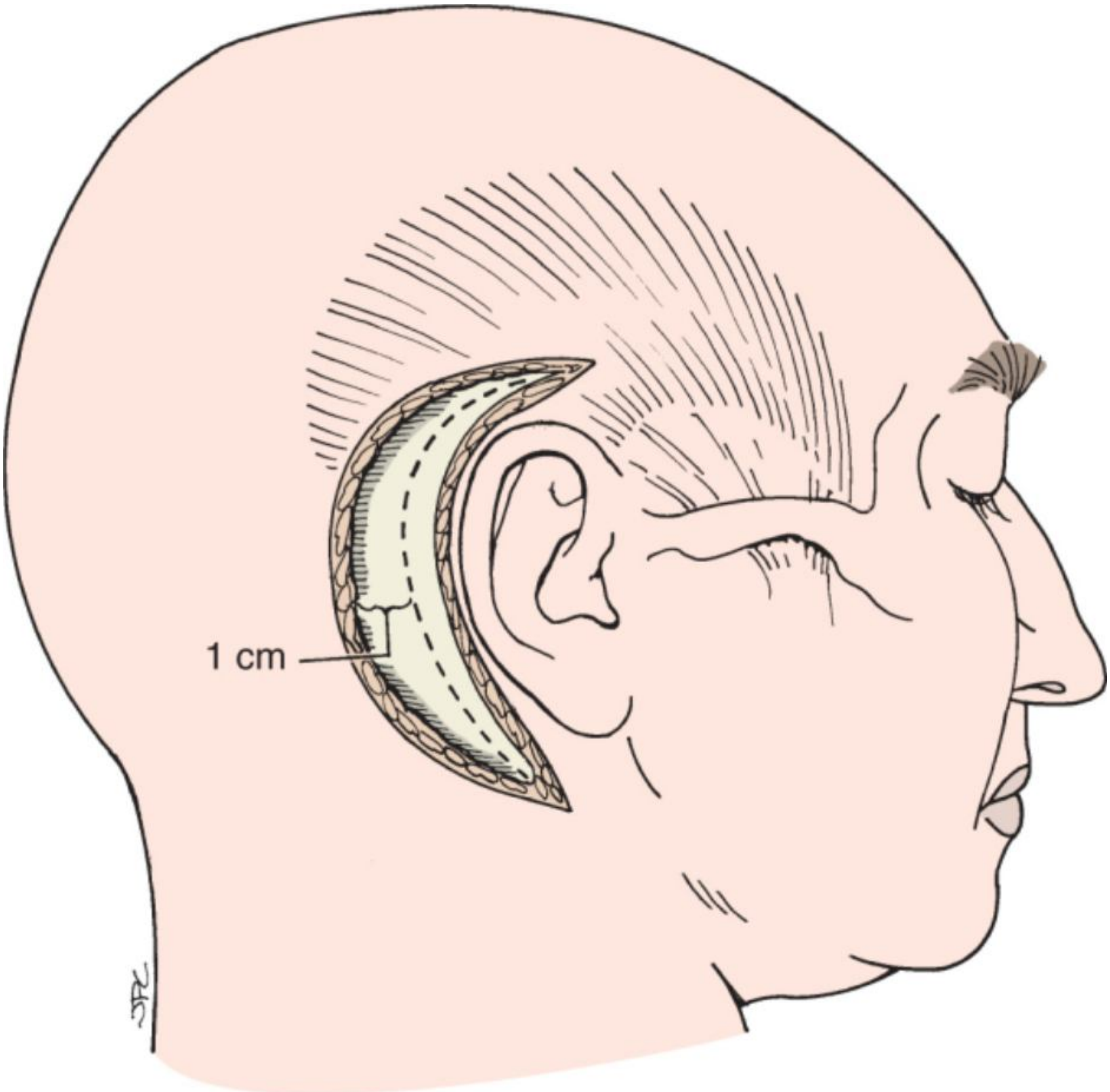


**Figure 124-9** The deeper incision divides the temporalis muscle just superior to the linea temporalis and continues in a curvilinear direction through the fibroperiosteal layer over the mastoid cortex, 1 cm anterior to the posterior skin flap.

Two self-retaining retractors are placed 90 degrees to one another. Using a large cutting burr and suction irrigation, a transcortical mastoidectomy is performed. Once the antrum has been identified, the bone dissection is enlarged to expose the lateral and inferior aspect of the middle fossa dura, sinodural angle, sigmoid sinus, and mastoid tip. The posterior bony canal wall is thinned to fully expose the antrum, fossa incudis, epitympanum, and air cells over the facial recess. The bone overlying the sigmoid sinus and retrosigmoid posterior fossa dura must be removed. This is initially accomplished with cutting and then using diamond burrs. Preservation of an island of bone (Bill's island) over the sigmoid sinus minimizes direct trauma to the wall of the sinus from retraction (Fig. 124-10).

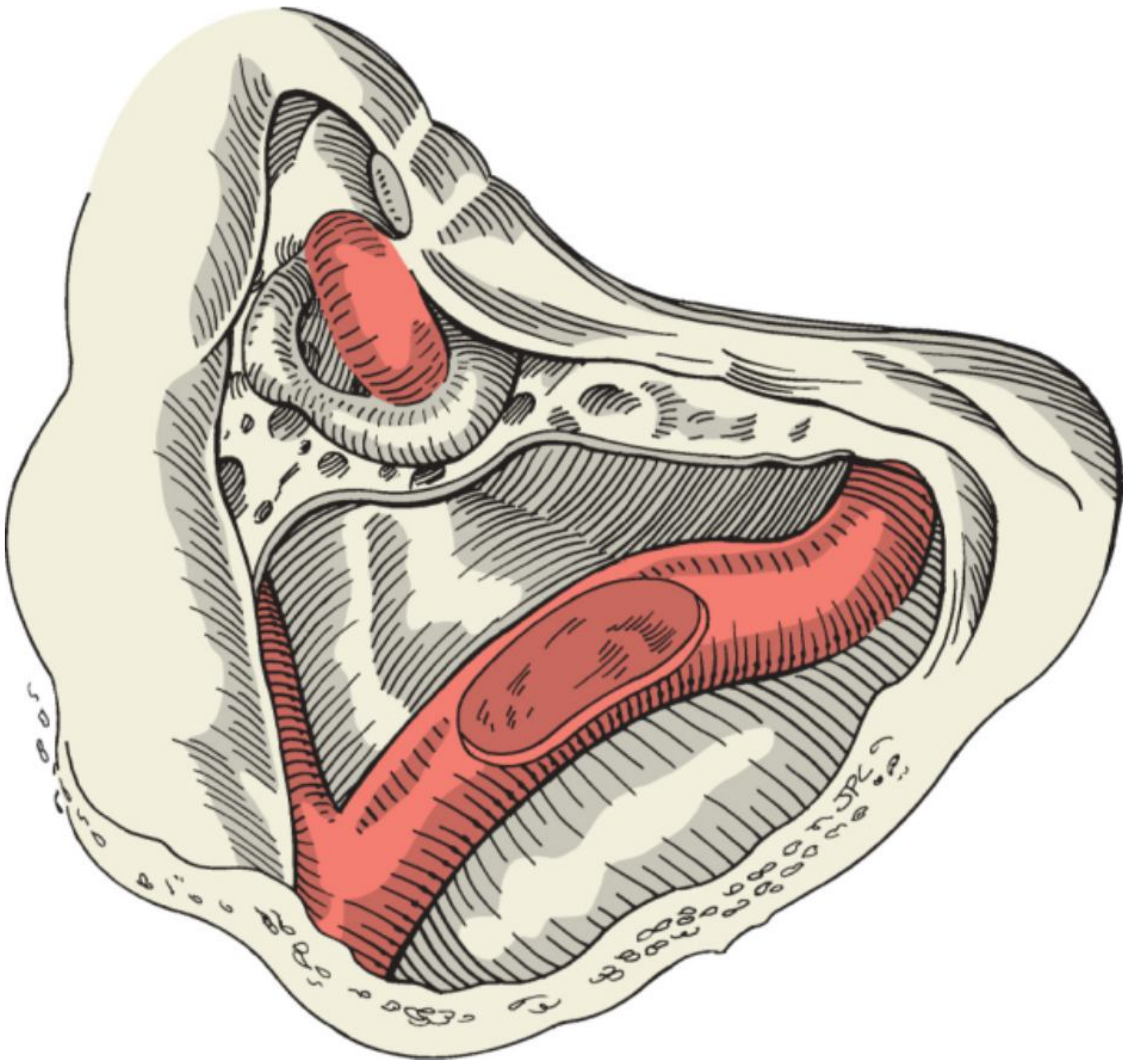

**Figure 124-10** The transmastoid approach requires exposure of the middle and posterior fossa dura, leaving an island of bone over the sigmoid sinus. The antrum is opened, and the incus is identified. The posterior bony canal wall is thinned, with a bone remaining over the vertical facial nerve. The digastric ridge is outlined inferiorly.

In order to obtain a watertight closure and avoid CSF rhinorrhea, the eustachian tube is obliterated through an extended facial recess approach. The incus is separated from the stapes and removed. The posterior buttress is drilled to increase exposure of the middle ear. Pieces of Surgicel and muscle are placed through the enlarged facial recess directly into the eustachian tube (Fig. 124-11). If space permits, the short process and body of the incus are also placed into the eustachian tube after removing the incus long process. Additional small pieces of Surgicel and muscle are placed into the eustachian tube orifice.

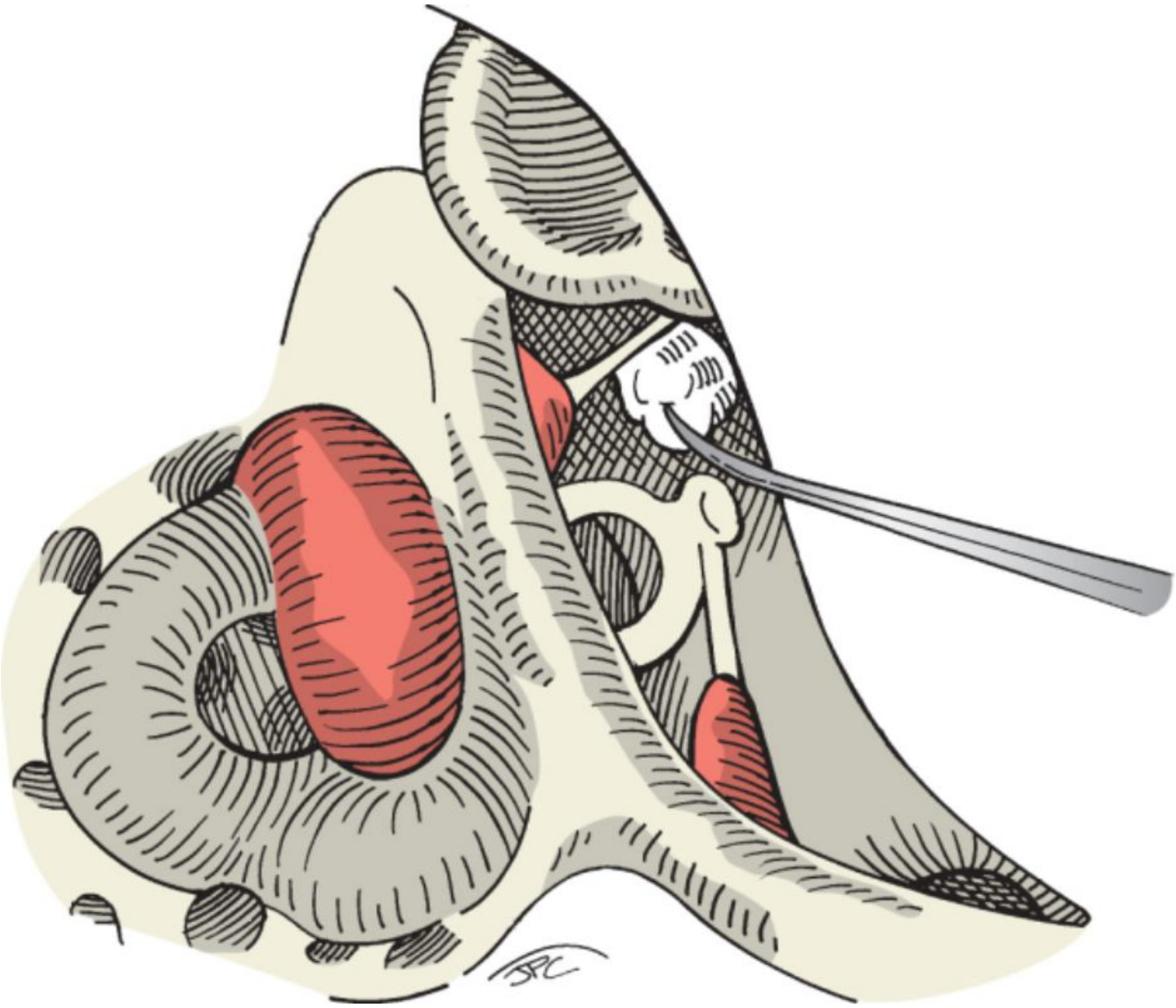

**Figure 124-11** The incus is removed from the fossa incudis, and the facial recess is extended by drilling the posterior buttress. The eustachian tube is packed with Surgicel and muscle using a curved pick.

A labyrinthectomy is then performed. The dissection continues through the horizontal semicircular canal, which is used as the initial landmark for the horizontal segment and second genu of the facial nerve. A thin shell of bone is left over the distal horizontal, second genu, and vertical portions of the facial nerve. The pink color of the nerve can be seen through the bone. The labyrinthectomy is taken through the vestibule and the medial wall of the otic capsule. It is necessary to remove all bone from the middle and posterior fossa dura, sinodural angle, and jugular bulb. This is initially accomplished with cutting and then using diamond burrs. Once the bone is of appropriate thickness, it can be removed with a dissecting instrument such as a Lempert, Penfield, duckbill, Freer, or Cottle elevator (Fig. 124-12).

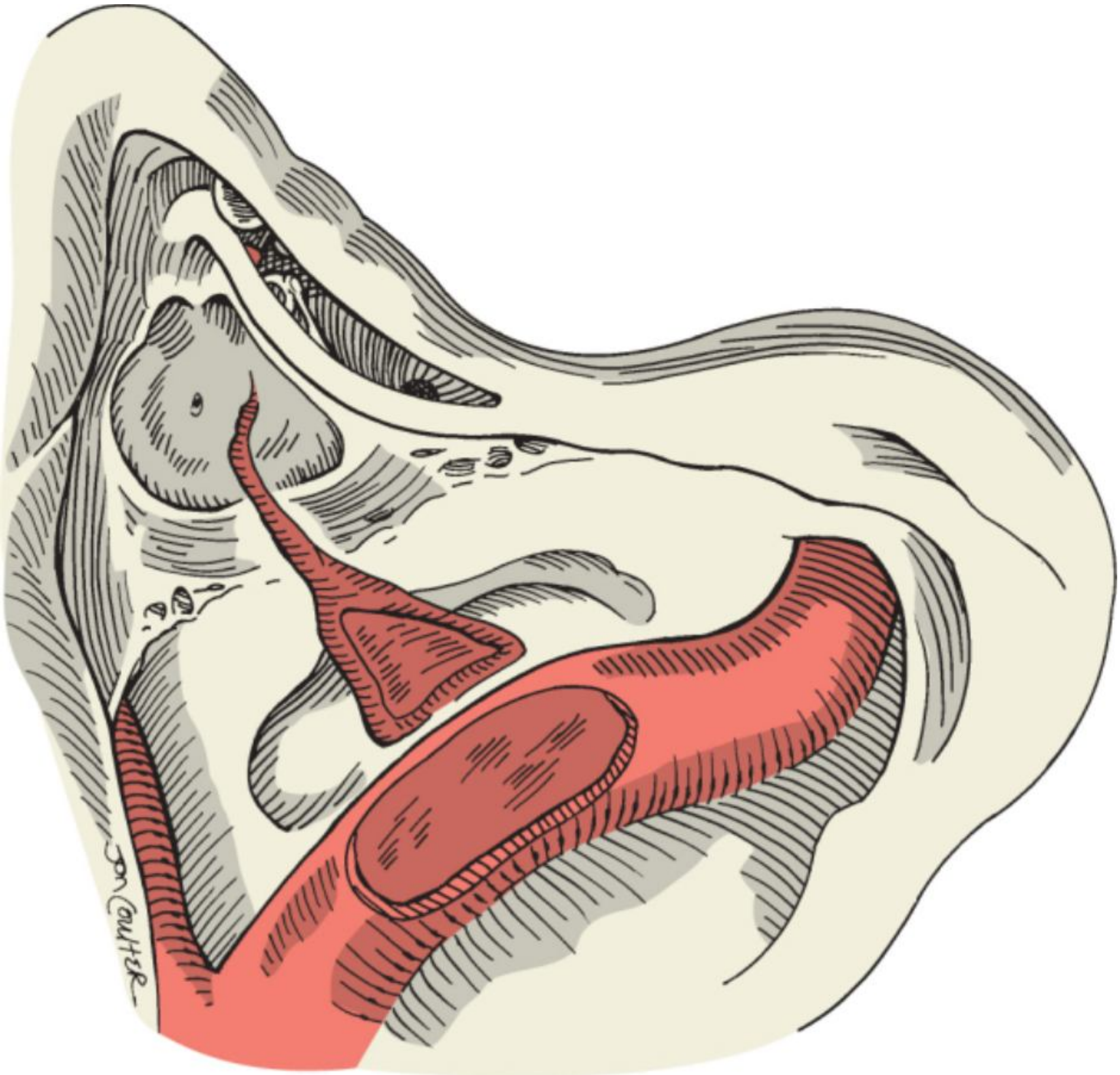

**Figure 124-12** A labyrinthectomy has been completed, opening into the vestibule. The more medial bone of the middle fossa tegmen and posterior fossa is removed. The endolymphatic duct and sac are identified. The subarcuate artery may persist in the solid angle.

