Expert CONSULT Expert Consult: Online and Print

Chapter 128 – Temporal Bone Trauma

Elizabeth H. Toh

Injuries resulting from trauma to the temporal bone range from temporary and minor disorders to severe and permanent ones. Identifiable fractures are usually associated with more severe neurologic deficits, but even in the absence of a fracture, the auditory and vestibular systems may have sustained concussive damage resulting in clinically significant functional sequelae. Dysfunction of the facial nerve occasionally occurs even in the absence of radiographically demonstrable fracture. Blows to the side of the head or penetrating trauma from foreign bodies introduced through the external auditory canal may result in trauma to the tympanic membrane, ossicular chain, inner ear, and, rarely, the facial nerve. Injuries to the middle ear generally can be dealt with using the same techniques outlined in Chapter 114. The scope of this chapter is restricted to management of the sequelae of temporal bone fractures.

PATIENT SELECTION

Fractures of the temporal bone have traditionally been classified anatomically into longitudinal, transverse, and mixed, based on their relationship relative to the long axis of the petrous pyramid (Figs. 128-1 and 128-2). This traditional scheme of classification has been shown to be of limited value in reliably predicting clinical complications resulting from injury to the temporal bone. With the advent of high-resolution computed tomography (HRCT) imaging, several authors have proposed the use of “otic capsule sparing” and “otic capsule violating” terminology to better define and prognosticate the clinical impact of these injuries.[1,2] The most serious injuries, and those most often requiring surgery, are the result of transverse or otic capsule–violating fractures. Table 128-1 lists the most common sequelae of temporal bone fractures. Facial nerve palsy and the rare persistent cerebrospinal fluid (CSF) leak are the primary clinical conditions that require the determination of suitability for surgical intervention in the early postinjury setting. Hearing loss and dizziness do not generally require early intervention; in many cases, these conditions resolve spontaneously. Less common symptoms, such as facial hypesthesia and paresis of the abducens nerve, are also frequently self-limited. Any associated lacerations of the external auditory canal and violation of the tympanic membrane may initially be managed conservatively with dry ear precautions and ototopical antibiotics. Elective surgical repair of persistent perforations of the tympanic membrane may be offered for a safe dry ear or hearing improvement following a 6- to 8-week trial of conservative management. The risk of delayed meningitis and secondary cholesteatoma formation should be kept in mind in patients with temporal bone fractures.

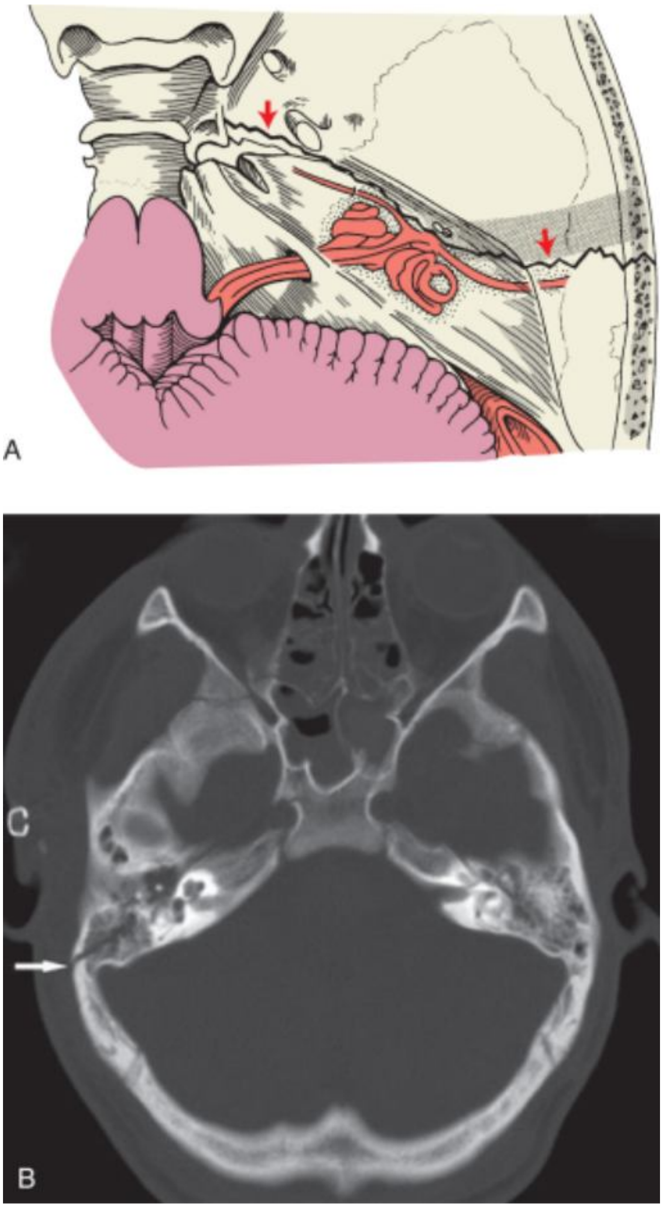

Figure 128-1 **A,** Longitudinal temporal bone fracture *(arrows)* sparing the otic capsule and internal auditory canal. **B,** Computed tomography scan showing a longitudinal fracture *(arrow)*.

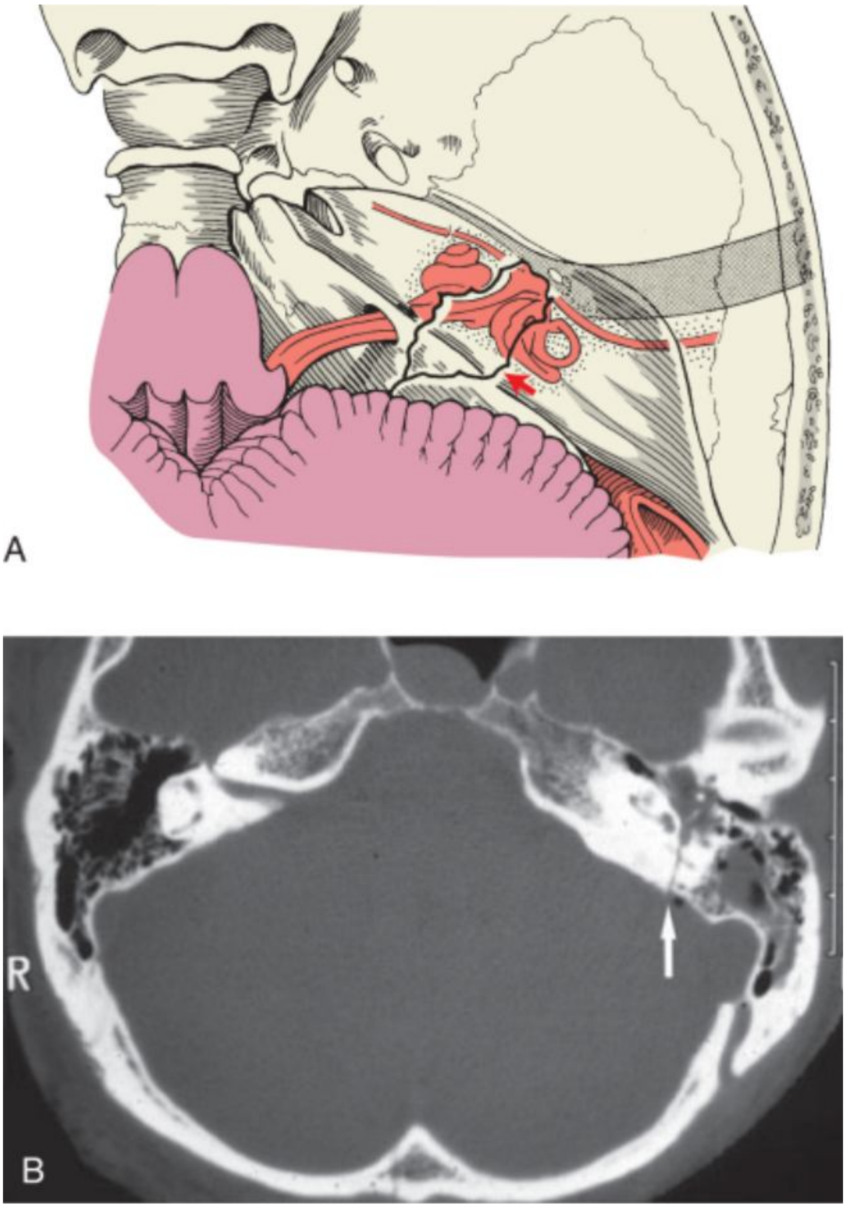

Figure 128-2 **A,** Transverse temporal bone fracture *(arrows)* with involvement of the otic capsule and the contents of the internal auditory canal. **B,** Computed tomography scan showing transverse fracture *(arrow).*

Table 128-1 -- SYMPTOMS AND SIGNS FOLLOWING TEMPORAL BONE FRACTURE

Symptom/Sign	Treatment
Hearing loss	No immediate treatment necessary.
Dizziness	Vestibular suppression followed by rehabilitation.
Facial weakness	Early determination of status is necessary. Surgical exploration for immediate onset paralysis with poor prognostic indicators.
Cerebrospinal fluid otorrhea	Usually resolves spontaneously; not a surgical consideration for at least 7 days.

