The surgical treatment for the conductive hearing loss in otosclerosis over the past 50 years required replacement of the stapedial footplate, with a prosthesis anchored to the long process of the incus. Although total stapedectomy with tissue-wire replacement had been the initial choice for this procedure [11], the preferred choice is a small fenestra stapedotomy, limiting exposure of the vestibule, which accepts a piston like prosthesis [4, 7, 12]. Several varieties of prostheses and techniques exist for fenestrating the stapes footplate. The goal is to atraumatically create a fenestra in the footplate and replace the crural arch with a piston prosthesis of appropriate size and length for the fenestra. The universal employment of this procedure for over 50 years has been associated with one of the most predictable and successful hearing levels in all surgery. However, some minor and a few major complications may result during evaluation of a patient preoperatively, the conduct of the surgical procedure, and in the postoperative period.

This chapter focuses on adverse events that may occur intraoperatively and perioperatively in surgery for otosclerosis. The discussion is followed by a videotape of the stapedotomy procedure and some of the complications described in the text.

### Core Messages

- Confirm audiometric results with tuning fork (512 cycles per second) and speech reception using Barany masker in contralateral ear.
- Manage anatomical and pathologic conditions of the external ear canal before the stapedotomy.
- In unilateral conductive hearing loss, consider malleus and/or incus fixation.
- Stapedotomy is preferred to stapedectomy in otosclerosis surgery.
- Prosthesis length must be carefully assessed.
- In sensorineural hearing loss after stapedotomy suspect reparative granuloma.

### 1.1 Preoperative Phase

Preoperative evaluation concerns the patient's age, medical status, and expectations. The hearing loss in otosclerosis usually is brought to the attention of the otologist in patients from the second to the fourth or fifth decade, when the progressive loss has stabilized, and the patient is able to give informed consent [6]. Patients in the second decade of life are encouraged to delay operative intervention until the beginning or middle of the third decade, allowing for a slowing in the activity of the otosclerotic bone and its tendency for regeneration. However, younger patients with a disabling magnitude of conductive hearing loss or aversion to the use of amplification may be acceptable candidates for surgery. The upper end of the age scale is more arbitrary. Since the surgical procedure may be performed under local anesthesia with sedation, it can be safely employed in the older patient. An associated existing sensorineural hearing loss component may limit the restoration of hearing even in the best surgical result, leaving the patient still dependent on amplification. However, patients with a severe, mixed hearing loss pattern receiving limited improvement with maximal electronic amplification may benefit from elimination of the conductive component by successful stapedotomy. Such patients are uncommon but do represent an exception to the rule.

Although 10–15% of clinical otosclerosis presents with a unilateral conductive loss [6], this audiometric pattern should raise suspicion of a cause other than otosclerosis. Fixation of the malleus head in the attic typically presents with a predominant low-frequency conductive hearing loss [5]. Mobility of the manubrium can be assessed by pneumatic otoscopy or palpation with an instrument. The possibility of a “shadow” threshold curve caused by transmitted bone conduction to an inadequately masked contralateral normal ear should also receive serious consideration in the assessment of a unilateral hearing loss. The use of 100+ decibels (dB) white noise masking delivered by a Bárány noise box to the contralateral ear while
speech reception is tested in the affected ear will effectively identify an unsuspected “dead” ear.

Coexistent retrolabyrinthine or labyrinthine disease may exist in patients with atypical symptoms and clinical findings. A conductive hearing loss with a sensorineural component and discrimination score that is significantly lower than that of the contralateral ear should raise the suspicion of a retrocochlear lesion (i.e., acoustic neuroma), while severe vertigo associated with a low-frequency sensorineural hearing loss suggests endolymphatic hydrops, which would be decompressed at stapedotomy, leading to sensorineural hearing loss postoperatively (Fig. 1.1).