The IAC is skeletonized for at least 180 degrees of its posterior circumference. It is important to remove bone both superior and inferior to the IAC. During the exposure of the inferior aspect of the IAC and dome of the jugular bulb, the cochlear aqueduct is entered and CSF is typically encountered (Fig. 124-13). The trough superior to the IAC and inferior to the middle fossa dura is drilled cautiously. The lateral aspect of the IAC is further dissected with a small diamond burr. In addition to drilling the IAC laterally to the fundus, a trough superior to the IAC is developed to provide access to the superior and lateral aspect of the tumor (see Video 124-1). The final bony dissection is over the labyrinthine portion of the facial nerve. At this point, Bill's bar, separating the facial nerve and superior division of the vestibule nerve, is identified.

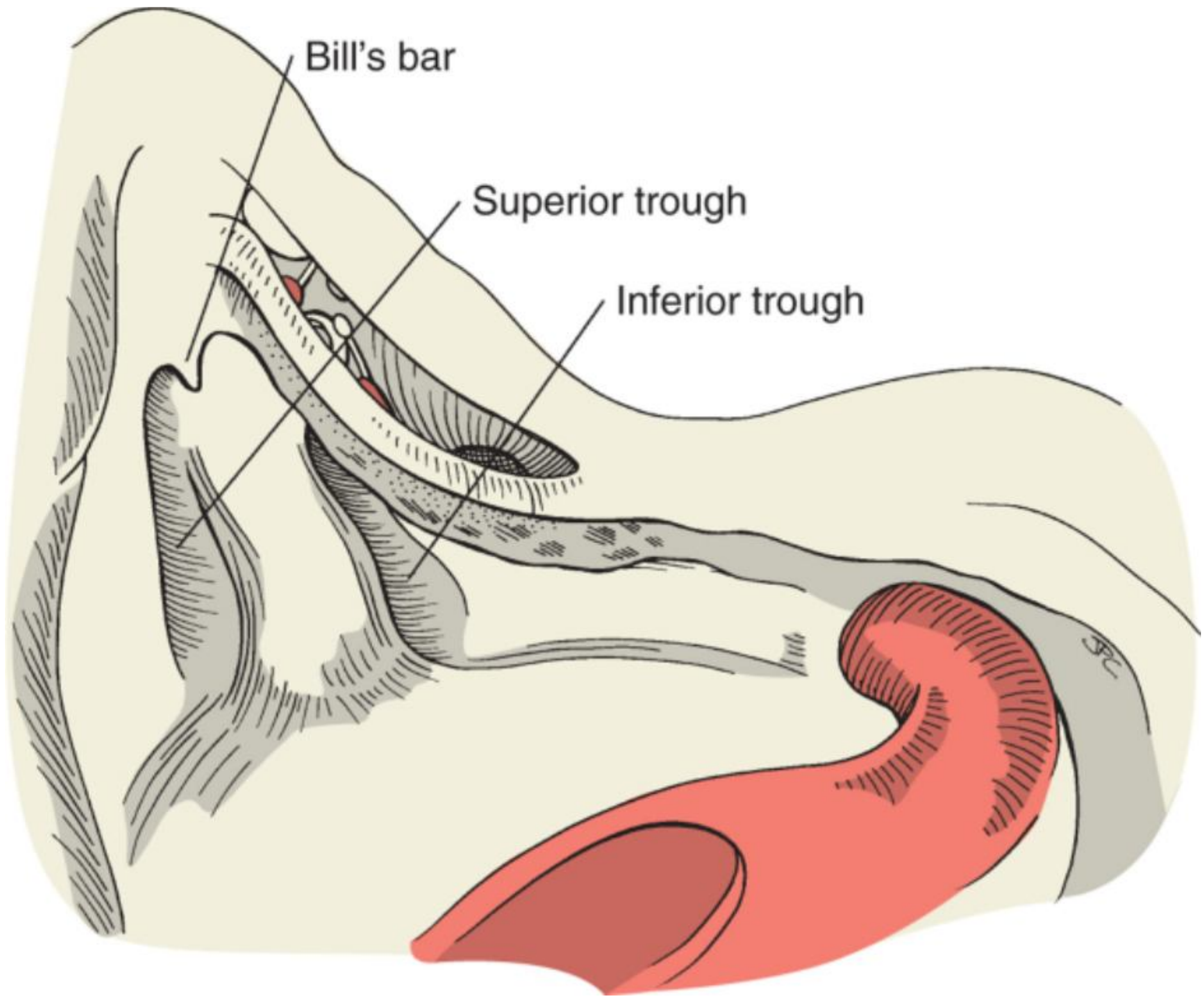


**Figure 124-13** The IAC is skeletonized, creating a superior and an inferior trough. Bill's bar is identified. Bone from the posterior lip of the porus acusticus must be removed. The cochlear aqueduct is located superior to the jugular bulb.

The dome of the jugular bulb may extend superiorly to the level of the IAC. This limits the working space for addressing both the IAC and CPA portions of the tumor. It is necessary to decompress this area of its overlying bone. The lining over the jugular bulb is thin so caution is needed when drilling over this area. Once the bone is removed, a neuropatty may be used to further compress the bulb inferiorly. Placing Surgicel under the neuropatty provides compression and packing of this area. The inferior trough can then be completed with jugular bulb displaced inferiorly from the surgical field (see Video 124-2).

The presigmoid dura is coagulated with bipolar cautery to obtain surface hemostasis. The dura and periosteum of the IAC are cut in a lateral-to-medial direction to give access to the IAC. The posterior fossa dura is cut sharply beginning just anterior to the sigmoid sinus. The incision of the dura continues toward the dural ring, defining the posterior rim of the porus. It then continues both superior and inferior to the IAC, providing wide access to the posterior fossa (Fig. 124-14; see also Video 124-3). The dural over the IAC is then opened. A McElveen knife permits dissection with a rounded tip and then cutting of the dural with the sharp portion of the instrument (see Video 124-4). The lateral insertion of the superior vestibular nerve is sharply dissected away from the facial nerve. Tumor present laterally in the fundus will be encountered at this time and is also sharply dissected away from the facial nerve.

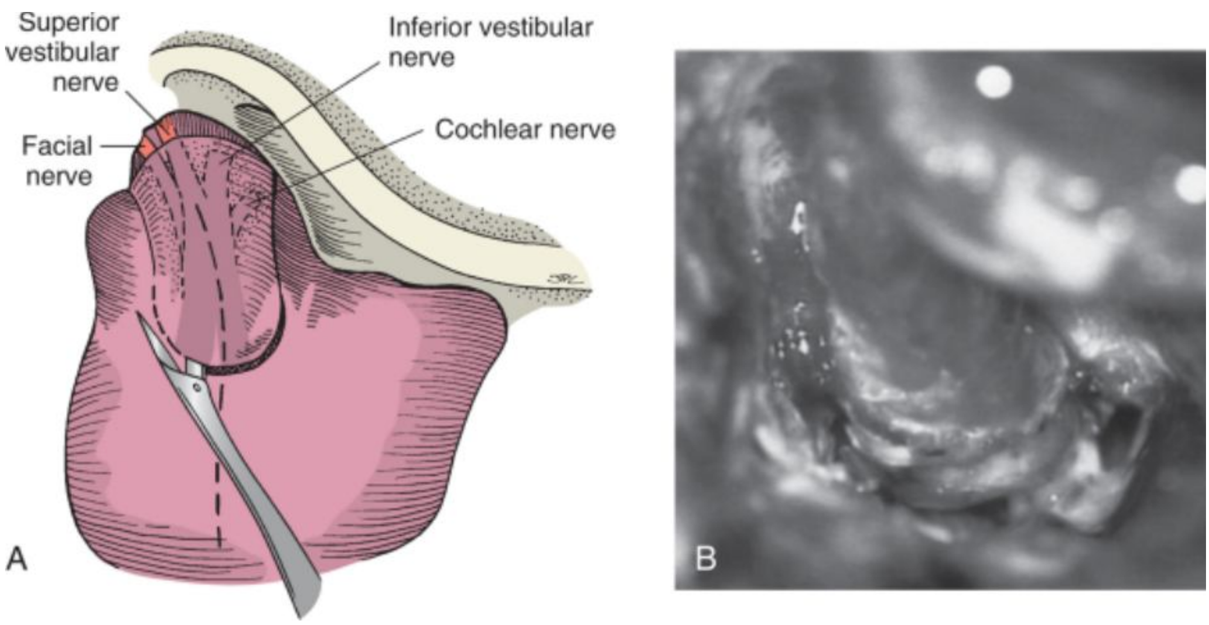


**Figure 124-14** **A,** The incisions in the IAC and posterior fossa dura are demonstrated. **B,** The IAC is dissected circumferentially, creating a superior and an inferior trough. The posterior fossa dura is opened.

Small tumors limited to the IAC and the area of the porus can be removed in a lateral–to-medial direction. Unless the cochlear nerve is involved, it is best to leave it undisturbed, so as to avoid any potential injury to the perineural vessels that may also supply the facial nerve. The facial nerve monitor and stimulator are invaluable for performing this procedure. The minimal current output of the nerve stimulator should be used in order to establish current thresholds.

When operating on large tumors, the specimen will need to be removed in a piecemeal fashion. The tumor is initially dissected in a subarachnoid plane. Prominent surface vessels are coagulated with bipolar cautery. When most of the tumor is in the CPA, the capsule of the tumor is entered with sharp dissection (Fig. 124-15). Tumors with a firm consistency may need to be softened with cup forceps. Sections of the tumor are then removed with scissors dissection or Takahashi's forceps. Bipolar cautery not only assists in control of hemostasis but also shrinks the tumor, facilitating removal. The location of the facial nerve must be verified before cautery is applied. More rapid debulking of the central part of the tumor is accomplished with ultrasonic aspiration. The facial nerve is usually stretched over the anterior and medial surface of the tumor but, in some cases, may be located either inferiorly or superiorly. Rarely, the facial nerve is in a posterosuperior location. Debulking of the central part of the tumor leaves the tumor capsule with the adherent facial nerve. Identification of the facial nerve and cochlear vestibular complex at the brain stem facilitates removal of residual tumor. Care is taken to identify and preserve the anterior inferior cerebellar artery (AICA), which often lies between the seventh and the eighth nerves. The tumor capsule is moved posteriorly and inferiorly. The facial nerve stimulator is used to locate the facial nerve or its root entry zone on the brain stem. Cutting the proximal stump of the eighth nerve facilitates removal of the tumor (Fig. 124-16; see also Video 124-5). Dissection is then continued from the medial to the lateral direction. The remaining tumor capsule is sharply dissected away from the facial nerve. The wound, dura, and posterior fossa are irrigated with saline solution. Hemostasis is ensured with bipolar coagulation.

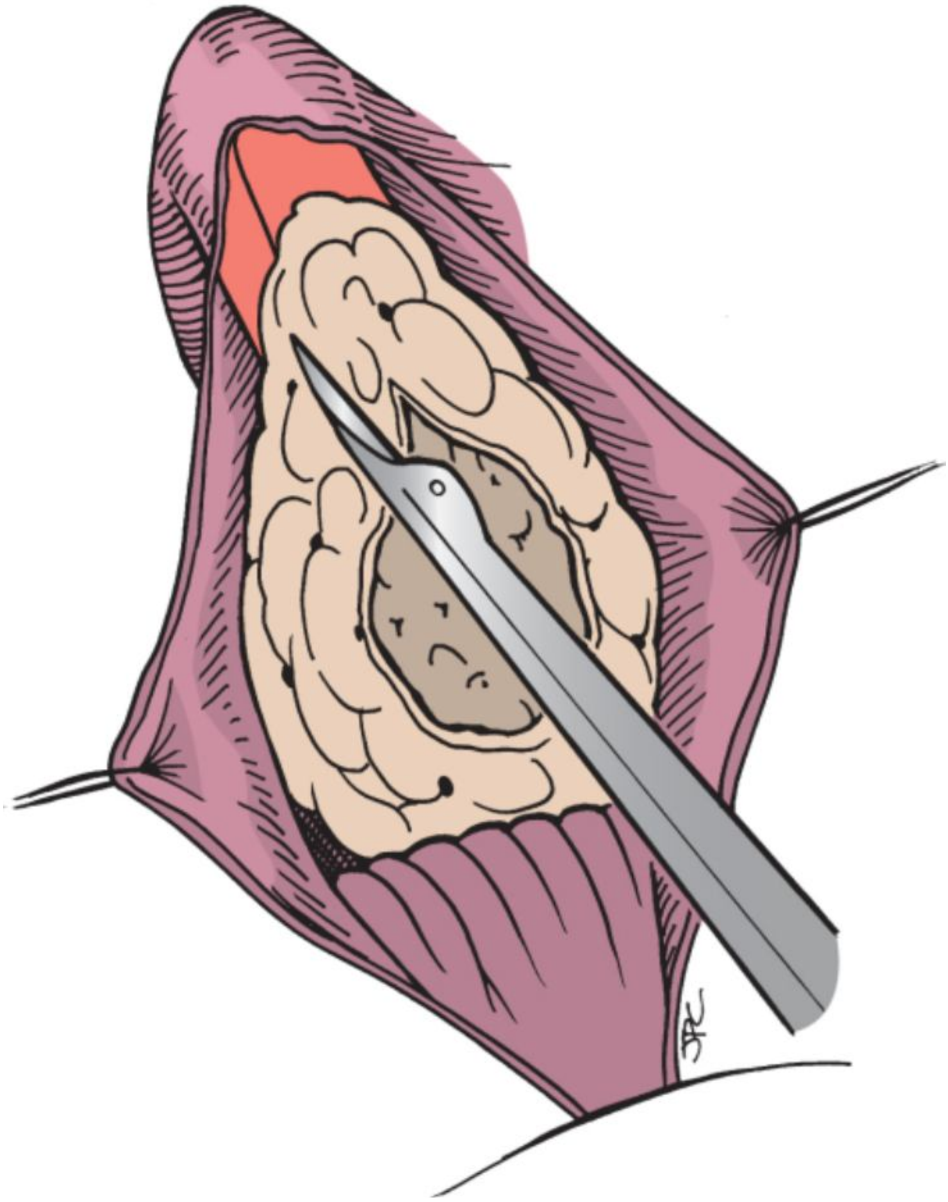

**Figure 124-15** Hemostasis is controlled on the capsule of the tumor with bipolar cautery. The tumor surface is entered with sharp dissection. The core of the tumor is then removed. The facial nerve is frequently located on the anterosuperior pole of the tumor.

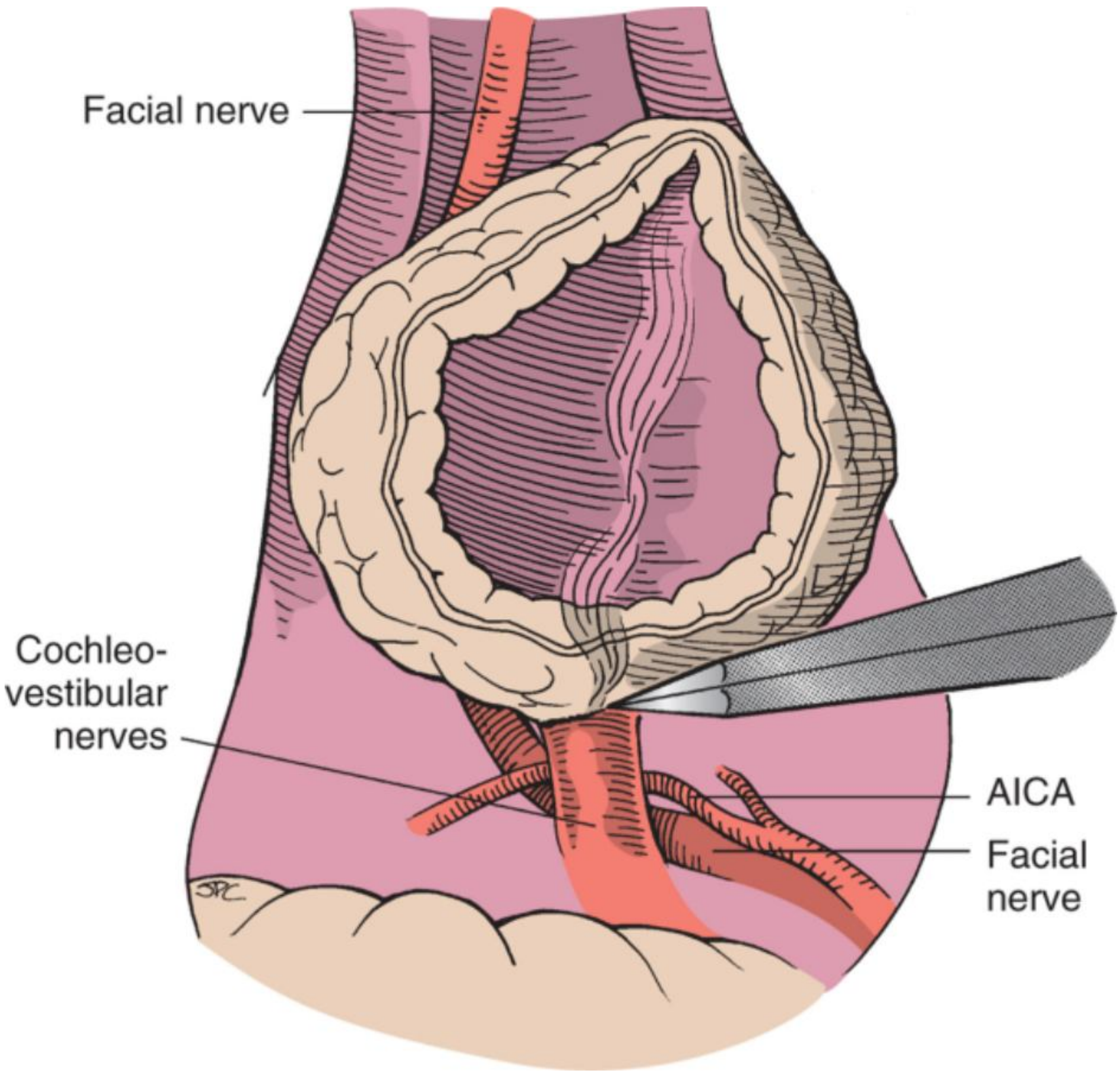


**Figure 124-16** After the tumor is debulked, the capsule may be moved posteriorly and inferiorly to identify the proximal facial nerve and cochleovestibular bundle. A loop of the anterior inferior cerebellar artery (AICA) is frequently found between the nerves. The proximal end of the tumor is coagulated with the bipolar cautery and the cochleovestibular nerves are transected.