Facial Paralysis

Weakness of the facial nerve may be immediate or delayed in onset, partial or complete. Although there is universal agreement that delayed-onset facial paralysis usually portends favorable clinical recovery and should be managed conservatively, much controversy surrounds the role and timing of surgery in the patient with immediate-onset weakness.[3–5] Most traumatic facial palsies resolve without surgical intervention and the decision to operate is usually based on predictors of poor functional outcome. We agree with the otologic consensus that surgical exploration is of benefit in patients with immediate-onset complete facial paralysis because of the greater likelihood that the nerve has been anatomically disrupted or is compressed by a bone spicule. Surgery in these patients appears to facilitate early recovery with minimal faulty regeneration.

The following criteria form the basis for surgical selection with respect to facial paralysis in temporal bone trauma:

1. Immediate onset paralysis with progressive decline of electrical responses on electroneuronography (ENoG) to less than 10% of responses on the normal side within the first 14 days.
2. Immediate-onset paralysis with significant disruption of the fallopian canal demonstrated on HRCT.

The decision to intervene surgically is more challenging in patients with incomplete immediate-onset facial paralysis. Conservative management is the general rule when partial function remains. Aggressive eye care is critical while awaiting functional recovery in all patients. In the absence of any medical contraindications, the administration of a tapering course of systemic steroids (prednisone 1 mg/kg body weight or equivalent, tapered over 1 week) is generally thought to be helpful in reducing any traumatic neural edema and promoting early recovery. Care must be taken to rule out extratemporal nerve injuries in patients in whom only one or several branches are involved.

Cerebrospinal Fluid Leak

CSF leak associated with temporal bone fractures may manifest as otorrhea, rhinorrhea, or otorhinorrhea. A high percentage of CSF leaks associated with skull base fractures resolve with conservative management within a week. Strict bed rest, head elevation, and the administration of stool softeners usually suffice to control these leaks. Lumbar drainage is used with an indwelling catheter for approximately 3 to 4 days when spontaneous resolution does not occur within the first 3 days of bed rest and head elevation. When drainage persists despite these measures or when HRCT identifies obvious severe bone disruption, surgery is indicated. The overall incidence of meningitis following temporal bone trauma with an associated CSF leak is less than 10%.[3] The use of prophylactic antibiotics is recommended in select patients with increased risk of meningitis, including those with persistent CSF leaks beyond 7 days, those with concomitant infections elsewhere, and those who have a lumbar drain in place. Indiscriminate use of systemic antibiotics may mask the early signs and symptoms of meningitis. White blood cell counts help in early detection of meningitis, and diagnostic lumbar puncture should be performed when any clinical suspicion of infection arises.

PREOPERATIVE EVALUATION

Dedicated HRCT of the temporal bones at 1- to 1.5-mm thickness intervals using bone algorithm is the best imaging modality for evaluating temporal bone injury. Axial and true or high-resolution reconstructed coronal images should be requested. A routine CT scan of the head obtained for the purpose of ruling out intracranial trauma is inadequate for evaluating the intratemporal facial nerve and ossicular chain. When evaluating the fallopian canal, one should look for multiple fracture sites because this is more common than is usually recognized.[6] The status of the otic capsule and the ossicular chain can be ascertained as well. Longitudinal or otic capsule sparing fractures will most often compromise the facial nerve at or distal to the geniculate ganglion. Conversely, transverse or otic capsule involving fractures usually injure the facial nerve medial to the geniculate ganglion (Fig. 128-3). The degree of pneumatization of the mastoid and level of the middle fossa dural plate are of interest if surgical intervention is contemplated. The significance of these factors is discussed later in the chapter. Magnetic resonance imaging plays a complementary role in the evaluation of associated intracranial trauma.

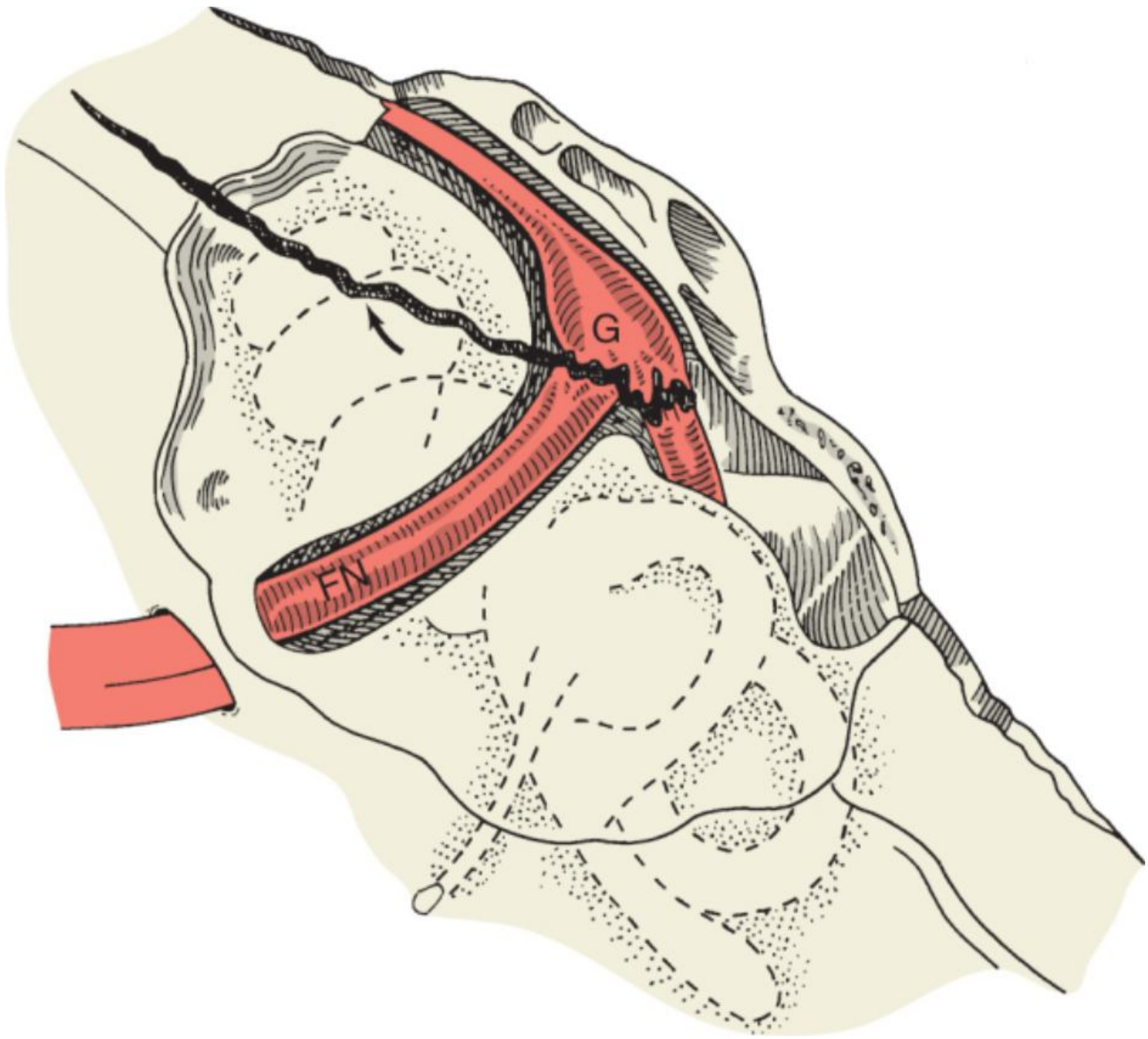

Figure 128-3 Superior view of a transverse fracture line *(arrow)* involving the facial nerve (FN) medial to the geniculate ganglion (G).