Local conditions in the ear canal may adversely affect the performance of the stapedotomy procedure. Small exostoses on the posterior canal wall can be removed by curettage after elevation of the tympanomeatal flap, permitting completion of the stapedotomy procedure (Fig. 1.2). However, if the exostoses are large enough to require canaloplasty with a motorized drill, then the stapedotomy should be performed as a staged procedure.
The presence of external otitis should be controlled medically prior to performing the surgery in order to avoid contamination of the middle and inner ear. If the external otitis is chronic, and not responsive to chemotherapeutic drugs, then resection of the infected skin with replacement by split thickness skin grafts, followed by a sufficiently long waiting period for healing, should precede the stapedotomy. Anatomical anomalies such as a dehiscent jugular bulb adjacent to the eardrum inferiorly (Fig. 1.3) should be recognized by preoperative otoscopy as a vascular blush in the hypotympanum [9]. Avoidance of such anatomical variants during flap elevation is mandatory.

Recognition of a descending bone conduction curve in the ear with a conductive loss should be carefully evaluated in anticipation of the postoperative result (Fig. 1.4). Tilting the audiogram by closing the air-bone gap with stapedectomy could result in a loss in speech discrimination because of the descending bone conduction curve. The patient should be aware of this possible loss of word discrimination before the stapedotomy procedure.
1.2 Operative Phase

The following group of complications may occur and be recognized intraoperatively.

Tears of the tympanic membrane occur because of either a thin atrophic tympanic membrane or inattention to elevation of the fibrous annulus from its sulcus when raising a tympanomeatal flap. Simple tears without a loss of tympanic membrane tissue may be reapproximated by advancing the tympanomeatal flap when it is returned to its anatomical position. Gelfoam may be used in the middle ear for temporary support. A large defect in the drum that cannot be closed by meatal flap advancement should be repaired with adipose tissue from the earlobe.

The chorda tympani nerve should be preserved when curetting the posterior/superior canal wall. However, in a small number of cases, probably less than 20%, the chorda tympani nerve may be stretched or dried out in order to achieve adequate exposure of the oval window. Resection of the nerve segment will avoid aberrant neural regeneration responsible for a troublesome taste response postoperatively.

Associated fixation of the malleus or incus should be suspected in middle ear exploration [5]. It is routine during any stapedectomy procedure that all ossicles be individually palpated for mobility [6]. Palpation of the malleus by delicate displacement of the manubrium and of the incus by displacement of its long process after removal of the stapedial arch is a routine step in the procedure. Malleus ankylosis may be congenital or acquired and be obscured from visualization because of its location in the epitympanum (Fig. 1.5). Fixation of the incus may be caused by ossification of the posterior incudal ligaments, in the incudal recess (Fig. 1.6). Unrecognized ossicular fixation may be responsible for failure to close the air bone gap postoperatively.

Rarely, the incus may be dislocated during the stapedectomy procedure. The initial maneuver is to replace the incus into its anatomical position, relying on healing of the ligaments to retain it [6]. However, if the dislocation is severe, and the incus does not retain its relocated position, then malleus attachment for the prosthesis is the most reliable solution for a satisfactory result. Occasionally pneumatization of the long process of the incus may be responsible for fracture after crimping of the wire prosthesis. This event requires that an appropriately long new prosthesis be applied to the manubrium of the malleus.

The critical part of the stapedotomy procedure concerns fenestration of the ankylosed footplate. The accompanying figures demonstrate some of the anatomical variations in oval window pathology that affect the surgical technique. In the case of a thin footplate in an oval window niche with overhanging bone (Fig. 1.7), removal of the overhanging bone with a rotating burr will provide complete visualization of the annular ligament. Such overhanging bone may compromise the ability to retrieve a floating or depressed footplate. A thick footplate with marginal fixation will require careful pressure with the drill to avoid a floating foot-

![Fig. 1.5](image1) Anterior malleus head ankylosis may be congenital (arrow). I incus body