Disrupting the facial nerve in order to completely remove an AN is a rare occurrence. However, when it does occur, effort should be made to repair the nerve primarily. With the nerve having been stretched by the enlarging tumor, primary reapproximation may be feasible. Owing to the lack of epineurium, it may be difficult to get more than one 8-0 nylon suture placed to reapproximate the disrupted ends of the facial nerve. A few drops of fibrin glue may be used to further secure the anastomosis. This is facilitated by placing small pledgets of Gelfoam around the reapproximated nerve ends. If there is inadequate length to perform a primary anastomosis, then a cable graft using the sural or greater auricular nerve is performed.

The edges of the posterior fossa dura are reapproximated using interrupted or running 4-0 dural sutures (silk or Nurolon). A convenient needle to use in this tight area is an Ethicon TF-4.[11] Complete closure is not possible owing to the dural defect at the IAC. Similar to a clothesline, the suture spans the dura defect, providing a lattice support for the next step of obliteration of the wound with adipose tissue (Fig. 124-17; see also Video 124-6). Abdominal fat, harvested from the infraumbilical area of the abdomen, is soaked in the bacitracin solution. Pieces of fat and temporalis muscle that were obtained earlier in the procedure are placed through the facial recess, filling the middle ear. The aditus is completely blocked with muscle. A small piece of Surgicel secures the muscle plug. The abdominal fat is then cut into strips and advanced through the dural defect (Fig. 124-18). The remainder of the mastoid cavity is also packed with abdominal fat. Fibrin glue is applied around the fat (see Video 124-7). The wound is closed in three layers. The mastoid cortical defect is covered with a titanium plate fixed to the temporal bone with self-tapping screws. The fibroperiosteal and temporalis muscle fascial flap is closed with interrupted sutures. The subcutaneous skin flap is also approximated with the same suture. A running interlocking 4-0 Nurolon suture closes the skin. Skin staples may also be used. Antibiotic ointment and a Telfa pad are placed over the incision, and a sterile pressure dressing is applied.

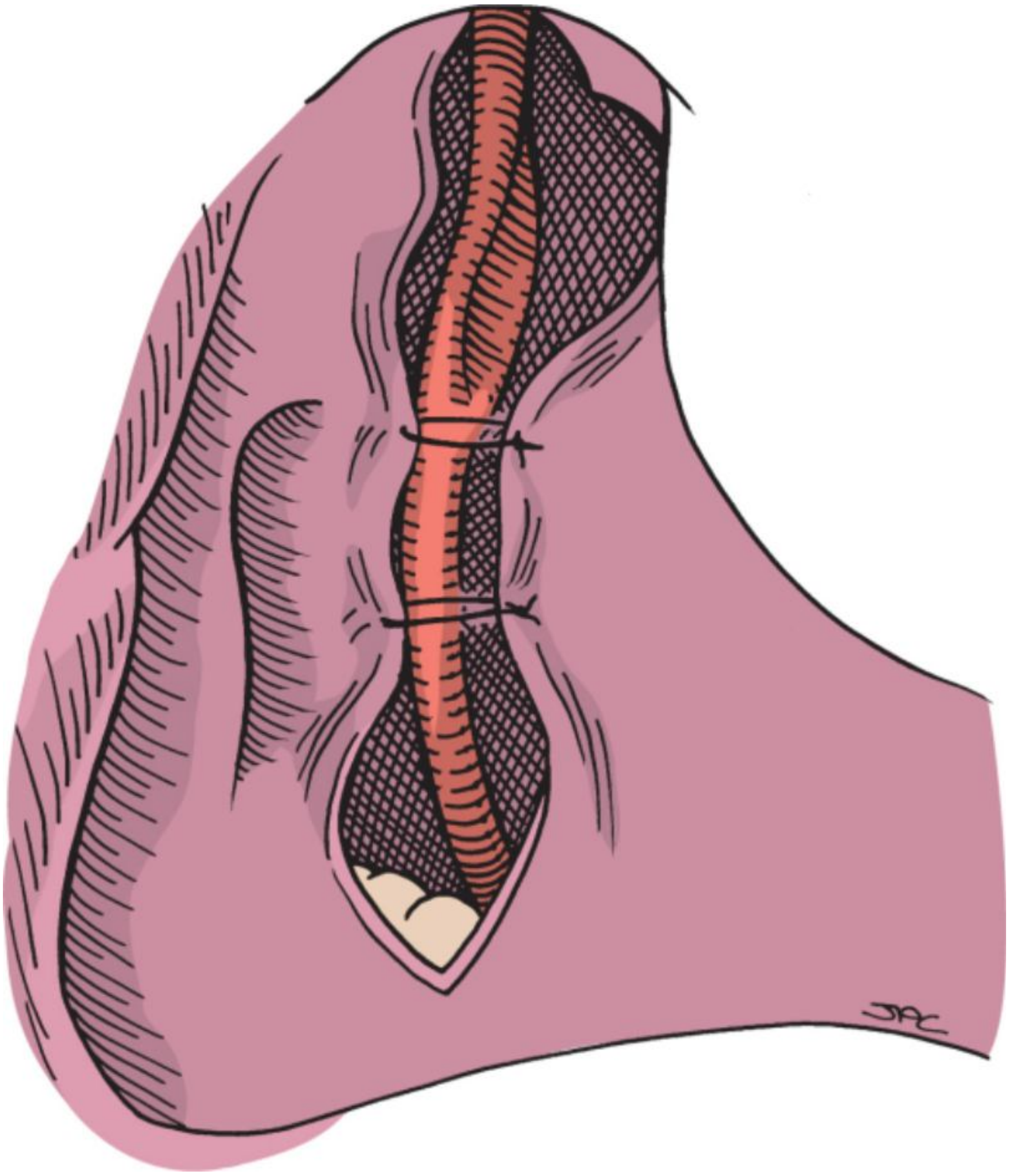

**Figure 124-17** The remaining edges of the porus and posterior fossa dura are reapproximated to support the fat graft. Note the ribbon-like attenuation of the facial nerve at the porus.

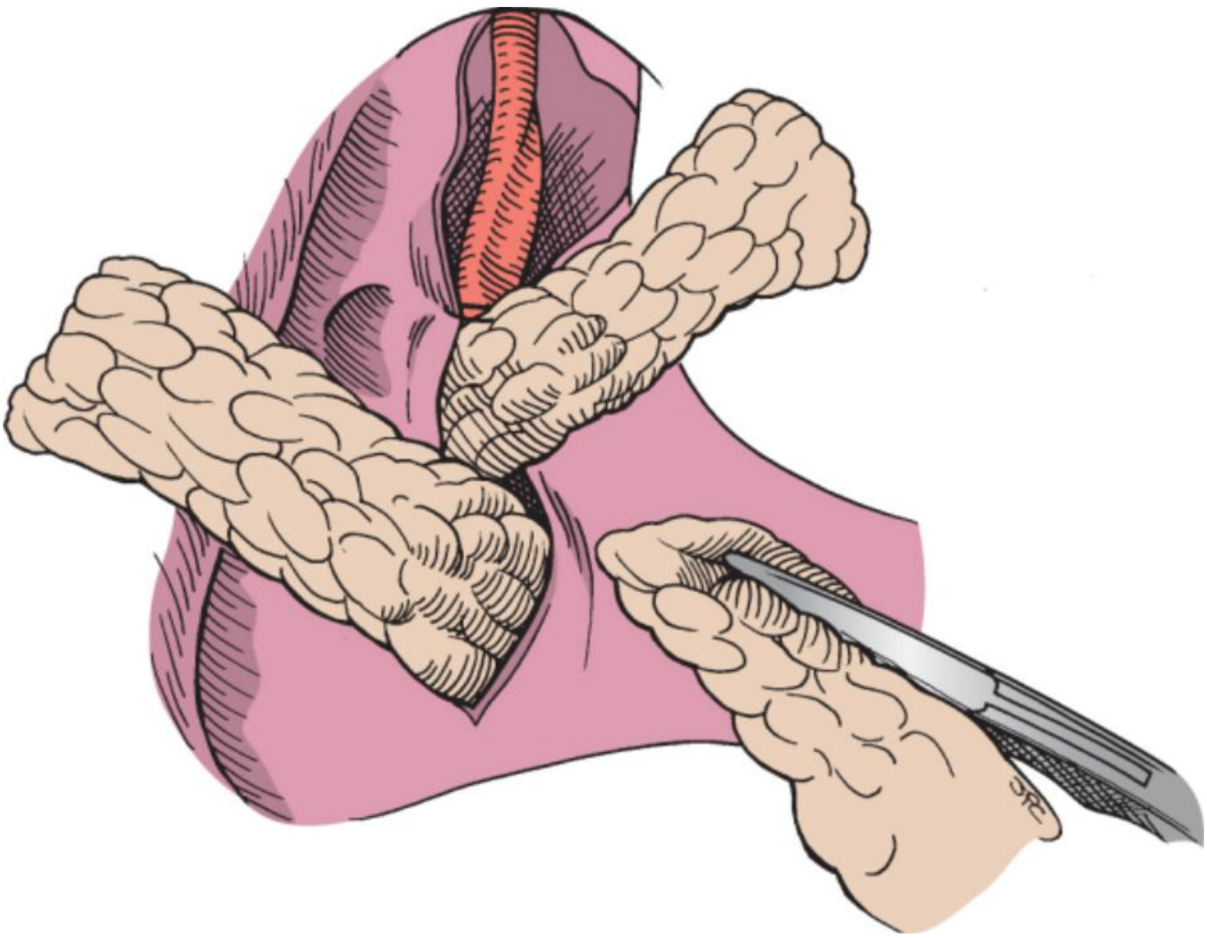

**Figure 124-18** The ends of strips of fat are placed through the dural openings into the posterior fossa.

## Middle Fossa Approach

The patient is positioned supine on the table and placed in a Mayfield head holder with the head turned with the involved ear facing the ceiling. The hair is shaved in the preauricular region from the tragus to the superior temporal line. Electrodes for facial nerve monitoring are placed. In order to monitor the ABR, a sound source is placed into the ear canal affixed with a foam rubber plug and bone wax to secure the ear phone. This is covered with an Op–Site dressing, and the area is prepared and draped. Extraction of fluid from the soft tissue of the brain permits easier retraction of the temporal lobe. Techniques used to shrink and soften the brain include removal of CSF via a spinal drain, mild dehydration using intravenous mannitol and furosemide, and lowering the patient's partial pressure of carbon dioxide ($P_{CO_2}$) through hyperventilation. A lumbar drain, although not used routinely, is inserted after induction of general anesthesia by turning the patient in a lateral position. The patient is returned to the supine position once the catheter has been secured. Mannitol and furosemide are given at the time the skin incision is made.

The design of the skin incision depends in part on the surgeon's preference but also on the goal of the surgery. Figure 124-19 shows three common modifications of the preauricular skin incision used for the middle fossa approach to the IAC. We prefer an incision that extends vertically with a slight curve at the superior extent depicted by line B. The incision is outlined, and a solution of 1% lidocaine (Xylocaine) with 1 : 100,000 epinephrine is injected to help with hemostasis during the initial elevation of the skin flap. Once the skin and subcutaneous tissues have been incised and the skin flaps undermined, the area of the temporalis fascia and muscle above the root of the zygoma will be exposed. The temporalis muscle is incised in order to create an inferiorly based pedicled flap at its origin. The temporalis muscle is cut along the linea temporalis above the mastoid and continues vertically and superiorly to the superior temporal line. A cuff of fascia and periosteum is preserved superiorly for suture reapproximation at the conclusion of the procedure. Anteriorly, the descending temporalis muscle incision divides the muscle body as it extends toward the zygomatic arch. A periosteal elevator is used to mobilize the temporalis muscle inferiorly to the root of the zygoma. Hemostasis is obtained with bipolar coagulation or bone wax. The temporalis muscle is also retracted inferiorly with a 2-0 Dexon or silk suture. The external auditory canal, root of the zygoma, and glenoid fossa are important landmarks.

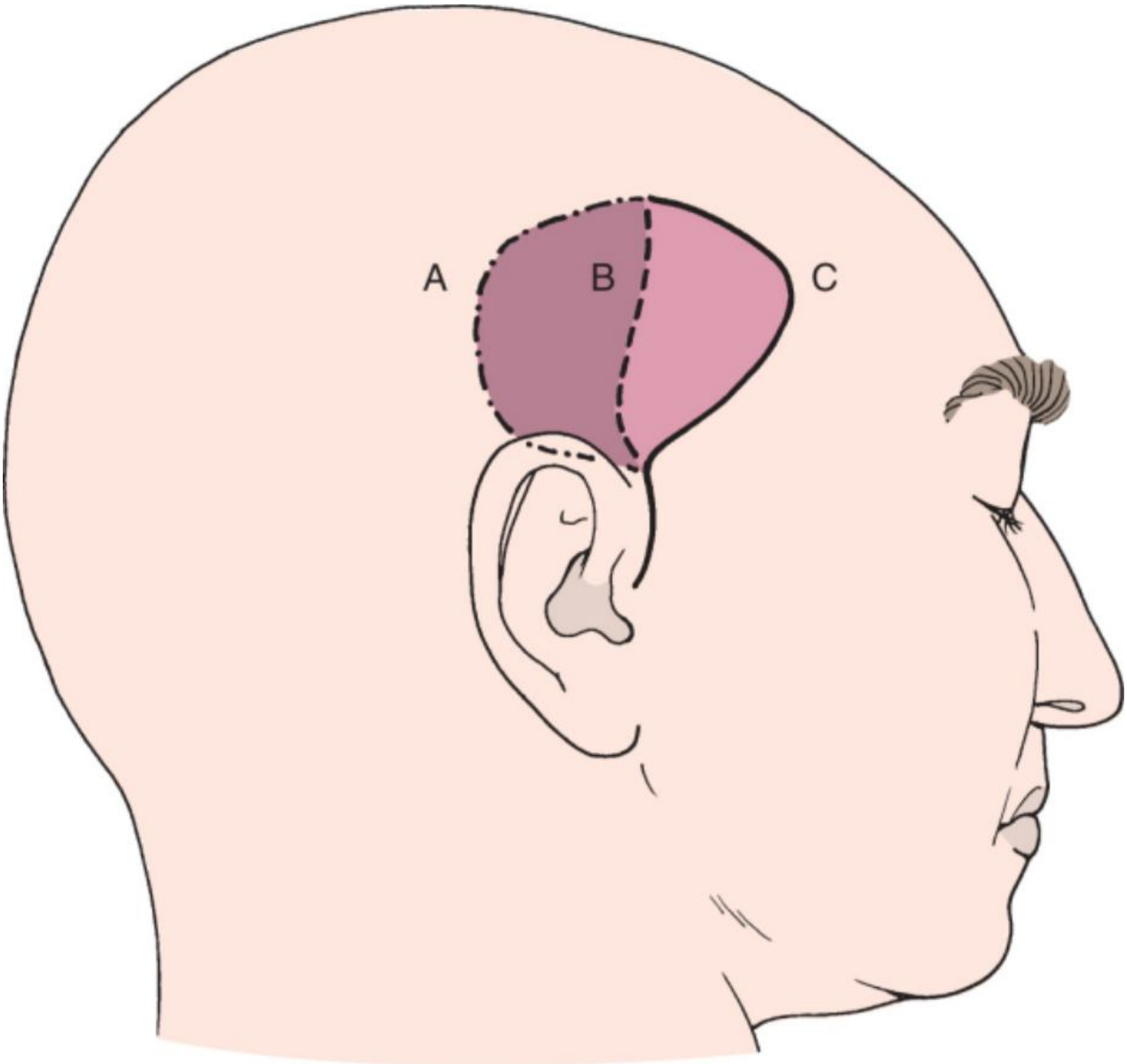


**Figure 124-19** Skin incisions available for a middle fossa approach to an acoustic neuroma. Our preference is B.

A temporal craniotomy is then performed over the squamous portion of the temporal bone. The craniotomy flap is positioned approximately one–third posterior to and two–thirds anterior to the external auditory canal. It measures approximately 5 cm in the vertical dimension and 4 cm in anteroposterior width. The inferior aspect of the craniotomy is based on the root of the zygoma and should be placed as low as possible. The flap is dissected with a medium cutting burr that defines the perimeter of the bone flap (Fig. 124-20). Another method of turning the bone flap is to place four burr holes at each corner of the bone dissection. A craniotome with a footed attachment on a high-speed drill is used to finely cut the two vertical and superior horizontal bone cuts, connecting the burr holes. Because of anatomic limitations, it is often difficult to use the footed attachment for the inferior horizontal cut. The inferior horizontal cut is made with a round cutting or matchstick burr. Using an elevator, the bone flap is lifted while the underlying dura is cautiously detached from the inner table. The dura underlying the craniotomy site is elevated. Hemostasis is secured with bipolar coagulation. Once the bone flap is removed, the inferior aspect of the craniotomy should be lowered to the level of the floor of the middle fossa using a rongeur or cutting burr (Fig. 124-21). Rough edges of the craniotomy site and bone flap are smoothed with a rongeur or drill. The dura is elevated from the floor of the middle fossa. Dissection requires patience and slow but progressive retraction of the temporal lobe. Adequate brain softening should have been achieved from the previously administered osmotic agents.