Topographic testing of facial nerve function, including the Schirmer test, has been found to be unreliable in localizing the site of lesion and has limited clinical utility in this setting. Audiometric testing is a necessary component of a full clinical evaluation and should be obtained at the earliest feasible time. It is helpful not only to determine the type of hearing loss but in the case of sensorineural impairment, to decide whether residual function is useful. Hearing results do not dictate the necessity for surgery in the early posttrauma period, but they do influence the selection of surgical approach, when it becomes necessary. Conductive hearing loss will often resolve spontaneously; hearing losses that remain can be surgically corrected later. Sensorineural hearing impairment is usually permanent, although it sometimes improves slightly over time. Vestibular testing plays no role in the early evaluation of fractures of the temporal bone. The vast majority of vestibular symptoms are expected to resolve and may, in any case, be delineated later.

When the decision has been made to surgically explore the facial nerve, empiricism dictates that undue delay is counterproductive. Once the patient is neurologically stable and the site of lesion identified on HRCT, surgery should proceed. The organization of blood clot and the development of scar and fibrous tissue can only affect results negatively. This active approach to these injuries is obviously not always possible because some patients are seen for the first time after many weeks or months have elapsed. These patients will nevertheless benefit from exploration, as long as they meet the criteria elaborated earlier.[7] When persistent CSF leak is the only indication for surgical intervention, closure should proceed after 7 to 10 days of conservative management because the risk of meningitis increases significantly thereafter.[3]

SURGICAL TECHNIQUES

Selection of surgical approach is dependent on both site of injury and hearing status in the involved ear. Injuries of the facial nerve at or distal to the geniculate ganglion can be approached via a standard transmastoid exposure. Injuries medial to the geniculate ganglion may be approached in several ways, depending on residual hearing in the affected ear and the degree of pneumatization of the temporal bone. Severe sensorineural hearing loss allows for translabyrinthine exposure of the facial nerve. Conversely, when hearing conservation is indicated, the middle cranial fossa approach may be elected. In the case of a well pneumatized epitympanum in which the middle fossa dural plate is relatively high, the labyrinthine portion of the facial nerve may be exposed via a transmastoid transepitympanic approach (Fig. 128-4). This approach, however, does not provide adequate exposure for the meatal segment of the facial nerve.

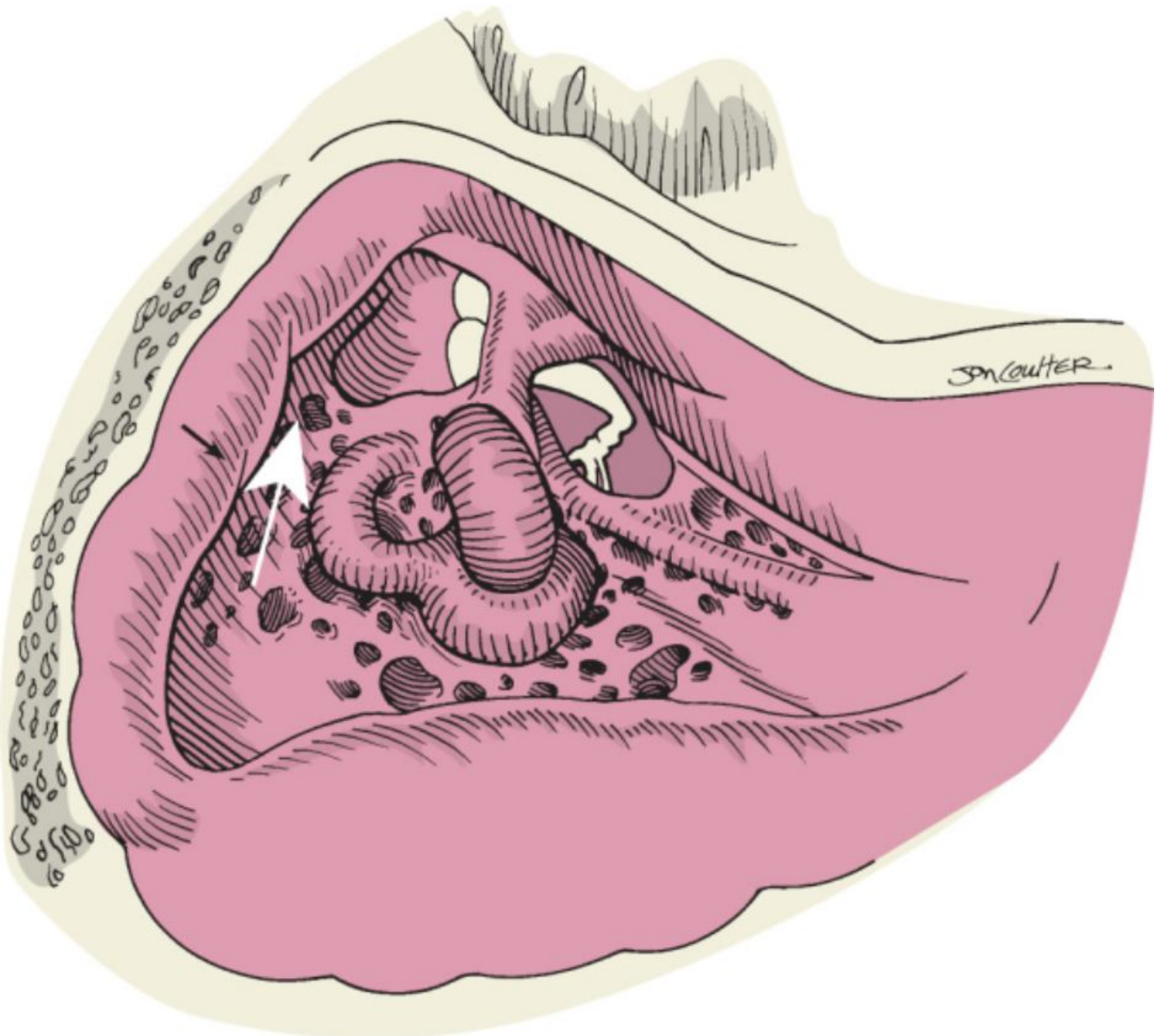

Figure 128-4 Transmastoid exposure of temporal bone that is suitable for transepitympanic exploration (*large arrow*) of the facial nerve because of a high middle fossa tegmen. (*Arrow,* level of middle fossa dura.)

Although repair of a disrupted tympanic membrane and defects of the ossicles may be accomplished simultaneously, it is often necessary to delay these reconstructive efforts due to edema of the mucosa, bleeding, and the friability of traumatized tissue within the middle ear. In cases of severe bony tegmen disruption with herniation of brain tissue, associated repair of the encephalocele is indicated.

Transmastoid Approach for Facial Nerve Injuries at or Distal to the Geniculate Ganglion

A complete mastoidectomy (see Chapter 115) is performed to access the mastoid antrum and locate the lateral semicircular canal. Bony dissection is then continued anterosuperiorly toward the epitympanum until the body of the incus is identified. The parasagittal plane of the incus is extrapolated posteriorly to identify the level of the facial recess, which is then opened and saucerized to delineate the vertical facial nerve within the mastoid. The mastoid segment of the nerve may also be identified at its point of exit from the stylomastoid foramen by following the digastric ridge anteriorly in the mastoid tip. Skeletonization of the fallopian canal should be performed with care using 2- to 3-mm diamond burrs and copious irrigation. In most cases, the fracture line is often observed on the surface of the mastoid cortex and can be followed medially to the site of injury. Working alternately between the facial recess and the epitympanum, the surgeon can remove thin bone from the tympanic portion of the fallopian canal if bony decompression of this segment is indicated (Fig. 128-5). If necessary, the incus can be removed in order to improve exposure of the tympanic facial nerve. In this case, the incudostapedial joint is separated through the facial recess using a small sharp hook and the incus retrieved through the epitympanum, taking care not to sublux the stapes. Preserving a small bony bridge in the fossa incudis for support of the short process of the incus allows for easy replacement of the incus with little or no hearing deficit.

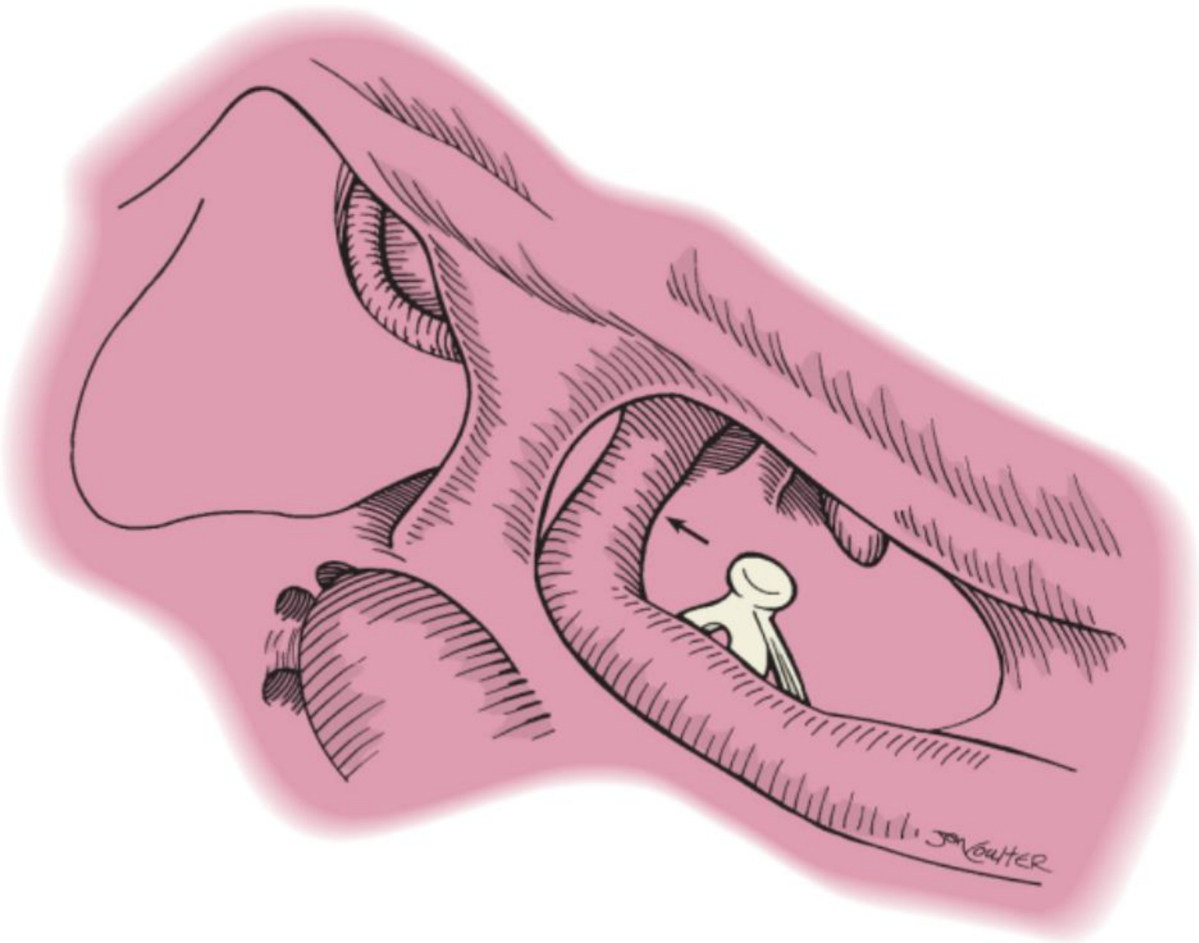

Figure 128-5 Exposure and decompression of the horizontal portion of the facial nerve *(arrow)*. (Incus removed.)

Injuries to the facial nerve produced by stretching or compression are managed with decompression of the fallopian canal proximal and distal to the injury until normal nerve is identified. The need for additional incision of the epineural sheath is controversial. Any bone chips impinging on the nerve should be removed. The integrity of the axonal bundles within the nerve sheath must also be determined. Transection of nerve fibers by trauma may be total or partial. It is generally considered advantageous to preserve the facial nerve when 50% or more of the diameter of the nerve appears intact. Complete transection may be repaired with primary end-to-end apposition. If tension-free reapproximation or reanastomosis cannot be accomplished or maintained, facial nerve rerouting for primary reanastomosis or interposition grafting should be considered. Eliminating the second genu of the facial nerve, for example, is an effective technique for shortening the distance of proximal and distal nerve segments lateral to the geniculate (Fig. 128-6A). Anastomosis might also proceed directly from the internal auditory canal (IAC) to the vertical segment of the facial nerve by dividing the greater superficial petrosal nerve at the geniculate ganglion, rerouting the intact distal segment, and interposing a cable graft (see Fig. 128-6B). For interposition nerve grafting (Fig. 128-7), the great auricular nerve is the preferred donor site because of the nerve's proximity and size compatibility. Epineurium must be carefully trimmed back and nerve fascicles sharply sectioned for optimal end-to-end contact. For both primary repair and interposition grafting of the labyrinthine, tympanic, and mastoid segments, the fallopian canal provides an excellent bed for anastomosis and usually the nerve does not require any suturing. With repair of the nerve within or medial to the IAC, one or two 8-0 monofilament sutures may be placed in the epineurium. Standard layered mastoidectomy wound closure and ear dressings are used.

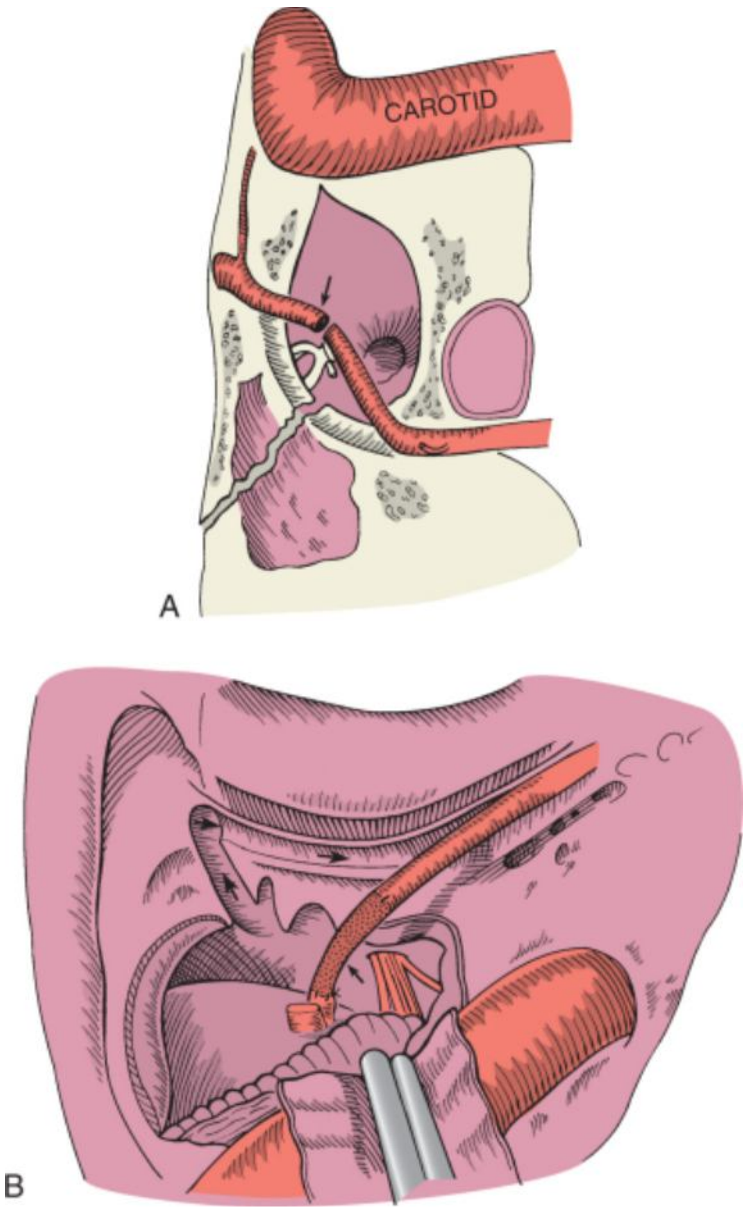

Figure 128-6 **A,** Reconstructive technique for gaining length and avoiding an interposition graft by eliminating the second genu of the facial nerve. (*Arrow,* transpositioned facial nerve.) **B,** Anastomotic technique using an interposition graft and "short-circuiting." (*Large arrows,* normal course of the facial nerve; *small arrow,* shortened course of the facial nerve.)