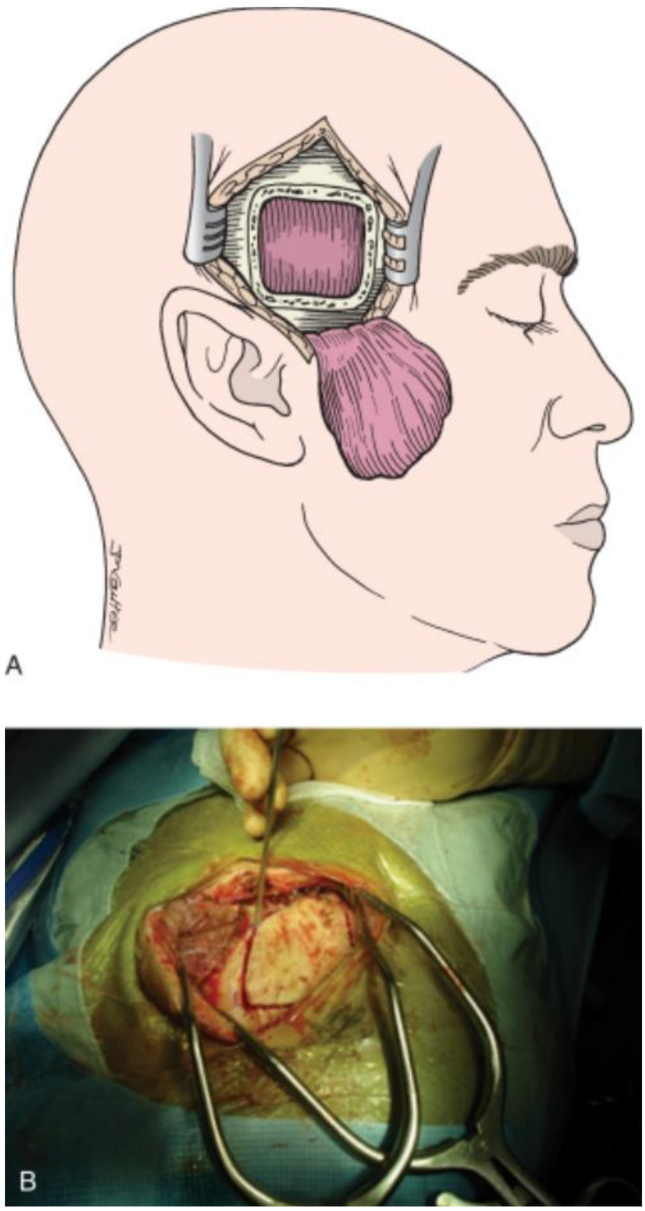

**Figure 124-20** **A,** A craniotomy, 5 × 4 cm, is developed with a medium-sized cutting burr. It is positioned two–thirds anterior and one–third posterior to the external auditory canal. **B,** Photograph of right ear showing the outline of the bone flap before elevation. The temporalis muscle is transposed anteriorly and inferiorly.

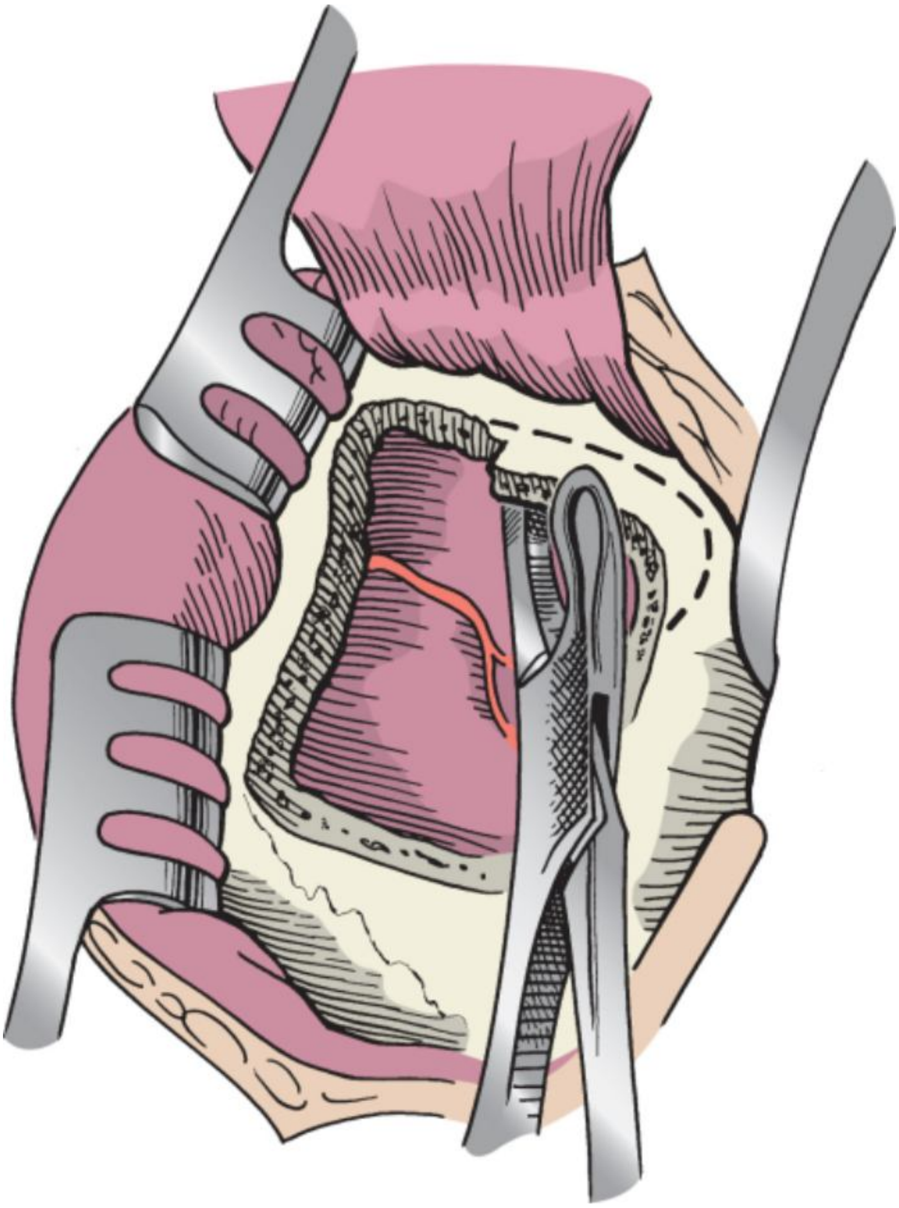

**Figure 124-21** The inferior aspect of the craniotomy site is enlarged, removing sharp protruding edges. A rongeur or drill burr is used to smooth the edges.

Familiarity with the surface anatomy of the floor of the middle fossa is essential to facilitate this operative approach. The most lateral adhesion of dura occurs at the petrosquamous suture. Anteriorly, the middle meningeal artery enters through the foramen spinosum. The lesser and greater superficial nerves run parallel from the sphenopetrosal groove. The greater superficial petrosal nerve (GSPN) courses from posterior to anterior, leaving the geniculate ganglion through the facial hiatus. Deep to the GSPN lies the horizontal portion of the petrous carotid artery. Lateral to the carotid artery is the tensor tympani muscle above and the eustachian tube below. The internal carotid artery courses medially and inferiorly to the mandibular division of the trigeminal nerve (V3). The arcuate eminence lies posteriorly and medially on the floor of the middle fossa. This is the bony convexity of the superior semicircular canal. Posterior to the arcuate eminence is the tegmen of the mastoid. The superior petrosal sinus runs obliquely from posterolateral to anteromedial and forms the medial boundary separating the middle from the posterior fossa. This anatomy relative to the ossicles, geniculate ganglion, facial nerve, IAC, vestibular labyrinth, and cochlea is demonstrated in Figure 124-22.

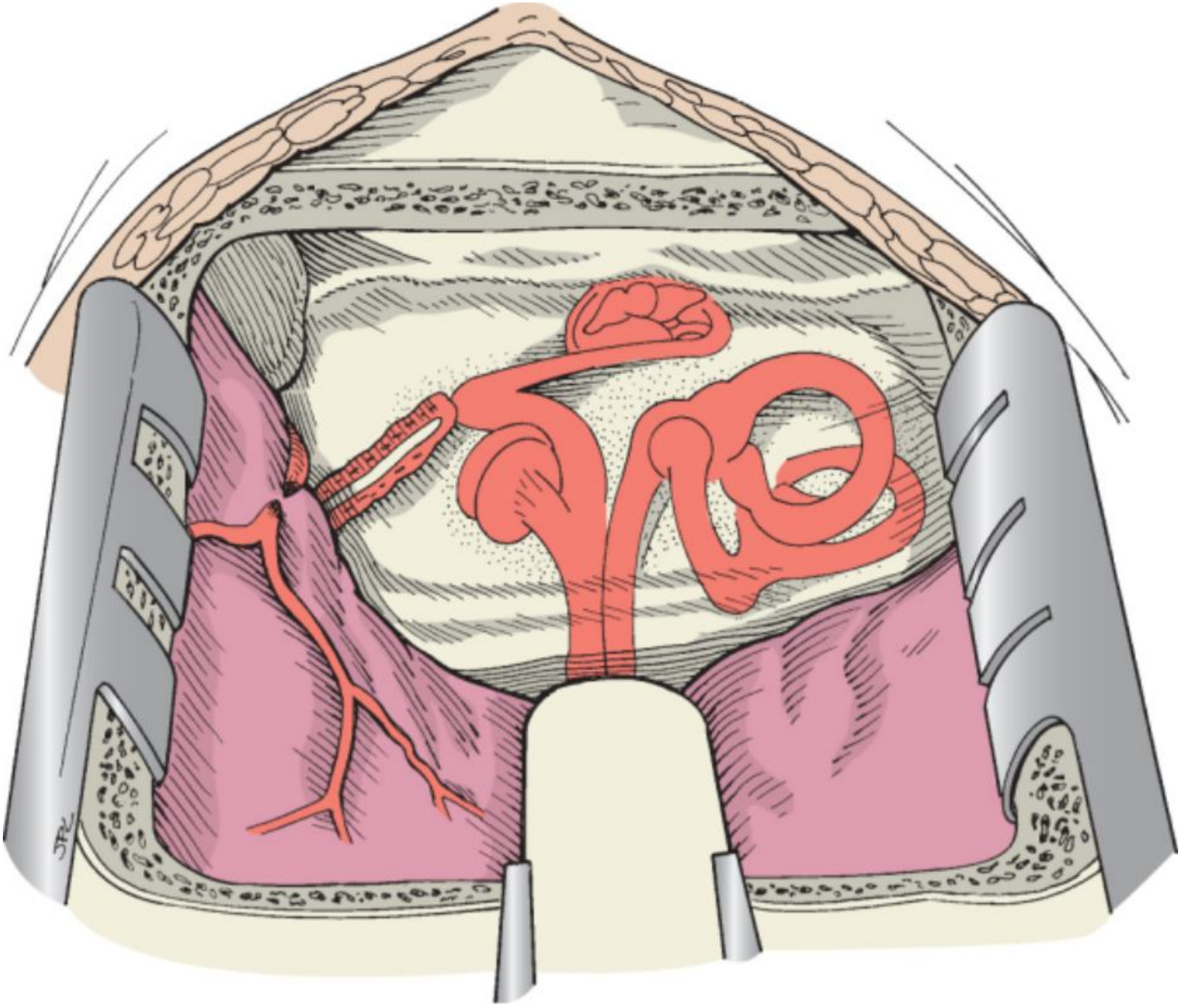

**Figure 124-22** The anatomy deep to the floor of the middle fossa is illustrated. The middle meningeal artery has been divided. The greater superficial petrosal nerve can be traced posteriorly in the geniculate ganglion. The facial nerve courses between the basal turn of the cochlear and ampullated end of the superior semicircular canal. The ossicles are demonstrated.

Using an operating microscope, a Lempert elevator, and small suction, the dura is elevated from the floor of the middle fossa in a lateral-to-medial and posterior–to-anterior direction. Laterally, within the first 10 mm of dural elevation, the petrosquamous suture line is encountered. The dura may be firmly attached along this suture line, and occasionally, a few small perforating veins will be noted and can be coagulated or waxed. Further medially and anteriorly, the next landmark along the floor of the middle fossa is the middle meningeal artery. Commonly, venous bleeding from a periarterial venous plexus will be encountered and should be controlled with bipolar electrocautery or small pledgets of Surgicel. The middle meningeal artery is isolated by circumferential dissection around the artery. Although not routinely necessary, if extended exposure is needed, the artery is cauterized and then divided using microscissors. It is helpful to dissect the artery far enough to allow a small cuff of vessel to be retained on both the cranial and the dural sides. Unsuccessful hemostasis is controlled with a hemoclip.

Dissection of the dura from posterior to anterior avoids injury to the geniculate ganglion from retrograde elevation of the GSPN. The prominence in the floor of the middle fossa is the arcuate eminence, which is another key landmark. The middle fossa dura is elevated medially until the edge of the petrous bony ridge is palpated. Care is taken not to tear the superior petrosal sinus. The dura is dissected along the ridge of the petrous bone. Once the middle fossa dura has been dissected to the level of the sulcus of the superior petrosal vein, a retractor is repositioned and secured. Two methods of retracting the dura and temporal lobe have been used. The first method is with a Greenberg retractor secured to a Mayfield head holder. The second method is to use a House-Urban or Fisch middle fossa retractor. The rigid blade elevating the temporal lobe is then placed.

Important landmarks for identifying the IAC are the arcuate eminence and the GSPN leading posteriorly toward the geniculate ganglion (Fig. 124-23). The course of the GSPN and arcuate eminence form an angle of approximately 120 degrees. A line bisecting this angle forms a 60-degree angle with both the GSPN and the arcuate eminence. This line, parallel with the external auditory canal, overlies the course of the IAC. If the anatomy is uncertain, then the arcuate eminence is bluelined to define the superior semicircular canal. Another method for identifying the IAC is by retrograde dissection of the GSPN. This will identify the geniculate ganglion and, in turn, the labyrinthine segment of the facial nerve. Meticulous and careful dissection is necessary in the labyrinthine segment because the basal turn of the cochlea lies immediately anterior and lateral to this structure.

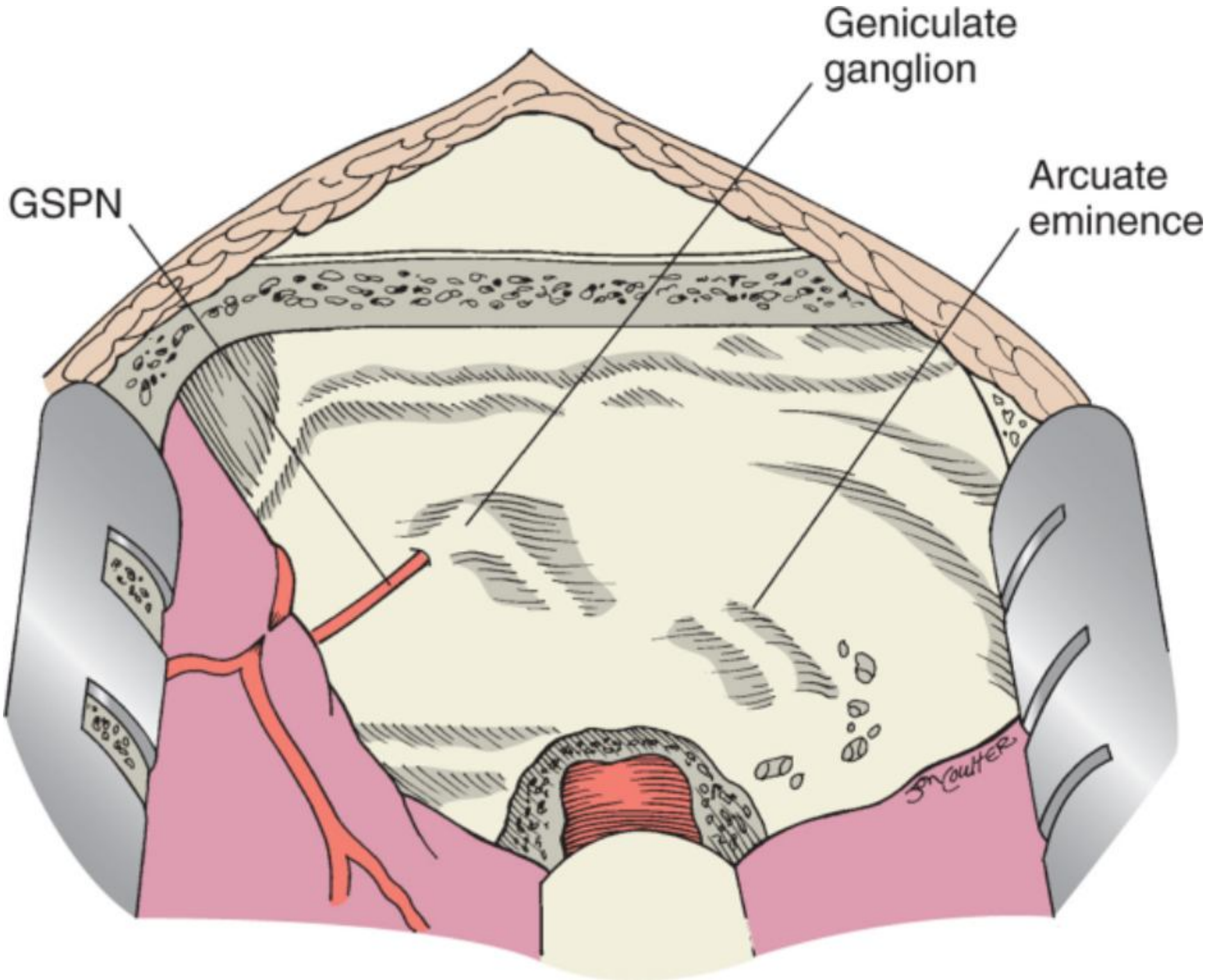


**Figure 124-23** The greater superficial petrosal nerve (GSPN) exiting the facial hiatus and the arcuate eminence are noted. Dissection begins medially where the proximal IAC and the superior lip of the porus acusticus are identified.

Once the important landmarks are determined, drilling is begun at the most medial aspect of the presumed location of the IAC. This area provides a wide margin of error, allowing the surgeon to work in a safe but rapid fashion. If the arcuate eminence is not obvious, drilling posteriorly will identify the mastoid tegmen and air cells. These can then be followed anteriorly until the dense otic capsule bone of the superior semicircular canal is identified. An additional method for identifying the anatomic structures is by drilling over the tegmen tympani to identify the ossicles, horizontal portion of the facial nerve, and geniculate ganglion. The nerve can then be traced proximally toward the IAC. It is necessary to expose at least 180 degrees of circumference of the IAC, especially medially. As the dissection of the IAC progresses from medial to lateral, the extent of circumferential dissection of the IAC must be reduced so that the upper basal turn of the cochlea and ampullated portion of the superior semicircular canal are not inadvertently entered (Fig. 124-24).