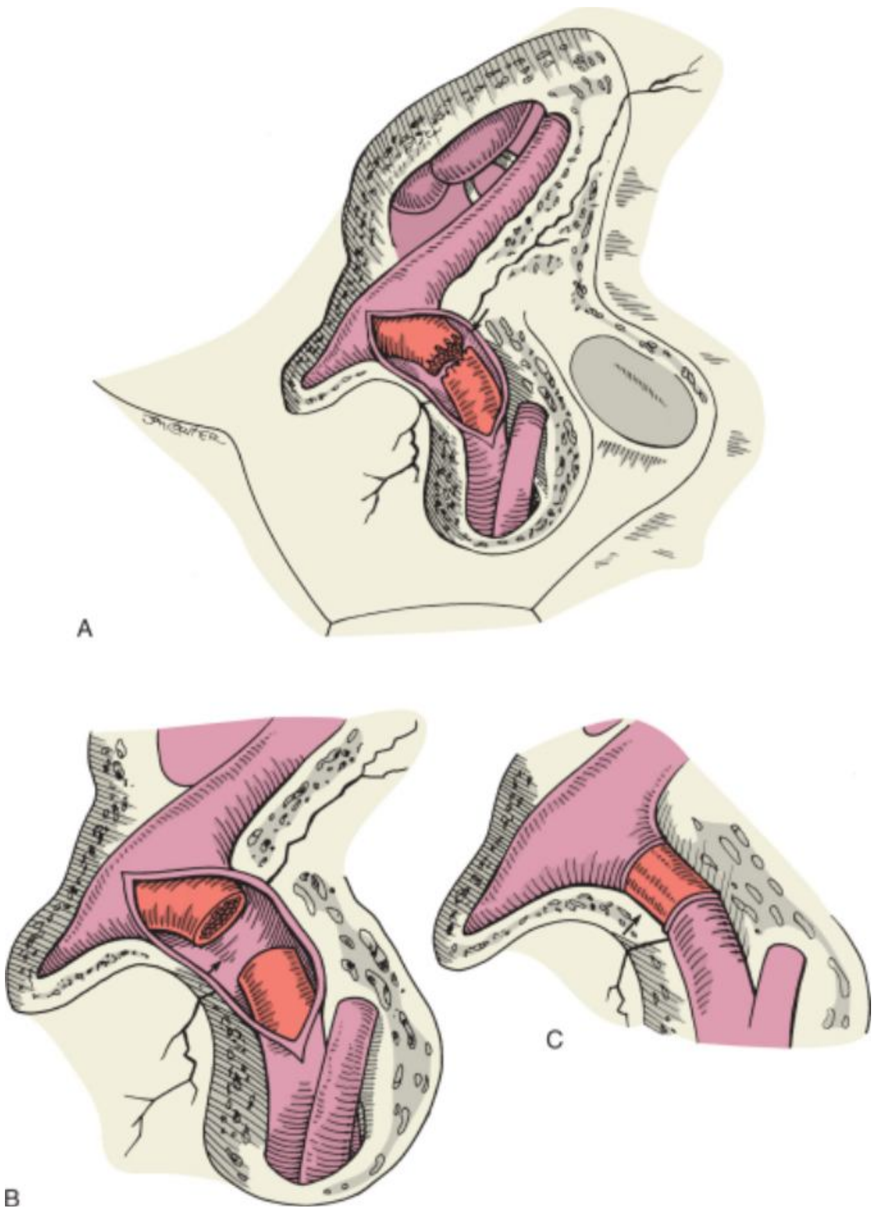

Figure 128-7 Use of an interposition graft for repair of a facial nerve defect in the internal auditory canal by the middle fossa approach. (*Arrows,* site of nerve transection, freshening, and repair.)

Transmastoid Translabyrinthine Approach for Facial Nerve Injuries Medial to the Geniculate Ganglion without Useful Hearing

The procedure described in the preceding section is carried out and followed by a complete labyrinthectomy and skeletonization of the IAC from the porus acusticus to the fundus (see Chapter 124). When drilling through the semicircular canals, care should be exercised when following the posterior semicircular canal anteriorly under the second genu of the facial nerve to its ampulla. The superior limit of the lateral IAC is defined by the location of the superior vestibular nerve, which lies immediately anterior to the ampulla of the superior semicircular canal. The IAC is skeletonized laterally to permit identification of Bill's bar (vertical crest), which separates the facial nerve anteriorly from the superior vestibular nerve posteriorly. Skeletonization of the facial nerve is then continued anteriorly to the geniculate ganglion using a small diamond burr. The entire intratemporal course of the facial nerve can then be exposed (Fig. 128-8). If facial nerve rerouting is necessary to achieve tension-free repair, the greater superficial petrosal nerve is divided at the geniculate ganglion and the facial nerve gently elevated out of the fallopian canal. Grafting techniques are similar to those described earlier, except the repair of a transected nerve is considerably more difficult in the IAC because of gravity and the presence of CSF pulsations. Collagen or Silastic sleeves can add support to the anastomosis following suturing and add greater strength to the graft sites. Closure is similar to that described for translabyrinthine removal of acoustic neuromas and requires the obliteration of the eustachian tube and middle ear with temporalis muscle, packing of the mastoid cavity with abdominal fat, and layered wound closure. A pressure dressing should be maintained over the operated ear for 3 to 4 days to minimize the risk of postoperative CSF leakage.