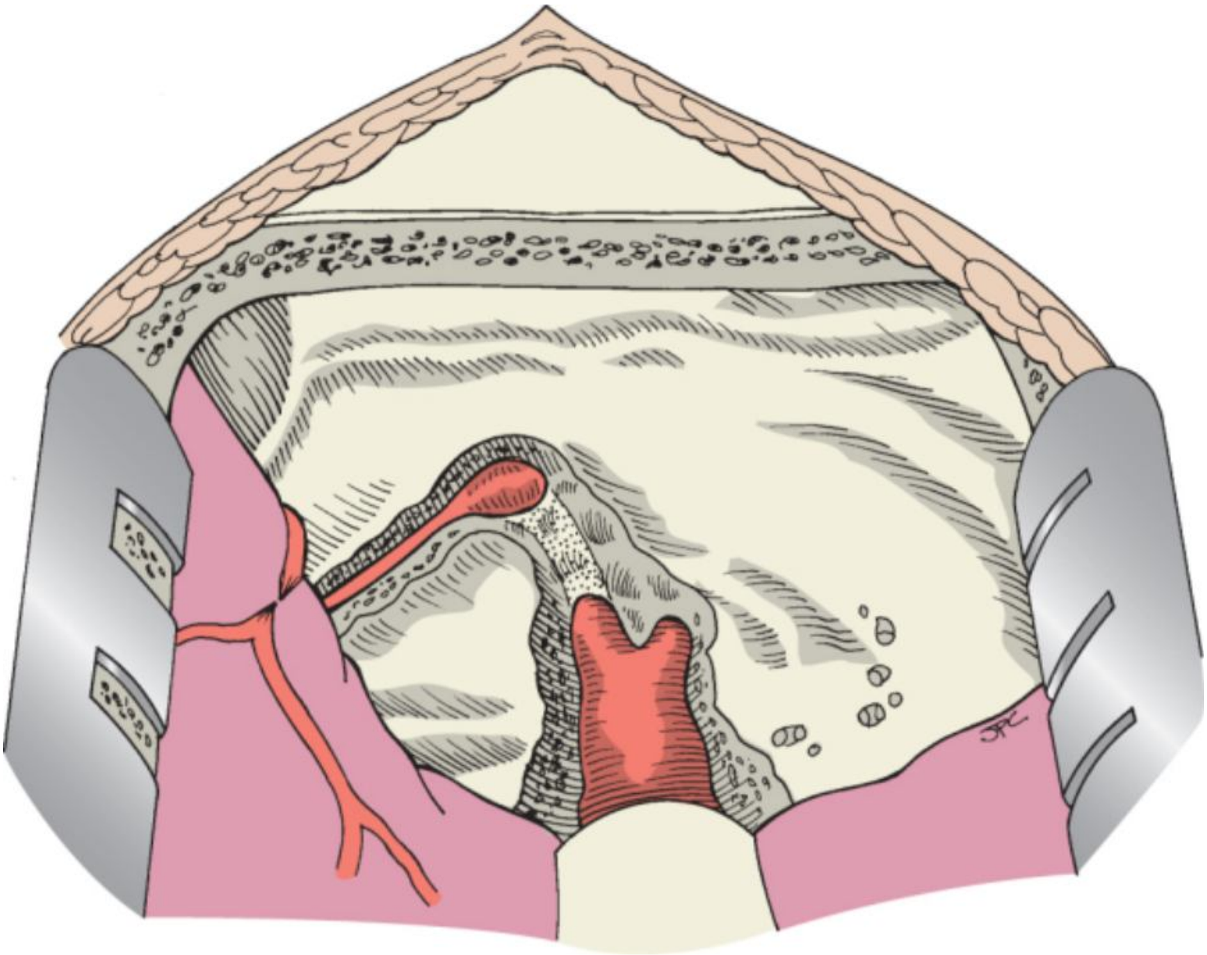

**Figure 124-24** Drilling over the IAC is continued laterally, exposing the proximal fallopian canal containing the labyrinthine segment of the facial nerve. The IAC may also be identified by retrograde dissection of the greater superficial petrosal nerve to the geniculate ganglion.

Following completion of all bone drilling exposing the IAC, the IAC is entered. The dura is opened most safely on the posterior aspect of the IAC, away from the facial nerve, reflecting the dura anteriorly (Fig. 124-25). It is important to dissect the tumor away from the facial nerve carefully and sharply. If the tumor originates from the inferior vestibular nerve, the fascicles of the superior vestibular nerve are sharply divided and dissected. This also facilitates identification and isolation of the facial nerve. It is preferable to remove the tumor from a medial to a lateral direction, avoiding stretch and injury to the labyrinthine segment of the facial nerve and the cochlear nerve. The proximal end of the vestibular nerve is cut, and the tumor is carefully dissected laterally. However, if the tumor obscures the CPA it may need to be debulked or removed from lateral to medial (Fig. 124-26). If hearing is to be preserved, care is taken not to cauterize vessels that are running along the course of the cochlear nerve.

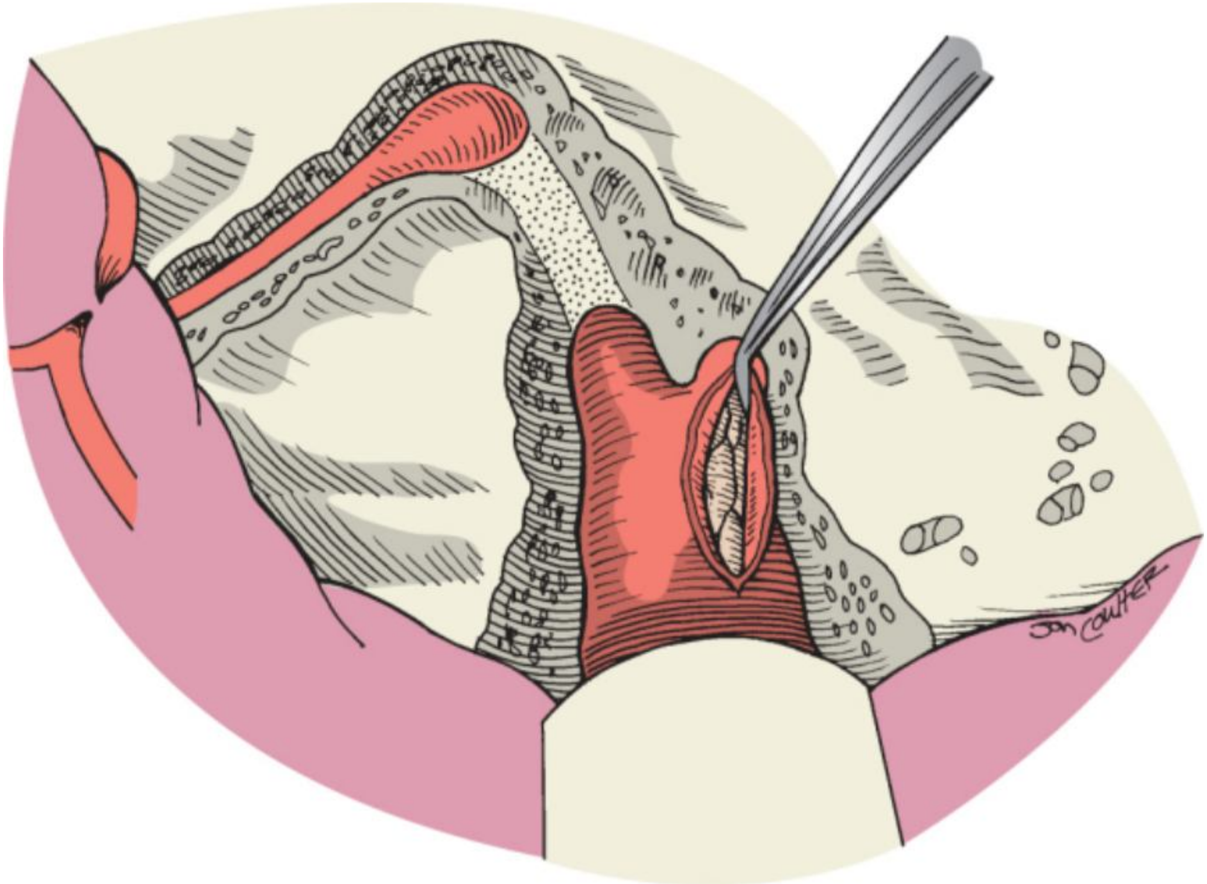

**Figure 124-25** The dura overlying the superior vestibular nerve is incised along the posterior wall of the IAC. Tumor is evident through the dural opening.

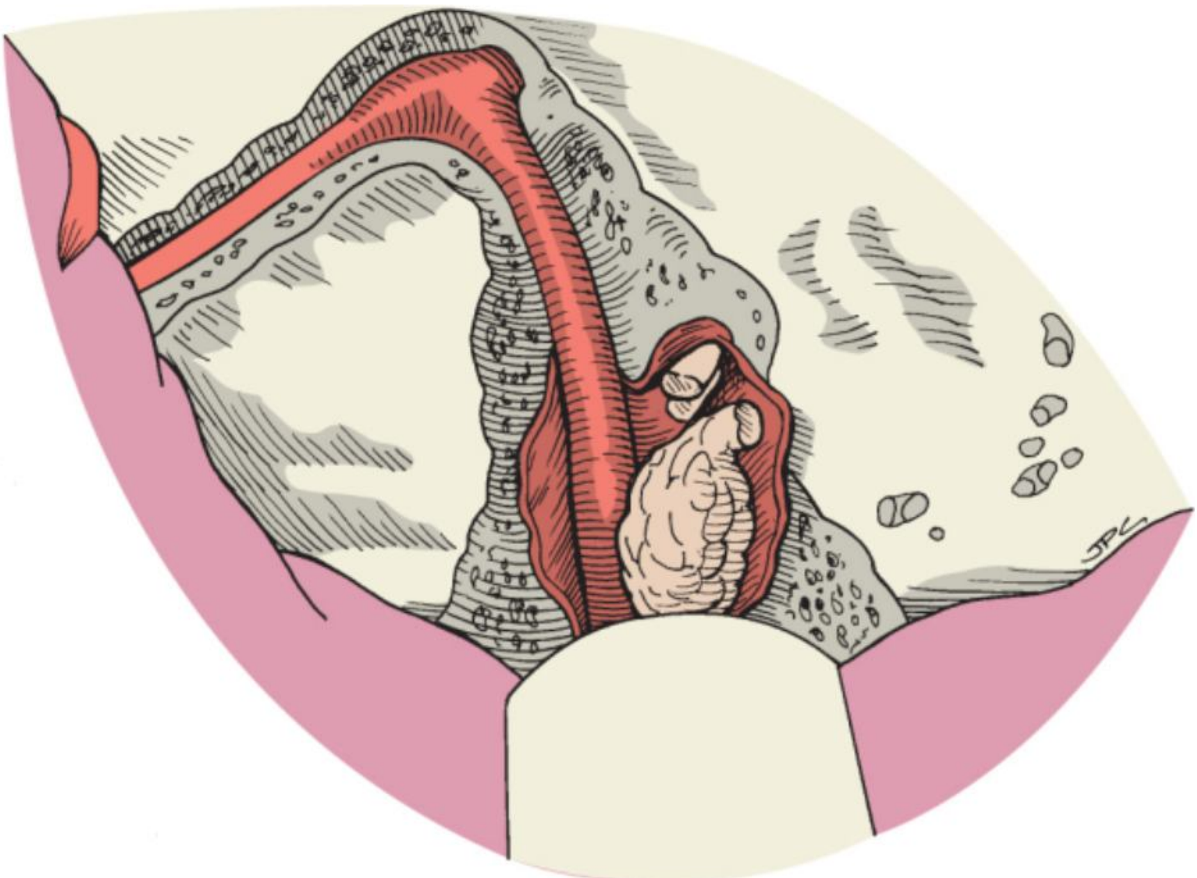

**Figure 124-26** The tumor is separated sharply from the facial nerve. In this situation, the superior vestibular nerve is divided distally and the tumor is dissected from lateral to medial.

Despite having a flap of dura and periosteum over the IAC, a watertight closure cannot be obtained. Fat is harvested from the abdomen and is soaked in bacitracin solution, and small pledgets are placed into the roof of the IAC. Hemostasis is ensured over the middle fossa dura. Any other tears or defects in the dura are primarily closed or repaired (Fig. 124-27). Two dura tacking sutures reapproximate the dura to the edges of the craniotomy through burr holes made previously. The bone flap is then replaced over the dura and secured with miniplates. The temporalis muscle flap is carefully reapproximated with absorbable sutures. A Jackson–Pratt drain is placed subcutaneously attached to a closed system and the wound is drained overnight. Skin is closed subcutaneously with 2-0 Dexon or Vicryl sutures. The skin closure is completed with a running 4-0 nylon suture or staples.

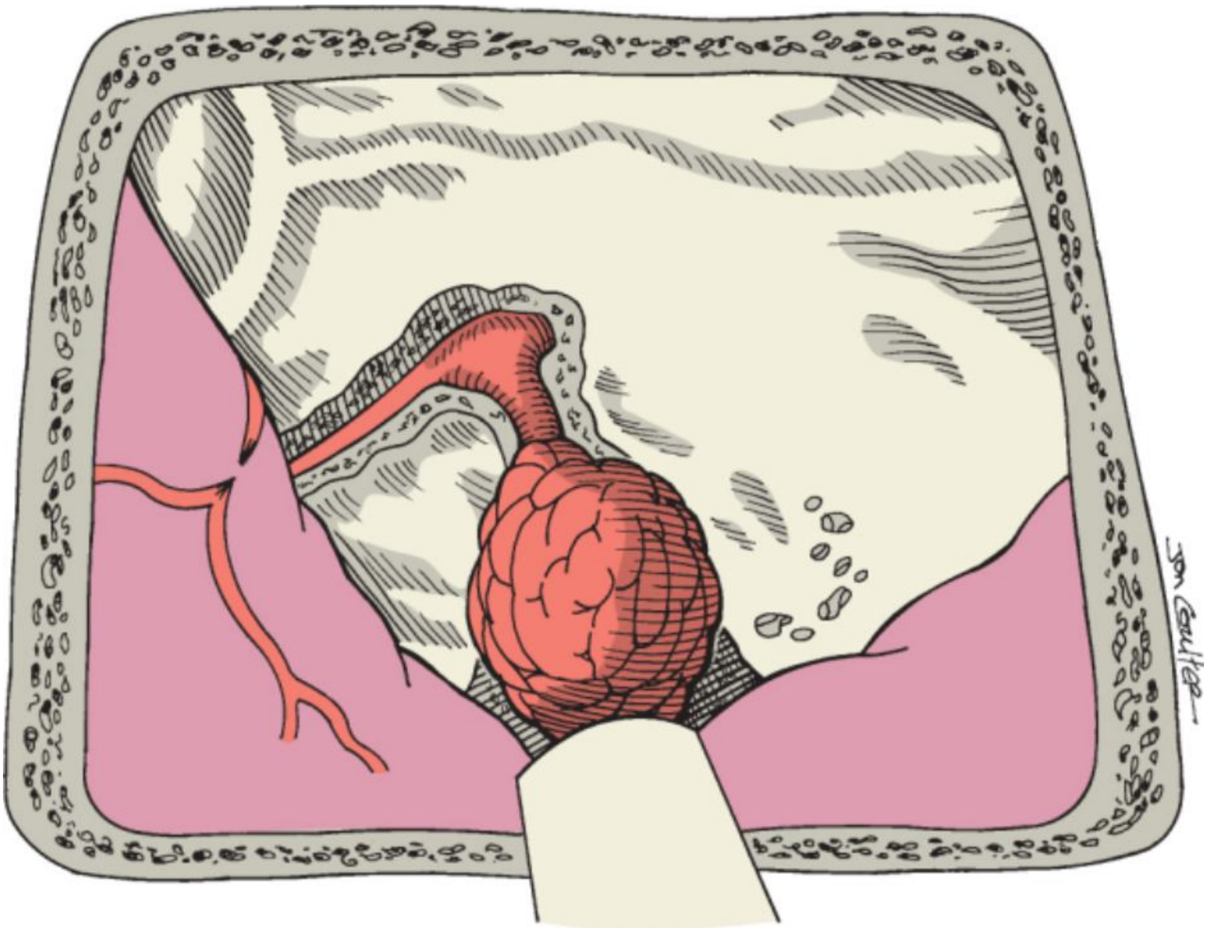

**Figure 124-27** Fat is placed in the defect in the dura over the roof of the internal auditory canal. The middle fossa dura will be tacked laterally to the edges of the craniotomy defect when the retractor is removed.

## Retrosigmoid Approach

The patient is placed supine on the table and general oral endotracheal anesthesia is induced. Appropriate venous and arterial lines are secured. Electrodes for facial nerve and ABR testing are placed. A sound source and ear mold are secured within the external auditory meatus of both ears. The patient is repositioned by elevating the ipsilateral shoulder, back, and hip, which are supported with wedges of rolled blankets or pillows. This assists with access to the suboccipital region. Gel pads lining the operating room table avoids pressure necrosis to the dependent hip and lateral thorax. Additional exposure is accomplished with neck flexion and head rotation toward the contralateral ear. A Mayfield head holder with three–point skeletal fixation is secured. The postauricular hair is shaved and a curvilinear oblique skin incision is marked over the retrosigmoid suboccipital area 2 cm medial to the mastoid process or 1 cm medial to the hairline (Fig. 124-28). The patient is prepared and draped in the usual sterile fashion.

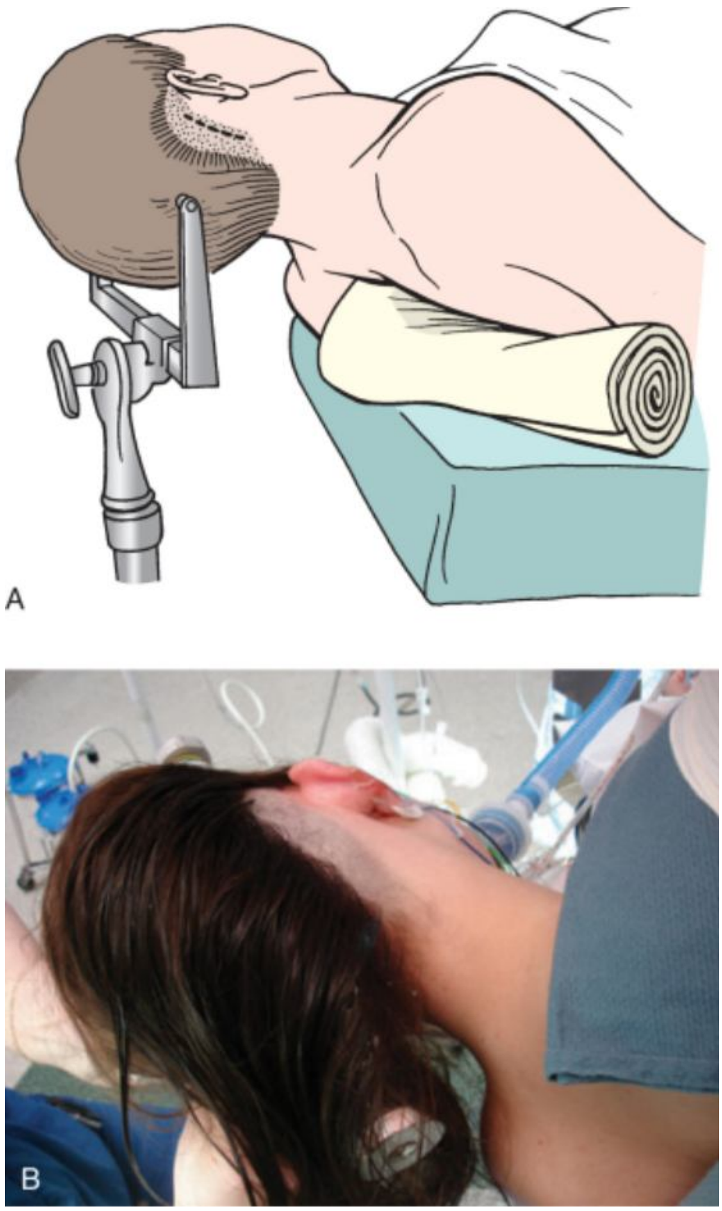


**Figure 124-28** **A,** The patient is positioned supine on the operating table, using an ipsilateral shoulder roll for additional rotation. Mayfield pin fixation secures the head position. The incision is marked on the skin. **B,** Positioning of patient for right retrosigmoid procedure.
*(A, Redrawn from Sekhar LN, Janecka IP [eds]: Surgery of Cranial Base Tumors. New York, Raven Press, 1993.)*

The incision is carried down to the suboccipital muscles. The occipital bone is exposed by subperiosteal muscle dissection and elevation in line with the incision. This exposes the lateral suboccipital bone medially and the mastoid process laterally. An emissary vein is typically encountered and requires bipolar coagulation, ligation, or compression with bone wax.

Using a high–speed drill, a suboccipital craniotomy is performed, exposing the dura of the cerebellar hemisphere. The limits of the exposure are the transverse sinus superiorly and the sigmoid sinus anteriorly. Hemostasis is obtained throughout the wound. Air cells that have been opened into the mastoid are obliterated with bone wax. Opening of the posterior fossa dura is performed to maximize exposure and facilitate closure. This depends on the anatomy of the transverse and sigmoid sinus and the posterior fossa exposure. The incision may be either semilunar or cruciate. The dural incision frequently used is demonstrated in Figure 124-29.

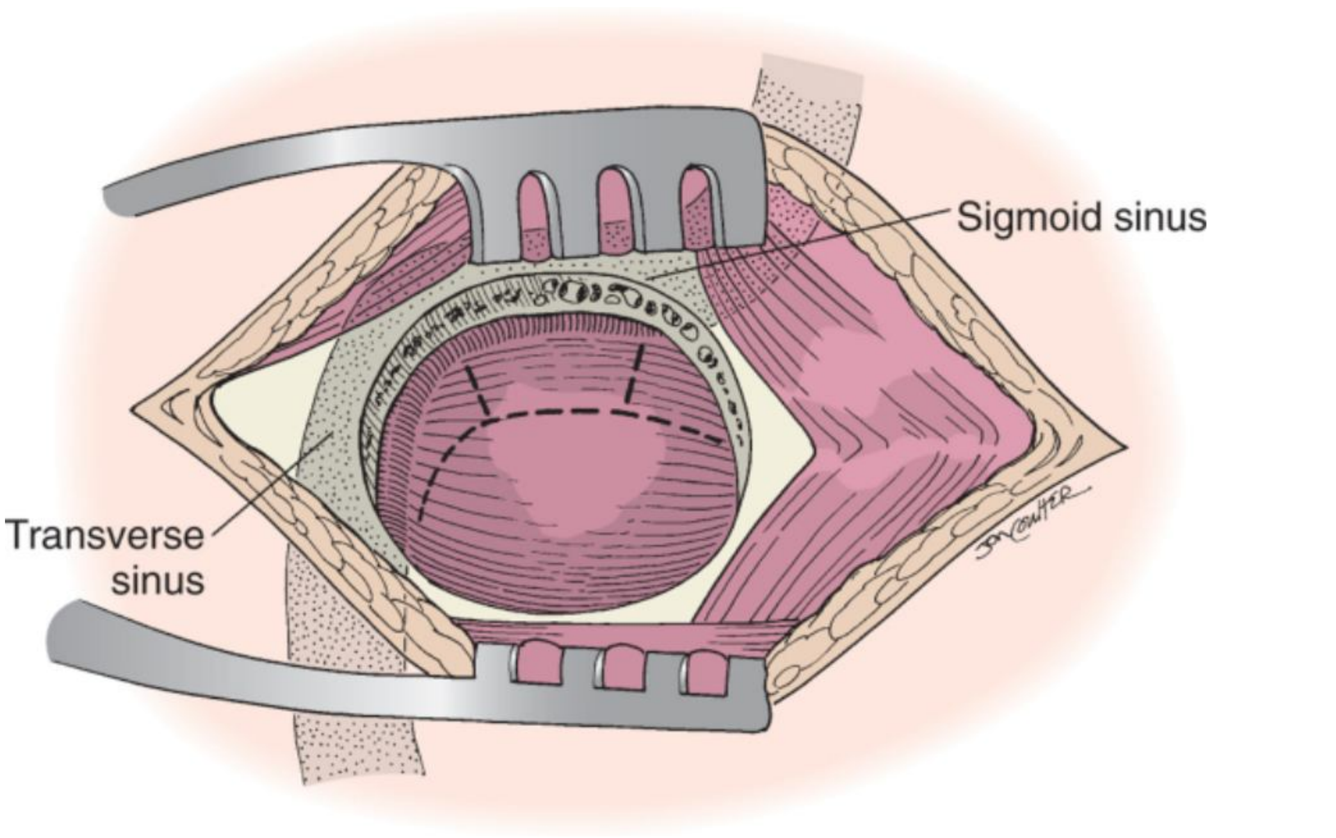


**Figure 124-29** The retrosigmoid craniotomy is limited by the transverse sinus superiorly and the sigmoid sinus anteriorly. The curvilinear and stellate incision in the dura is illustrated.

Entrance into the posterior fossa should be inferior to permit medial and superior elevation of the cerebellar hemisphere. This technique facilitates entry into the subarachnoid space and opening of the cerebellopontine cistern, which permits further relaxation of the cerebellum once CSF has been drained. The dura of the posterior fossa is opened. The operating microscope is brought into the field. The cerebellum is protected with a rubber dam and neuropatties. The arachnoid membrane encasing the cisterna magna needs to be opened. This allows egress of CSF, which reduces the pressure in the posterior fossa avoiding potential herniation of the cerebellum out of the wound. The lower cranial nerves IX through XI are identified. Further dissection inferiorly and medially provides exposure to the hypoglossal nerve as demonstrated in Video 124-8. If exposure cannot be maintained easily, a self–retaining Greenberg retractor is placed into position. The cerebellar hemisphere and flocculus are identified and retracted in a superomedial direction. This technique further relaxes the cerebellum, thereby providing exposure of the tumor (Fig. 124-30). Similarly, the root entry zone of the seventh and eighth cranial nerves is identified. The position and integrity of the seventh nerve should be verified initially with electrical stimulation. The origin from the brain stem can be located at the root entry zone of the ninth cranial nerve. Once the location and integrity of the proximal facial nerve is confirmed, a Teflon felt pledget is placed over the nerve for protection and subsequent identification (see Video 124-9). If the cochlear division of the eighth cranial nerve is identified, a direct nerve monitoring electrode is placed at its root entry zone if a hearing preservation procedure is undertaken. If the nerve is not identified, the wire electrode is placed in the vicinity of the lateral recess, superior to the ninth cranial nerve, which is in close proximity to the cochlear nucleus. If the tumor is too large to permit direct visualization of the brain stem, the tumor must be debulked.

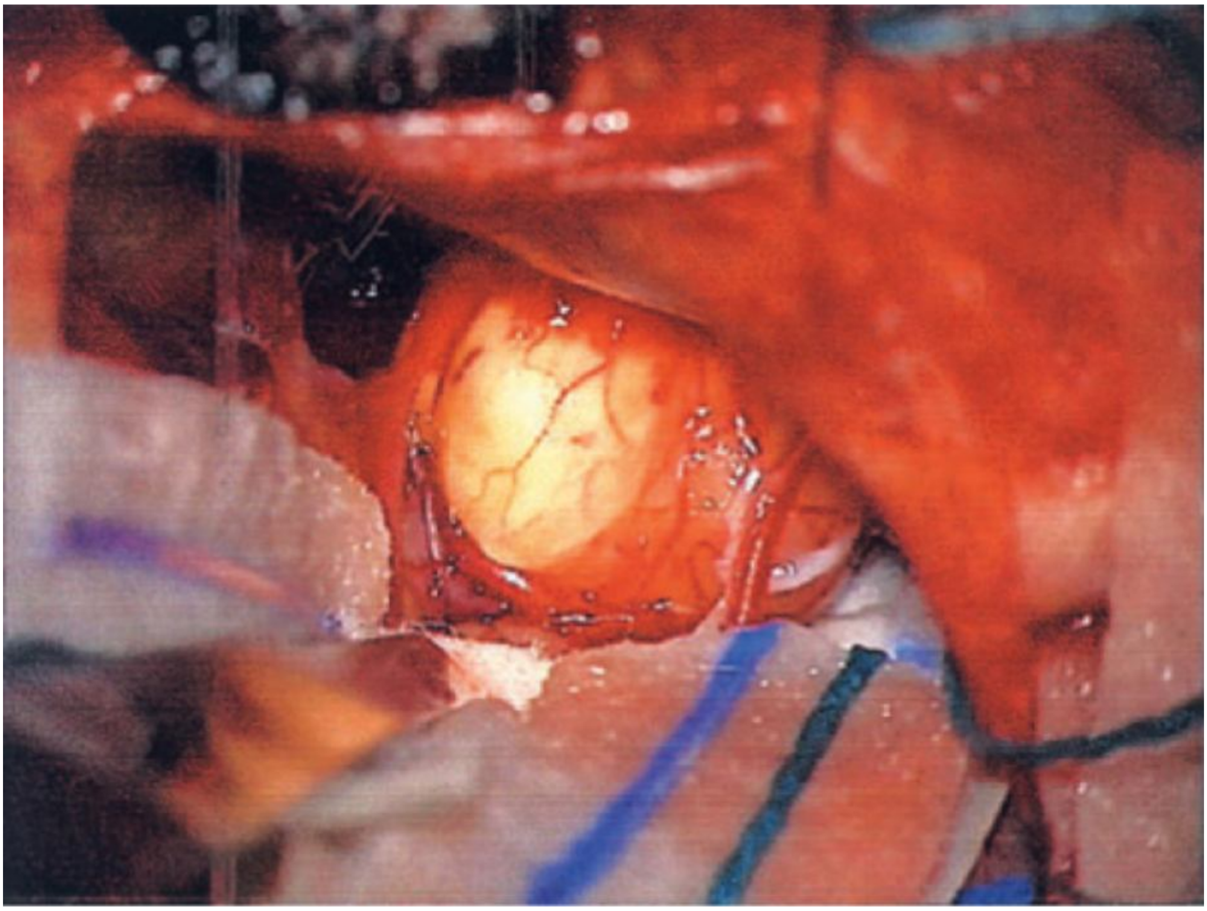

**Figure 124-30** Right retrosigmoid approach to an acoustic neuroma. A Greenberg retractor blade over a cottonoid patty gently retracts the cerebellum, exposing the tumor.

Excision of the tumor is done in a systematic fashion incorporating identification of the facial nerve, control of surface and parenchymal bleeding, and tumor removal. The dissection is carried out in a subarachnoid plane. The location of the facial nerve should be determined before removing tumor. A stimulator is used to map the surface of the tumor, assuring the facial nerve is not displaced on the posterior surface of the tumor. Once this is verified, bipolar forceps are used to coagulate vessels located on the surface of the tumor. Sharp dissection provides an entry point to the parenchyma of the tumor. The capsule of the tumor is opened and a representative portion is taken with a cup forceps for frozen section confirmation of the pathology. This will also assure that a specimen has been received by the pathology laboratory. The core of the tumor is progressively removed ("gutted") using an ultrasonic aspiration device leaving the outer walls of the tumor intact. Much of the bulk of the tumor resection is executed in this manner. The contents within the suction portion of this instrument are not readily available for histologic analysis, emphasizing the need for sending a frozen section. Decompressing the central core of the tumor thins the capsular walls allowing for further dissection of the tumor capsule away from normal structures such as the brain stem, tentorium, and trigeminal nerve. The surface of the tumor is again stimulated, looking for the position of the facial nerve. When it is verified that the nerve is not over the area being dissected, the capsule is again bipolared, controlling any surface vessels or bleeding. The capsule is then resected, diminishing the size of the remaining tumor in the CPA. Video 124-10 demonstrates this sequence and techniques for excision of the tumor.

If changes in auditory brain stem evoked potentials should occur, this part of the procedure is curtailed and retraction loosened. If ABR changes occur despite elimination of retraction, pieces of Gelfoam soaked in papaverine may inhibit vasoconstriction.

The facial nerve typically travels over the anterosuperior aspect of the tumor. Tumor dissection is continued until the walls of the anterior and superior capsule remain. Care is taken to avoid trauma to the AICA or the posterior inferior cerebellar artery (PICA) during the dissection. Neuropatties or rolled Teflon felt pledgets are used between the tumor capsule and the surrounding cerebellum, brain stem, cranial nerves, vessels, or tentorium. It may be necessary to dissect tumor from the fifth cranial nerve, depending on the size and location. The petrosal vein (Dandy's vein) is located superiorly and laterally in the posterior fossa, just inferior to the tentorium. Excessive stretch on this vessel leads to tear, resulting in bleeding that may be difficult to control. It is prudent to identify the vein and divide it using bipolar coagulation and microscissors. The petrosal vein can be safely sacrificed if it obstructs access to the tumor or if bleeding occurs. Video 124-11 demonstrates sacrificing the petrosal vein.

The tumor is further mobilized from the inferior aspect of the capsule. The direction of the dissection is between the brain stem and the capsule, keeping in mind the location of the facial nerve. Once the dissection plane is defined, pledgets of Teflon are placed to maintain separation of tumor from the surrounding normal structures (see Video 124-12 ).

In most cases, tumor is present in the IAC. The lateral extent can be determined from the contrast-enhanced T1-weighted MRI or CT scan. When adequate debulking is achieved or if the tumor is of small size, the porus of the IAC is identified. This can be confirmed by palpating the posterior edge of the lip with a right–angled hook. Bipolar coagulation is performed over the posterior surface of the petrous bone outlining the rectangular flap. A number 15 blade is used to cut the posterior flap of dura, which can be based either laterally or medially (posteriorly) along the petrous bone to the level of the operculum (see Video 124-13 ). This can usually be palpated with a Rosen dissector (Fig. 124-31). Care is taken to preserve the endolymphatic sac when hearing preservation is attempted. Gelfoam is placed superior and inferior to the tumor to avoid excessive bone dust from settling in the operative field.

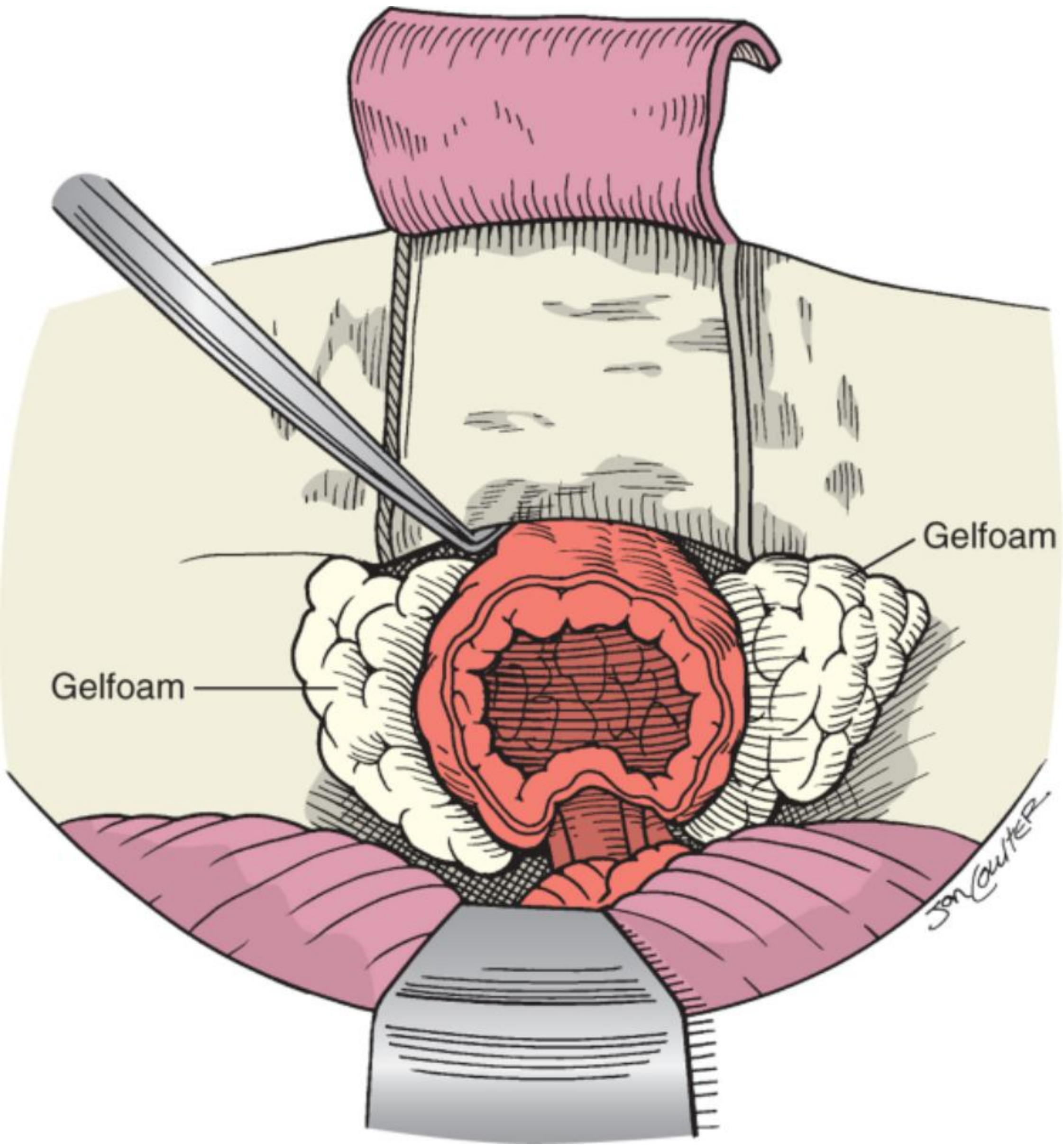

**Figure 124-31** The tumor has been partially gutted and resected. A right-angled hook is used to palpate the posterior bony meatus of the porus acusticus. A medially (posteriorly) based dural flap is incised and elevated. Gelfoam is placed superior and inferior to the tumor in preparation for drilling.