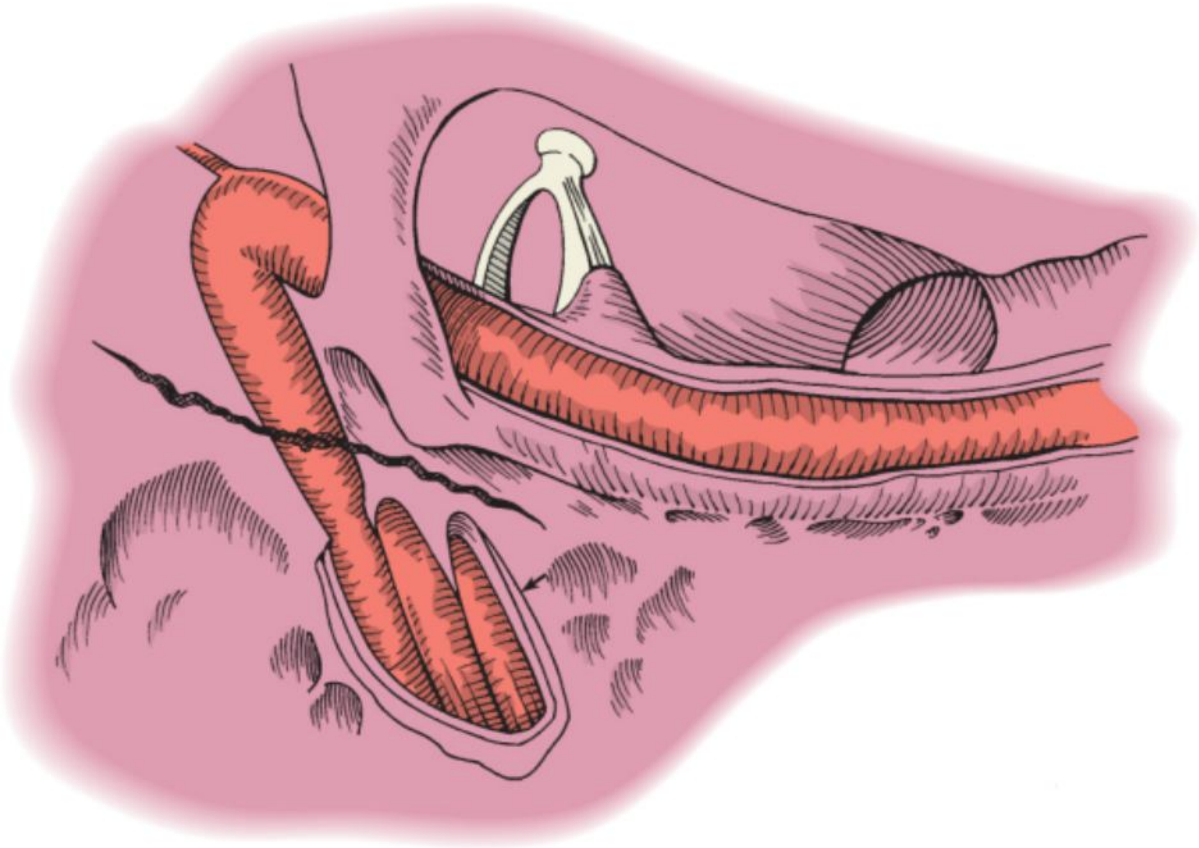

Figure 128-8 Transmastoid translabyrinthine exposure of the entire facial nerve. (*Arrow,* internal auditory canal.)

Transmastoid Transepitympanic Approach for Facial Nerve Injuries Medial to the Geniculate Ganglion with Useful Hearing

Following a complete mastoidectomy, the incus is removed as described earlier under Transmastoid Approach for Facial Nerve Injuries at or Distal to the Geniculate Ganglion. The geniculate ganglion is identified and followed posteromedially, staying anterior to the ampullated end of the superior semicircular canal (Fig. 128-9). The superior semicircular canal is skeletonized, allowing for exposure of the labyrinthine portion of the facial nerve. This portion of the nerve can then be decompressed; in fact, CSF is routinely encountered. Preoperative review of the HRCT scans must ensure that injury is lateral to the meatal portion of the nerve in order to achieve adequate exposure using this approach. When adequate exposure is in doubt, or if grafting of the meatal or proximal facial nerve is anticipated, the middle fossa approach should be used.

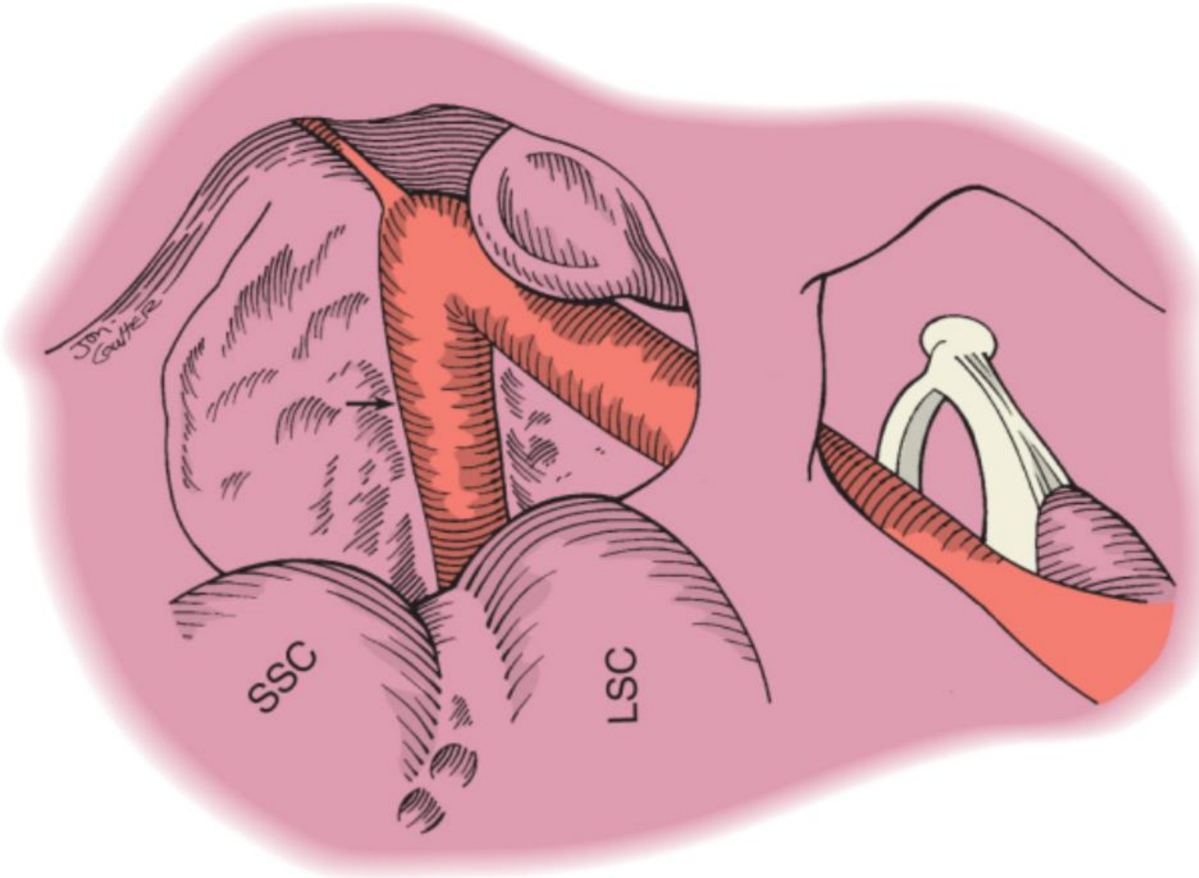

Figure 128-9 Transmastoid transepitympanic exposure of the labyrinthine portion of the facial nerve *(arrow)*. SCC, superior semicircular canal; LSC, lateral semicircular canal.

Middle Cranial Fossa Approach for Facial Nerve Injuries Medial to the Geniculate Ganglion with Intact Hearing

The superior surface of the temporal bone is exposed extradurally as described in Chapter 124. The extent of surgical exposure for decompression or repair of the facial nerve in this context is identification of the greater superficial petrosal nerve at its take off from the geniculate ganglion anteriorly. The nerve can then be followed proximally into the labyrinthine and IAC segments, recognizing the proximity of the labyrinthine facial nerve to the basal cochlear turn. Bone of the tegmen tympani may be removed to expose the tympanic segment of the nerve, taking care to avoid drilling directly on the head of the malleus and body of the incus. The middle fossa approach may be combined with a transmastoid exploration of the more distal nerve segment when indicated (Fig. 128-10). In that case, the transmastoid procedure should be completed first in order to fenestrate the middle fossa tegmen superior to the geniculate ganglion, thereby simplifying identification of the facial nerve and internal auditory canal through the middle fossa craniotomy. This combined exposure allows for surgical access to the entire intratemporal facial nerve from the cisternal segment to the stylomastoid foramen, while preserving hearing in the operated ear. Closure of the middle fossa craniotomy is identical to that described for removal of tumor via the middle fossa (see Chapter 124). The mastoidectomy wound is closed in a standard layered fashion.

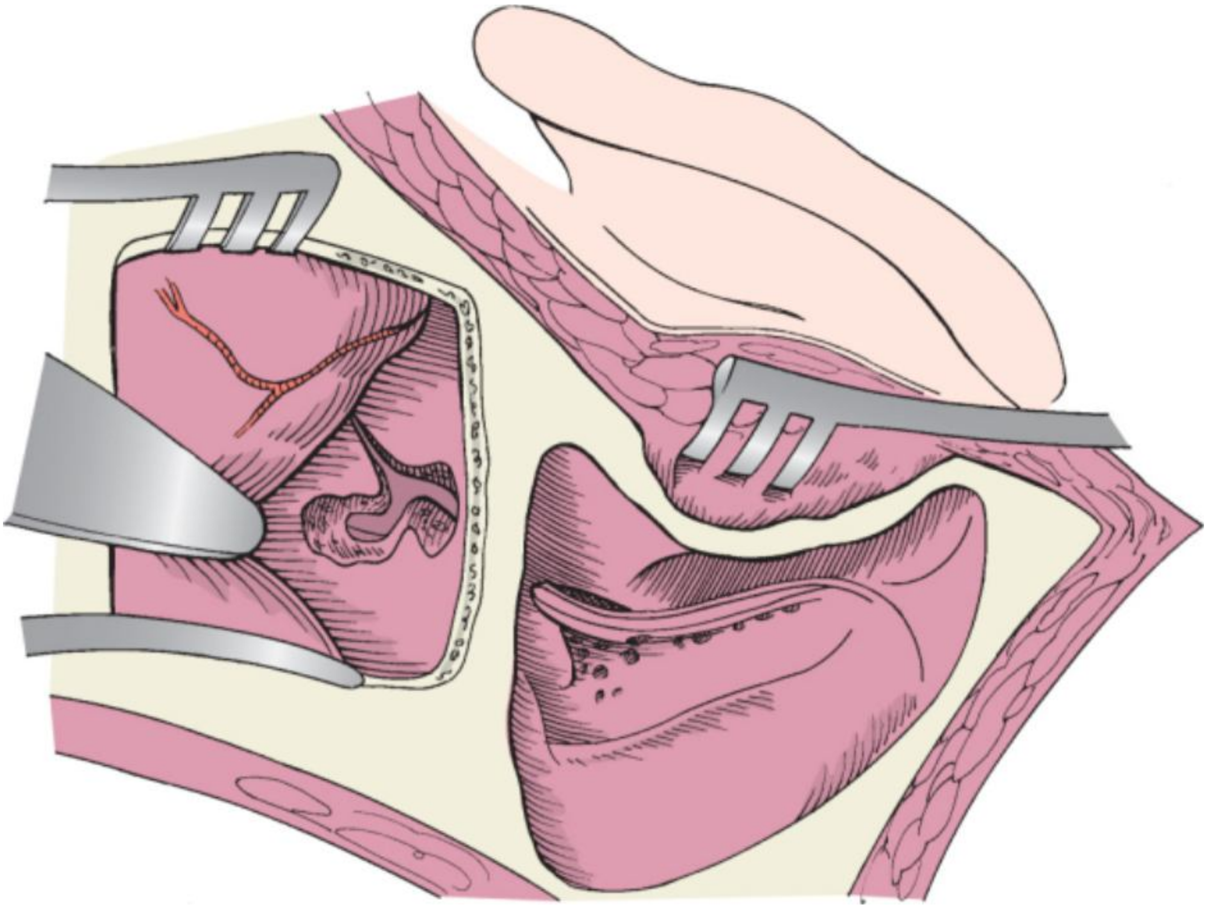

Figure 128-10 Combined middle fossa transmastoid approach to the facial nerve for hearing preservation.

Repair of Cerebrospinal Fluid Leaks

Surgical techniques for the sole purpose of repairing CSF leaks resulting from temporal bone trauma are influenced by (1) site of leak, (2) hearing status of the affected ear, and (3) presence of brain herniation through the tegmen. For fractures through the tegmen mastoideum with persistent CSF leak, "sandwich" grafts consisting of fascia or freeze-dried dura are placed intracranially and extracranially using a combined transmastoid mini-middle fossa approach (see Chapter 127), and bone paté is placed along the fracture line. Large dehiscences of bone may require bony autografts, fashioned bone plugs, or microplating for temporal lobe support (Fig. 128-11).

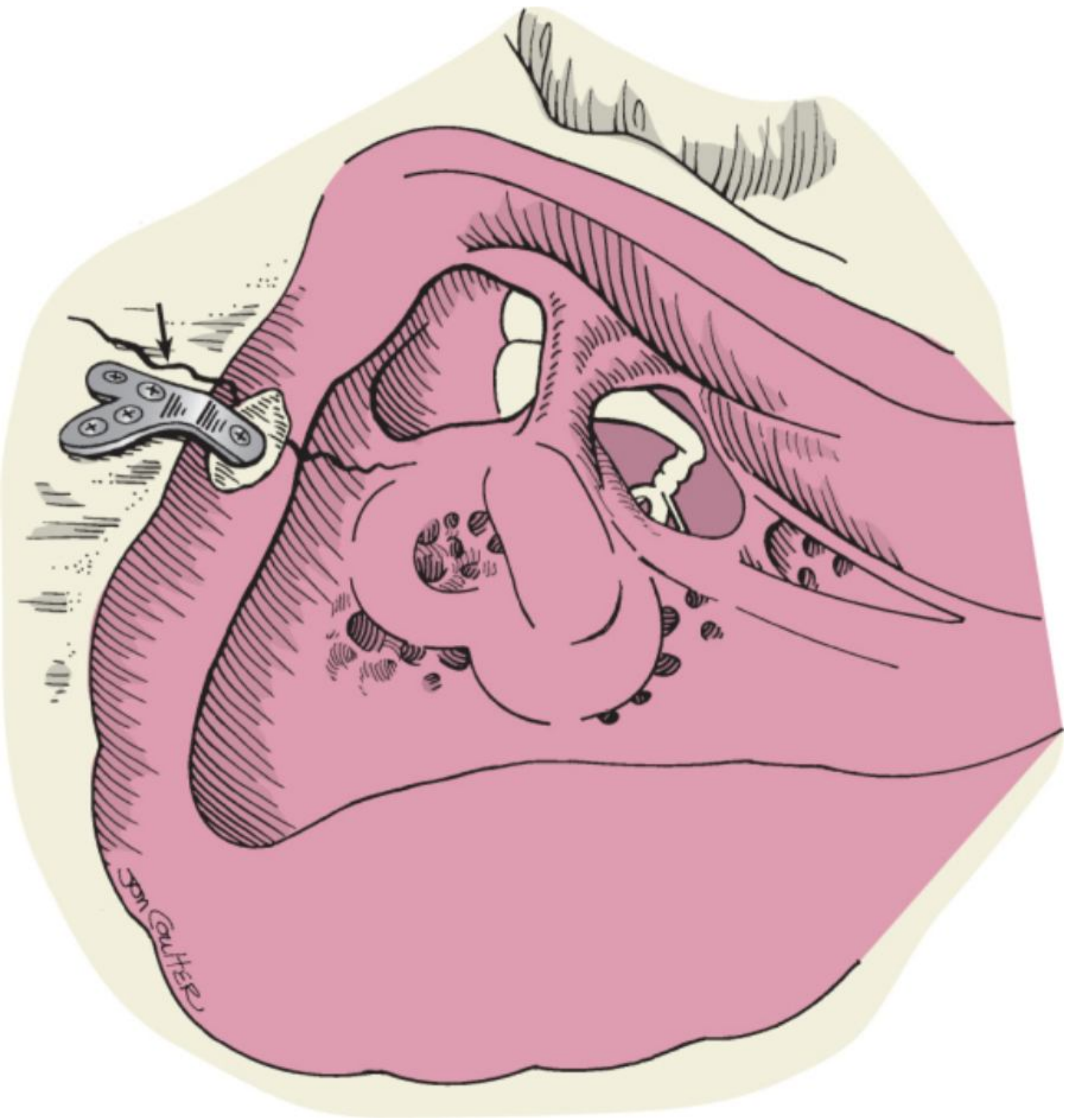

Figure 128-11 Bone grafting for repair of a middle fossa defect using a microplate *(arrow).*

When there is significant herniation of the temporal lobe through the fracture site, the devitalized brain tissue is débrided through a transmastoid exposure, and the viable brain and dura elevated back through am extradural mini-middle fossa approach. The resultant dural defect may be repaired using temporalis fascia or freeze-dried dura. The bony defect is reinforced using autologous bone harvested from the craniotomy flap to prevent further prolapse of brain tissue into the mastoid or middle ear cavities.

In patients with anacusis following trauma, obliteration of the middle ear and mastoid with blind sac closure of the external auditory meatus may be performed using a standard two-layered technique. A complete mastoidectomy is performed. The skin of the external auditory canal, tympanic membrane, malleus, and incus are removed, leaving the stapes intact. The eustachian tube is obliterated with muscle, and the middle ear and mastoid cavities are packed with abdominal fat.