Using a cutting burr, the posterior aspect of the porus and IAC is drilled. This is continued in a semicircumferential fashion, outlining the superior and inferior aspects of the IAC (see Video 124-14). Dissection is continued approximately 7 mm laterally. However, the extent of dissection is determined by the lateral extent of the tumor. In addition, a bone–windowed CT scan defines the relationship of the lateral aspect of the tumor to the posterior semicircular canal and vestibule. Similarly, although bone detail is absent, MRI clearly identifies whether tumor extends to the fundus. Drilling is continued initially with a cutting burr and then with smaller diamond burrs to create a trough both superior and inferior to the IAC (see Video 124-15). The exposure necessary requires the posterior 180 to 270 degrees of the IAC to be drilled.

The edges of the remaining IAC should be palpated with a narrow elevator. The dura is initially elevated from the underlying bone both superiorly and inferiorly. It is at this point that the surgeon can determine whether the amount of bone that has been removed is sufficient (see Video 124-16). The dura covering the posterior aspect of the IAC is then opened inferiorly exposing the underling tumor (Fig. 124-32). The tumor is then dissected away from the dura lining the IAC superiorly and inferiorly (see Video 124-17).

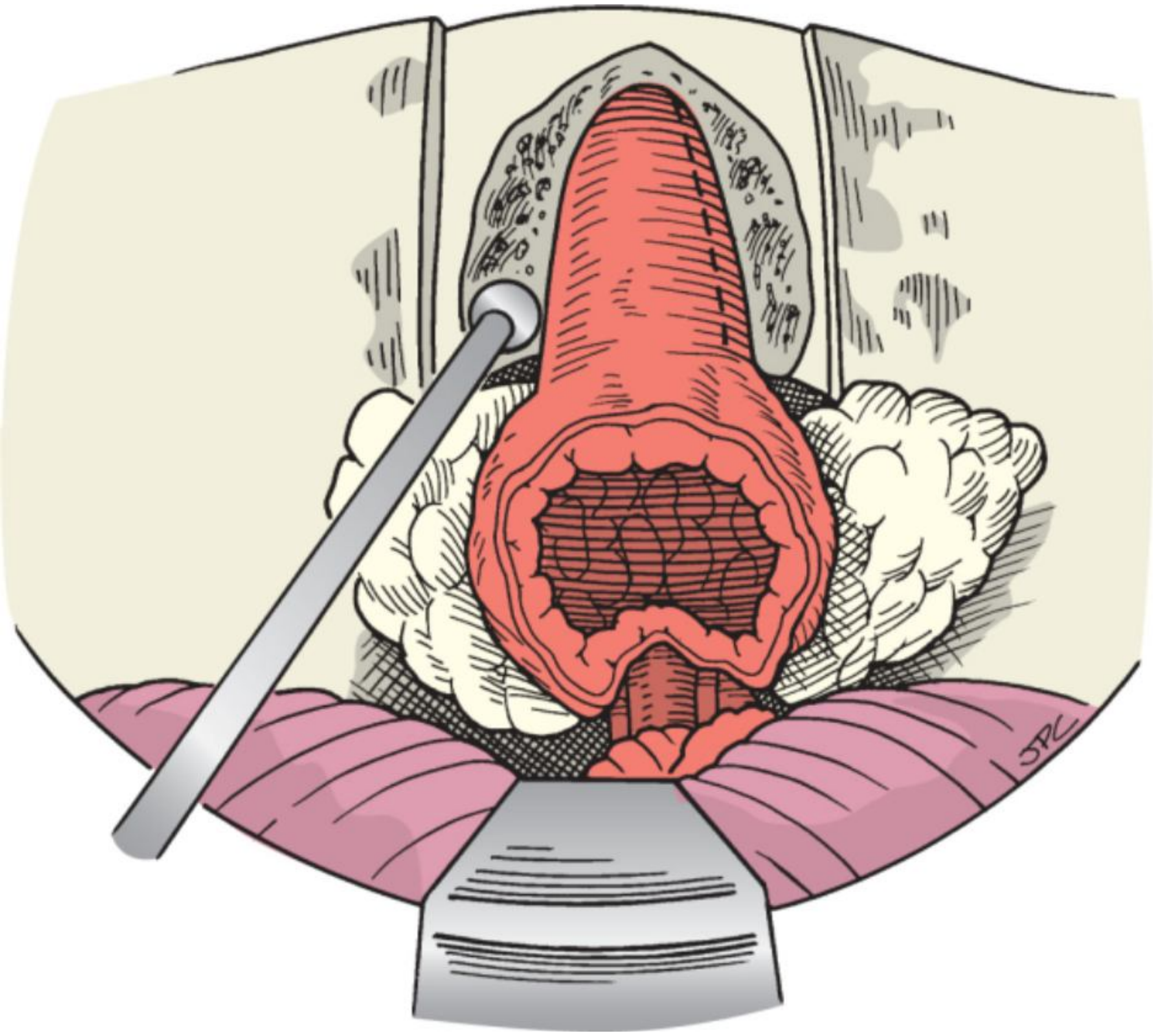

**Figure 124-32** The internal auditory canal is outlined by drilling a trough superiorly and inferiorly. The dura of the IAC is incised inferiorly *(dotted line),* away from the facial nerve.

If the tumor does not extend to the fundus, the lateral extent of the tumor is identified. A facial nerve monitor and stimulator are crucial to the success of this part of the procedure. Removal of tumor from the IAC can begin once the facial nerve has been identified. The facial nerve is routinely positioned in the anterior superior quadrant of the IAC. A facial nerve stimulator–dissector is used to initially confirm the location of the facial nerve (see Video 124-18). It is typically a distinct nerve at the distal fundus. Dissection can be accomplished with an excavator carefully separating the tumor from the facial nerve (see Video 124-19). The direction of dissection at this point is from lateral to medial. In a hearing preservation procedure, great care must be taken to avoid traction of the cochlear nerve as it is rolled medially. As the tumor is rolled out medially, it may remain attached to the lateral vestibular nerve. Sharp dissection is necessary to divide the vestibular nerve to release the tumor from the facial nerve (see Video 124-20). The facial nerve can be severely flattened along the anterior canal wall, especially at the anterior lip of the porus (see Video 124-21).

It is difficult to directly view the extreme lateral extent of the tumor occupying the fundus. The last 2 to 3 mm of the posterior bony wall of the IAC remains intact in hearing preservation procedures. Curved excavators are used to scoop out the remaining tumor (Fig. 124-33). Favorable dissection and excision occur when the lateral tumor is blunted and rolls out intact. Care is taken when dissecting the fibers of the vestibular nerve laterally in order to avoid injury to the underlying facial nerve entering the labyrinthine segment. Angled rigid telescopes occasionally help view this area to determine whether complete resection has been achieved.

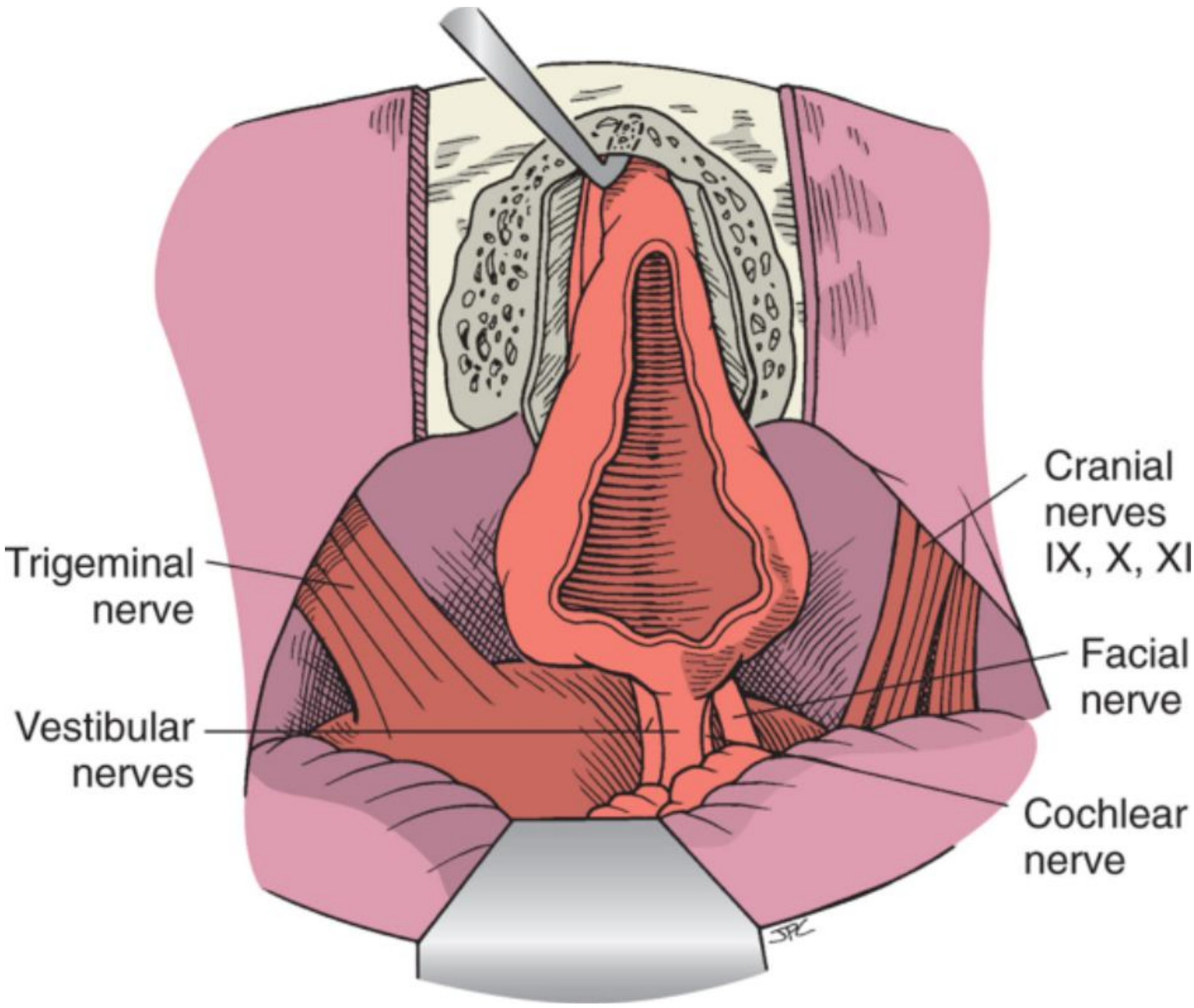


**Figure 124-33** The tumor is debulked centrally but extends into the fundus. The fundus is attenuated in the proximal internal auditory canal. A curved excavator rolls the most lateral extent of the tumor medially.

The central aspect of the tumor is removed from the IAC. Kartush stimulating dissectors are frequently used in this part of the procedure. The facial nerve is identified anterosuperiorly using a nerve stimulator. The facial nerve is frequently flattened, and meticulous dissection is performed, removing tumor from the nerve. Similar techniques are employed for the cochlear nerve, which is located anterior and inferior within the IAC. The focus of attention in the IAC dissection shifts between the facial nerve and the cochlear nerve, if hearing is to be preserved. Alteration in the ABR fifth–wave latency or amplitude warrants cessation of dissection in that area and relaxing the retractors if in place. Similarly, it is best to cease dissection around the facial nerve if the monitoring device indicates spontaneous neural firing, suggesting irritation or injury. Attention is turned to other areas of dissection.

Once the facial nerve is identified, the bulk of tumor in the CPA must be further debulked and removed. The ultrasonic aspirator can quickly vaporize the tumor. The facial nerve requires ongoing protection as the dissection proceeds. As the dissection proceeds, pledgets of Teflon felt are positioned over the critical structures (brain stem, cranial nerves, and significant vessels) for protection. Various instruments are available to sharply remove the tumor including scissors, a round knife, and sharp facial nerve stimulator/dissectors (see Video 124-22).

The residual tumor lies at the anterior face of the petrous bone. Meticulous dissection is undertaken from both a medial and lateral direction. The protective felt pledgets are removed from the nerve proximally to keep the nerve in view as the tumor is sharply dissected (see Video 124-23). The most difficult region is at the anterior wall of the petrous bone, central to the lip of the anterior porus, where the facial nerve is most often flattened and attenuated. Tumor must be meticulously dissected, often in a small piecemeal fashion (see Video 124-24). We accept leaving microscopic foci of tumor on the facial nerve if total removal would significantly compromise the integrity of the nerve. Resection of any residual tumor from the porus acusticus and CPA is completed. The vestibular nerves are divided proximally near the brain stem. Hearing preservation is attempted if a plane of dissection is obtained between the vestibular nerve and the cochlear nerve. Care is taken to avoid injury to the internal auditory artery (Fig. 124-34).

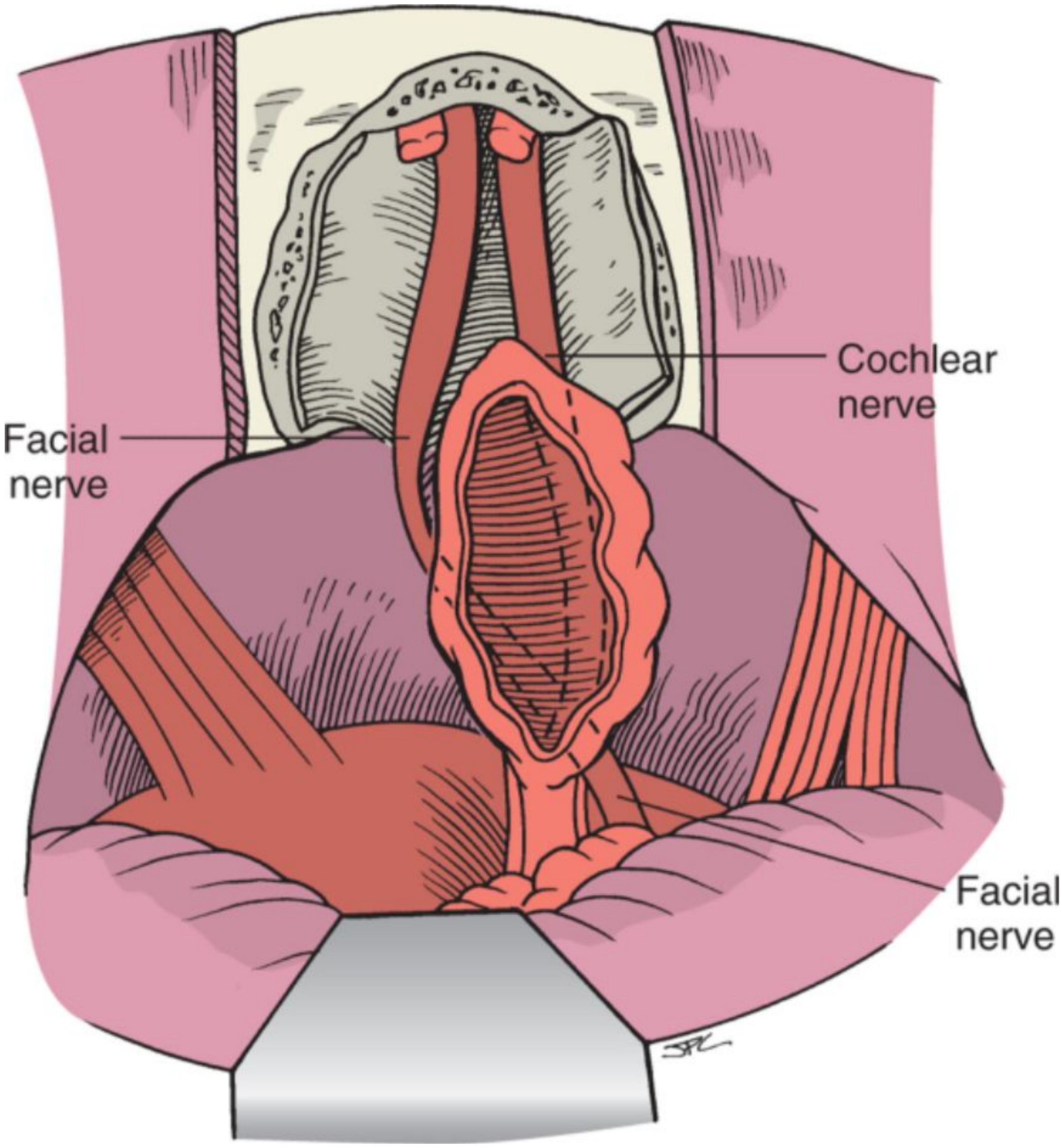


**Figure 124-34** The tumor remains pedicled on the vestibular nerves. The facial nerve runs medial and superior to the tumor. The cochlear nerve is intact inferiorly. Hearing preservation requires meticulous dissection of the tumor away from the proximal cochlear nerve.

Once tumor excision is completed, hemostasis is secured. The anesthesiologist is notified that monitoring is no longer necessary, permitting the use of paralytic agents. This facilitates a smoother emergence from general anesthesia. The wound is then irrigated with bacitracin solution. To prevent CSF rhinorrhea postoperatively, the bony edges of the IAC are checked for opened air cells. Bone wax on a cottonoid patty is compressed into open cells. If the temporal bone is well pneumatized, a muscle plug is gently placed within the IAC and supported with a piece of Surgicel. All neuropatties and rubber dams are removed.

The edges of the posterior fossa dura are reapproximated with 4-0 Nurolon. If desiccation has occurred, it may be necessary to supplement the dural closure with homograft dura, pericardium, or fascia. Isolation of the dura from the suboccipital muscles likely minimizes long-term headaches. A wafer of Gelfoam or Duragen is compressed and placed over the dura. A cranioplasty over the occipital and mastoid bony defect is performed using a titanium mesh plate. The wound is closed in multiple layers using uninterrupted sutures of Dexon. Skin is closed using staples or 4-0 Nurolon. A sterile pressure dressing is applied, and the procedure is terminated. The anesthetic is reversed, and depending on its depth and concern for the patient's neurologic status, extubation may be done in the operating room or subsequently in the recovery room.

## PATHOLOGY

The histopathology of acoustic neuroma can vary. There may be gross and microscopic cystic areas. There are two predominant patterns of cellular architecture. The first is called *Antoni A,* which is characterized by sheets of dense, organized, palisading nerve cells. The other pattern is *Antoni B*, demonstrating a looser array with a cystic stroma (Fig. 124-35). It is unclear whether the morphology of these patterns has direct implication toward the biologic activity of these tumors.

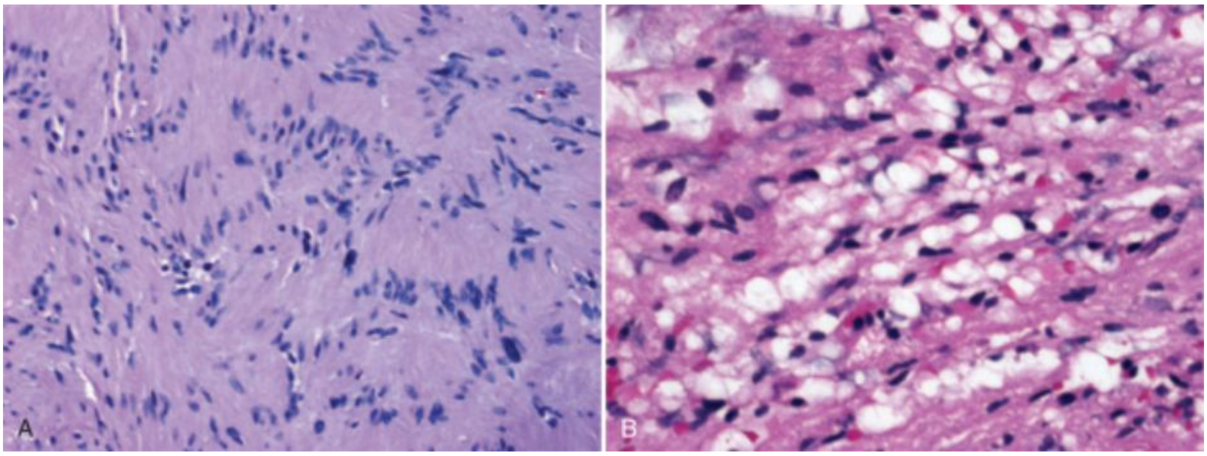


**Figure 124-35** Histologic patterns of cellular architecture in acoustic neuroma. **A,** Antoni A. **B,** Antoni B.

## POSTOPERATIVE MANAGEMENT

Regardless of the approach, a sterile pressure dressing is applied and remains in place for 2 days. Patients are monitored in an intensive care unit in the immediate postoperative period. Hourly vital signs and neurologic checks are recorded while the patient is in the intensive care unit. Blood pressure and urine output are carefully monitored for evidence of increased intracranial pressure, diabetes insipidus, or the inappropriate secretion of antidiuretic hormone. The risk of pulmonary emboli is minimized postoperatively with continued use of sequential compression devices until the patient is ambulating. Depending on the patient's degree of alertness, oral intake is advanced from clear liquids to solids as tolerated.

Immediate-onset or delayed facial paresis may occur. Patients with a poor Bell's phenomenon are at greater risk for corneal exposure. If inadequate eye closure is noted, comprehensive care of the cornea is provided to avoid desiccation and ulceration. Topical artificial tears are instilled every 2 hours or as needed. Ophthalmic ointment is placed in the lower conjunctival fornix at night. A clear eye shield or moisture chamber is used during the day for further protection.

Patients are encouraged to ambulate as soon as possible. Depending on the degree of residual vestibular function existing before surgery, patients may experience mild to severe vertigo and dysequilibrium following surgery. Patients with tumors that eliminated vestibular function preoperatively will experience less dysequilibrium. Nystagmus toward the contralateral side is often evident during the first few postoperative days. The long–term use of vestibular suppressants, such as meclizine, is avoided. Supportive care with antinauseants is provided as needed.

Patients are carefully observed for CSF leakage. This may occur directly through the incision or via the eustachian tube and out the nose. Clear watery rhinorrhea is evidence of a CSF leak. If the fluid content is in question, the specimen is sent for $\beta_2$-transferrin analysis. Management of this problem is reviewed under Complications later in this chapter. The dressing is removed on the second postoperative day. Bulging and pulsation of the wound following a translabyrinthine approach warrant replacement of a pressure dressing for a few more days. This finding has been minimized with the use of a miniplate over the transmastoid craniotomy and fat graft. Wound care consisting of twice–daily cleansing with peroxide and the application of an antibiotic ointment is provided. The abdominal wound used for a fat graft is inspected daily. The Penrose or Jackson–Pratt drain is removed when minimal drainage appears on the bandage, usually between the first and the third day postoperatively. Patients are discharged 4 to 6 days following the surgery, depending on the integrity of dural closure, nutrition, and ability to ambulate. MRI scanning is routinely obtained postoperatively. Patients manifesting a change in mental status or focal neurologic deficits also warrant urgent imaging to determine whether there is evidence of a bleed, hematoma, or vascular compromise. Sutures or staples are removed 10 to 14 days postoperatively. An MRI scan is obtained 6 months following surgery. This provides a baseline scan from which to compare subsequent images. The next scan is obtained 1 year later or 18 months following surgery. Dural enhancement often seen on the first scan is stabilized or less intense on subsequent scans. A third scan is obtained in 3 years. If this is also normal, a final scan is obtained in 5 years (Table 124-1).

**Table 124-1 -- POSTOPERATIVE MAGNETIC RESONANCE IMAGING SCHEDULE**

| Time Following Surgery | Interval |
|---|---|
| 3 mo | 3 mo |
| 15 mo | 1 yr |
| 51 mo | 3 yr |
| 111 mo | 5 yr |

## *COMPLICATIONS*

Regardless of the surgical approach, patients undergoing excision of AN may experience complications. These may occur both intraoperatively or postoperatively. Problems that may occur during the surgical procedure are similar to those of any other intracranial operation. The skin flaps and dura should be handled in an atraumatic fashion. Undue retraction and desiccation must be avoided. In particular, during the middle fossa approach, tears in the dura may be created during elevation of the temporal lobe. Once recognized, the tear should be repaired primarily at that time.

Bleeding may be arterial or venous. The most common sources of venous bleeding are from the sigmoid or transverse sinuses during translabyrinthine or retrosigmoid approaches. A superior petrosal sinus may also be lacerated during the middle fossa or translabyrinthine approach. Small defects may be closed with bipolar forceps. Larger defects should be covered with Surgicel and compression applied. The superior petrosal sinus may need to be ligated or clipped and divided in order to secure hemostasis. Arterial bleeding in the posterior fossa is a serious complication. This must be controlled. Bleeding from small vessels may be stopped with bipolar coagulation. Serious neurologic sequelae may result from injury to the AICA or PICA. These vessels are carefully dissected away from the tumor and, if necessary, isolated with neuropatties. Other methods that may be used to control bleeding include topical microfibular collagen hemostat (Avitene), bipolar coagulation, and hemoclips.

Compression or retraction on the brain stem may be manifested by changes in the ABRs and somatosensory potentials. More significant consequences result in hemodynamic instability manifested by hypertension or hypotension with bradycardia.

Large tumors approached through the posterior fossa may be in proximity to cranial nerves V, IX, X, and XI. Meticulous surgical technique must be exercised in order to avoid trauma to these nerves. Although sequelae may not be evident intraoperatively, a vocal cord paresis at the time of extubation may compromise laryngeal function and protection.

Another rare but serious intraoperative complication is air embolus. This occurs secondary to the opening of a large venous sinus, permitting air to be sucked into the vessel. A change in the auditory output of the precordial Doppler stethoscope is one of the earlier indicators of this event. The patient's hemodynamic status is subsequently compromised. Management consists of occluding the open vessel and turning the patient to the left side, head down. If a Swan–Ganz catheter is in place, air can be aspirated from the right atrium. A large piece of Surgicel is packed into the sinus, and compression with a neuropatty is applied.

## *POSTOPERATIVE COMPLICATIONS*

### Facial Paresis/Paralysis

Facial paralysis is not actually a complication of the procedure but rather an accepted risk. In the immediate postoperative period, this is more likely to occur with a middle fossa approach but is also dependent on the size and adherence of the tumor. If a mild paresis exists (less than House–Brackmann grade III), then comprehensive eye care may not be needed. However, with incomplete eye closure, poor Bell's phenomenon, and slow blinking, artificial tears, ophthalmic ointment, and a clear moisture chamber are provided. An anatomically intact facial nerve with low stimulation thresholds at the conclusion of the procedure implies a good prognosis for facial recovery. However, if large stimulation intensities were necessary to evoke a response, then return of function may not be evident for many months. In this event, we suggest that a gold weight be inserted. Ectropion may develop in older patients with increased skin laxity. Tightening of the lower lid with a lateral tarsal strip may be warranted. Rarely, the facial nerve must be divided in order to accomplish complete tumor removal. In this case, immediate end–to-end anastomosis or cable grafting provides the best functional outcome. Approximately 46% of patients who undergo cable grafting will recover to a House–Brackmann grade III, and an additional 25% will recover to grade IV.[37]

## Hearing Loss

Similar to facial nerve injury, hearing loss is another risk that frequently occurs following tumor resection, despite attempts at hearing preservation. Despite having good ABR waveforms at the conclusion of the procedure, complete hearing loss may still occur. The risk of hearing loss increases with tumor size, particularly for those tumors with greater than 15 mm in the CPA.[38] Worse preoperative hearing, increasing wave V latency, and inferior vestibular nerve origin have also been reported to increase the risk of hearing loss.[39] Postoperative hearing loss is more common in patients with significant adhesion between the tumor and cochlear nerve.[40] Additionally, patients who initially have preserved hearing following the retrosigmoid approach may go on to lose hearing in the operated ear at a rate exceeding that in the contralateral ear.[41] This result is contradicted by a report from the House Ear Institute, which found that surgery did not affect the postoperative progression of hearing loss in the operated ear.[24]

## Cerebrospinal Fluid Leak

When CSF leak occurs, it is usually evident through the incision or manifested as clear, watery rhinorrhea. It is unusual to observe CSF otorrhea in that the tympanic membrane and external auditory canal should not have been violated. A ballotable collection of CSF underneath the skin flaps is treated with a pressure dressing. The head of the bed should remain elevated. If clear fluid leaks through the incision, then the skin closure is augmented with single interrupted sutures. Liquid collodion is an effective skin sealant and can be painted over the wound if a slow leak persists. If this is not adequate for controlling the leak, then a lumbar drain is placed. The catheter is connected to a Buretrol device, which provides accurate monitoring of CSF drainage. By adjusting the height of the Buretrol device, a drainage rate of 6 to 10 mL/hr is maintained. The lumbar drain remains in place for 3 to 4 days. If the CSF leak or rhinorrhea persists but is subsiding, an additional 2 days may be needed. However, if an active leak remains despite 5 days of lumbar drainage, then reexploring the wound is necessary. Careful obliteration of any exposed air cells with bone wax, muscle, or fat will minimize the risk of CSF leak; some surgeons employ endoscopes to inspect the temporal bone for unseen exposed air cells.[42] For patients in whom petrous apex air cells open directly into the eustachian tube, obliteration of the entire length of the tube can be accomplished using a combined transaural/transnasal approach.[43]

## Meningitis

Patients developing new-onset headache with fever, vomiting, and a change in mental status should be immediately evaluated for meningitis. Bacterial meningitis occurs in approximately 2.5% of patients, although aseptic meningitis may be seen in up to 20% of patients.[13] A spinal tap identifies increased white blood cell counts with a shift to the left, elevated protein, and reduced glucose levels. A Gram stain may identify an organism that will direct one's choice for antibiotic coverage. Vancomycin and an aminoglycoside or a third–generation cephalosporin, such as ceftazidime or ceftriaxone, are used. If the Gram stain is negative and the culture shows no growth, antibiotics may be discontinued, and a presumed diagnosis of aseptic meningitis given. However, if the culture is positive, antibiotics are continued for 7 to 10 days.

## Intracranial Bleeding

Delayed postoperative bleeding usually occurs during the first 3 to 5 days. This may be intracerebral or cerebellar bleeding or a subdural collection or hematoma. Patients may manifest symptoms of altered mental status, lethargy, somnolence, limb weakness, or aphasia. An emergency CT scan is obtained to identify the nature of intracranial pathology. A noncontrast study is adequate to demonstrate a bleed or hematoma. In addition, hydrocephalus may be evident on the scan. Management is dictated based on the findings of the scan.

## Seizures

Seizures following translabyrinthine or retrosigmoid resection of ANs are rare. These are more likely to occur with a supratentorial injury following middle fossa retraction. Problems with receptive or expressive aphasia may occur from excessive retraction and injury to the left temporal lobe. The surgeon must be aware of the degree of temporal lobe retraction exerted through a middle fossa approach. Emergent treatment consists of intravenous diazepam and a loading dose of phenytoin. Oral phenytoin is continued postoperatively for 4 to 6 months.

## Trigeminal Nerve Dysfunction

Large ANs can extend superiorly through the tentorium and anteriorly to the petrous apex. Injury to the trigeminal nerve more typically affects V1 and V2 (sensory divisions) as opposed to V3 (the motor division). Facial hypesthesia and analgesia may result. This deficit, in conjunction with a facial nerve paralysis, is a potentially devastating combination injury. The hypesthesia of the cornea along with lagophthalmos intensifies the likelihood of corneal injury. Despite comprehensive prophylactic eye care, it may be necessary to perform medial and lateral tarsorrhaphies to minimize the dystrophic and erosive changes that may occur in the cornea. Similarly, the lateral ala of the nose is subject to ischemic necrosis. Patients can manually traumatize the involved insensate nares, initiating destruction of the alar rim.

## Lower Cranial Nerve Injury

Tumors that extend inferiorly are in close approximation to cranial nerves IX, X, and XI. The multiple fine fascicles of these cranial nerves may be injured during dissection. Despite anatomic integrity of these cranial nerves, pharyngeal and laryngeal dysfunction may result. Patients may develop dysphagia, dysphasia, aspiration, and breathy voice. Nasogastric tube feeding may be necessary if aspiration persists. Temporary resolution may be augmented with Gelfoam injection of the involved vocal cord. If the surgeon believes that substantial intraoperative injury has occurred, then a type I thyroplasty, which is reversible, can provide longer–lasting relief (see Chapter 38).

## Headache

Postoperative pain in the incision is common with any procedure. Patients undergoing a middle fossa approach may experience pain on mastication owing to temporary temporalis muscle dysfunction. Similarly, pain in the posterior aspect of the neck frequently occurs following a suboccipital approach. Symptoms are usually relieved with application of heat, parenteral or oral narcotics, and eventually, nonsteroidal anti–inflammatory medication. Regardless of the approach, headache and stiffness of the neck may develop 5 to 7 days postoperatively. Lumbar puncture and fluid analysis are warranted to rule out bacterial or aseptic meningitis. Xanthochromic CSF with few white cells, secondary to red blood cell breakdown, is the likely cause of meningeal irritation. Steroids are usually prescribed if routine analgesics are ineffective. Long–term postoperative headache is associated with the retrosigmoid approach. Symptoms may present for upward of 1 year. Treatment consists of nonsteroidal anti–inflammatory medications, nerve block, and rarely wound revision or rhizotomy.

**PEARLS**

- Given the current accepted alternatives of management, patients must receive a comprehensive discussion addressing surgical removal, stereotactic radiation treatment, and monitoring the tumor for further growth over time.
- Consideration should be given to observing the tumor with serial MRI scans in people older than age 70 years with small tumors.
- CT imaging can be helpful to identify a high jugular bulb providing useful information in anticipation of a translabyrinthine approach.
- Every effort should be given to complete all bone drilling and dissection before the dura is opened.
- Temporary placement of Teflon pledgets, which are less adherent than neuropatties, protect critical structures that are isolated as the dissection proceeds.

**PITFALLS**

- Inadequate exposure will significantly impede safe and complete access to the tumor for total removal.
- Proceeding with tumor dissection in the presence of the facial nerve monitor device indicating neurotonic discharge (irritation) may result in preventable irreversible injury. Attention should be directed to another area.
- Excessive manipulation and retraction of the temporal lobe during middle fossa surgery may result in brain injury, seizures, and dysphasia, especially on the left side.
- The use of the bipolar electrocautery adjacent to the facial nerve may cause permanent injury.
- Aggressive retraction and dissection of the tumor from the fundus can avulse the delicate cochlear and facial nerve fibers, resulting in hearing loss and facial weakness.