POSTOPERATIVE MANAGEMENT

Postoperative management in these patients is similar to that of chronic middle ear and mastoid surgery. With the exception of translabyrinthine craniotomies, mastoid dressings for all other cases are removed in 24 hours to check for hematoma, cutaneous CSF leaks, or wound infection. The dressing is reapplied as necessary. If the dura has been opened, perioperative antibiotic coverage is used for 48 hours and consists of either broad-spectrum cephalosporins or vancomycin in penicillin-allergic patients. In addition to achieving a watertight wound closure, elevation of the head by 30 degrees and use of stool softeners helps minimize postoperative CSF leakage. Steroids are given in moderate doses and tapered over 5 to 7 days unless medically contraindicated. The use of steroids in these cases, as in acoustic tumor surgery, has significantly decreased postoperative complaints of headache and neck pain. This is probably due to suppression of inflammation from the breakdown of red blood cells in the CSF. Supportive eye care is continued and varies greatly depending on age, skin laxity, and anticipated time for return of facial function. Young patients with good corneal coverage may require nothing but lubricants and moisture chambers. Others may require lateral tarsorrhaphy, gold weights, or even oculoplastic procedures if severe ectropion develops.

Early ambulation is encouraged for all the usual reasons, in addition to the benefits obtained in early vestibular compensation. Early enrollment in a formal vestibular rehabilitative and physical therapy program is helpful in older and multiply injured individuals. The early convalescent period is an appropriate time for more in-depth investigation of auditory and vestibular function in those who manifest persistent symptoms.

When the nerve has been determined to be intact or following adequate grafting, some return of function is to be expected. The repaired or grafted nerve will generally recover limited function with variable synkinesis. This is usually demonstrable within 6 months for lesions distal to the geniculate ganglion but may take up to 1 year for more proximal lesions. Failure of expected return of function within 1 year should motivate the surgeon to review the initial CT scan and perhaps even to repeat the study. Facial paralysis may persist in “old” temporal bone injuries long after spontaneous resolution should have occurred. Scarring and degeneration of the proximal nerve segment in these cases usually precludes successful primary repair. Anastomosis of the facial and hypoglossal nerves or nerve muscle pedicle reconstruction is advised in this instance.

Pseudoaneurysms of the internal carotid artery are very rarely seen following head trauma. These consist of disruption of the intima of the artery with consequent dissection of blood between the vessel wall and the adventitial layer (Fig. 128-12). Stabilization may be spontaneous, but continued dissection of the aneurysm may require treatment. Following balloon occlusion and xenon flow studies to determine contralateral flow, balloons can be angiographically inserted proximal and distal to the site by an interventional radiologist. Failure of the contralateral flow testing would necessitate bypass grafting of the carotid artery.

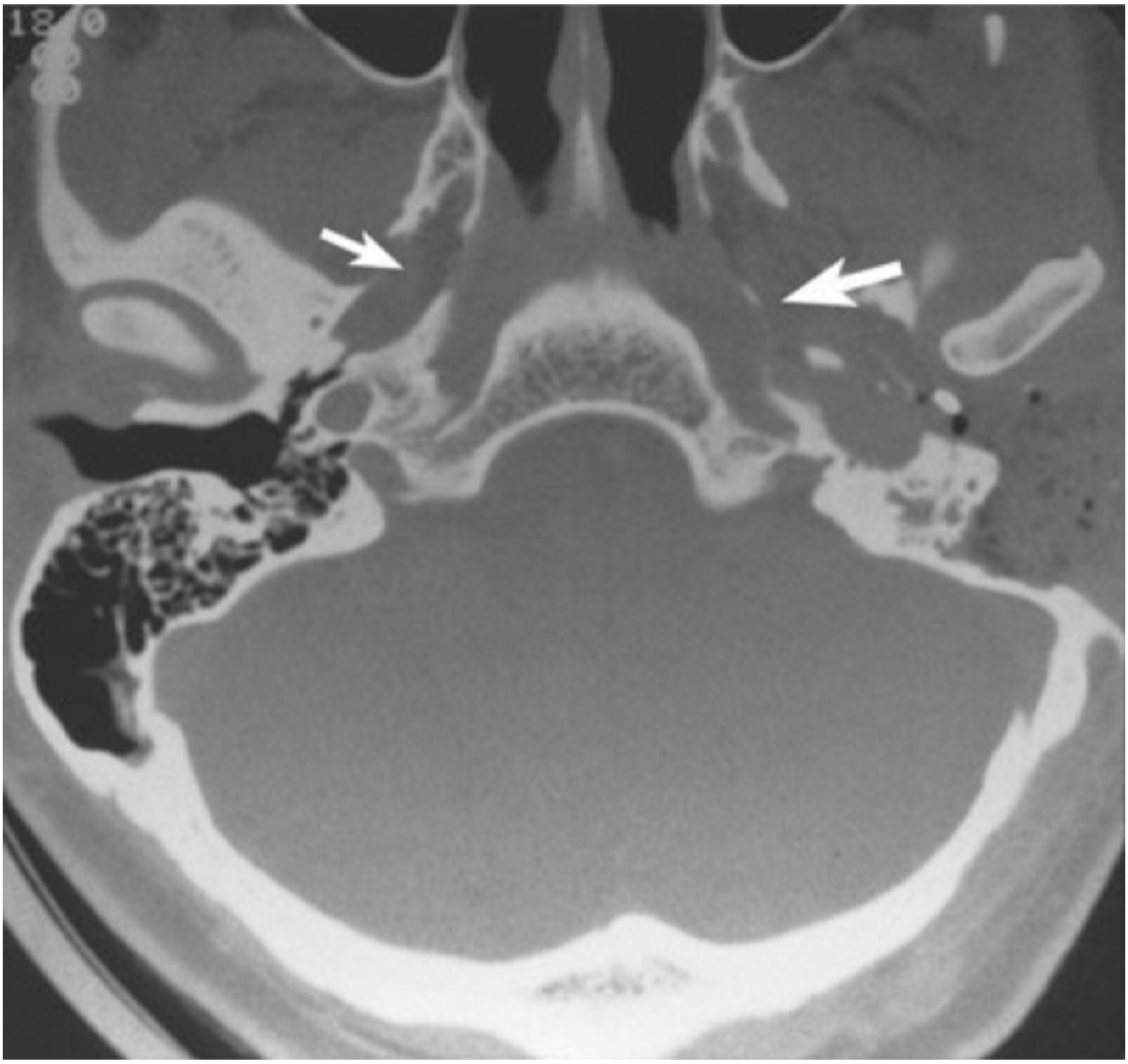

Figure 128-12 High-resolution computed tomography scan showing a posttraumatic pseudoaneurysm *(large arrow)* of the internal carotid artery. (*Small arrow*, normal carotid.)

PEARLS

- The primary indications for surgical intervention in temporal bone fractures are immediate complete facial paralysis with poor prognostic indicators, and persistent CSF leaks.
- Newer spiral CT scanners offer the ability to reconstruct high-resolution coronal images of the temporal bone, thus obviating the need for extreme neck extension needed to obtain true coronal images in these patients.
- Surgical approach is determined by hearing status in the affected ear and site of injury.
- When ENoG demonstrates less than 10% activity on the affected side, the adjunctive use of facial muscle electromyography to confirm the absence of electrical activity or appearance of fibrillation potentials is helpful in identifying surgical candidates for facial nerve decompression.[8]
- Facial nerve injuries distal to the geniculate ganglion are best accessed using the transmastoid approach, whereas facial nerve injuries medial to the geniculate ganglion may typically be accessed using the middle fossa approach in the hearing ear and using the translabyrinthine approach in the nonhearing ear.

PITFALLS

- Nerve repair under tension compromises microvascular circulation at the site of repair, resulting in scar formation, impaired axonal penetration, and uniformly poor functional outcome.
- Failure to recognize the presence of multiple sites of injury along the facial nerve will result in persistent facial paralysis following surgical decompression.
- Additional sensorineural hearing loss may result from drilling on the ossicular chain or violating the ampullated ends of the lateral and posterior semicircular canals when exposing the perigeniculate facial nerve through transmastoid approaches.
- Undue delay in surgical repair of persistent CSF leaks beyond 7 days may increase the risk of meningitis.
- When the external auditory canal is severely traumatized, cicatricial canal stenosis may develop with cholesteatoma formation medial to the stenotic segment.