![Fig. 1.6](image2) Fixation of the short process of incus (I) may be acquired by calcification in its ligaments (arrow). * air cell in the incus, L normal ligament
plate (Fig. 1.8). The end result to be avoided with the floating footplate is depression of the footplate into the vestibule, where it cannot be retrieved (Fig. 1.9). If this occurs, then the depressed footplate should be left in the vestibule, and a shorter-than-required prosthesis be inserted in the oval window. The technique for safe removal of the floating footplate, avoiding subluxation, is insertion of a small hook into the cleft between the margin of the footplate and the oval window [6]. Rotation of the hook 90° can bring it under the edge of the footplate for extraction by tilting. If this cannot be accomplished, then a 1-mm drill hole is made just outside the stapedio-vestibular joint for insertion of a small hook to lift the footplate [5]. The technique for removal of floating footplate is demonstrated in an accompanying video.

Dehiscence of the fallopian canal most frequently occurs in its tympanic segment (Fig. 1.10). Since this portion of the bony canal is formed by periosteal bone enveloping the facial nerve superior to the oval window, the extent of dehiscent bone may vary from very small to complete absence of bone with prolapse of the facial nerve. Usually stapedectomy or stapedotomy can be performed, avoiding trauma or impingement of the prosthesis on the nerve. In the rare instance where a prolapsed facial nerve completely obscures a view of the footplate, the procedure should be aborted and amplification recommended.

A persistent stapedial artery may be dealt with in various ways depending on the size of the vessel [3]. If the vessel is represented by a small mucosal vessel crossing the footplate, then bipolar cautery or laser obliteration can be performed, allowing for a routine stapedotomy procedure. However, if large, the vessel can be circumvented by a stapedotomy and insertion of a piston prosthesis adjacent to the vessel.

The presence of round window involvement by otosclerosis should be routinely recorded to explain an unsatisfactory hearing result after stapedotomy [6]. As long as a dimple can be recognized in the round window niche, it is generally felt that the round window niche and membrane have not been immobilized (Fig. 1.11). Even without the presence of a dimple, there may be a microscopic opening into the niche, which is responsible for satisfactory hearing result. In no case should the bone around the round window niche be drilled out, as it is prone to regeneration, and the procedure may violate the round window membrane, causing sensorineural hearing loss (Fig. 1.12).

1.3 Postoperative Phase

The postoperative complications of stapedectomy/stapedotomy are usually related to the prosthesis [1]. The most common of these is incomplete tightening
of the wire loop around the long process of the incus, which gradually leads to bone erosion and the development of fluctuating conductive hearing loss. Auto-inflation of the middle ear improves hearing, and as the middle ear air volume is released by the Eustachian tube, the contact between the incus and the prosthesis is lost leading to a conductive loss. Erosion of the bone of the incus long process is the result of loosely applied wire prosthesis, and when it occurs, it should be revised by replacement of the prosthesis in a more superior position on the long process of the incus or to the manubrium of the malleus. Revision surgery after total stapedectomy is aided by lateral displacement of the membrane seal in the oval window (Fig. 1.13). Such displacement produced by the pressure in the perilymphatic compartment offers counterpressure to a sharp

Fig. 1.8 This thick footplate is marginally fixed in a narrow oval window niche. This can be suspected at surgery by a cleavage plane around the footplate (arrow). The round window niche is obliterated by otosclerotic bone (*).

Fig. 1.9 Subluxation of the floating footplate (FP) can cause a traumatic labyrinthitis manifested by endolymphatic hydrops (arrowheads).
instrument in the creation of a fenestra small enough to accept piston prosthesis.

The prosthesis may be too short or too long. If it is too short, as shown in a celloidin-embedded temporal bone (Fig. 1.14a) with the histopathology of the bone and soft tissue deep to the oval window (Fig. 1.14b), then the prosthesis will be ankylosed, recreating a conductive hearing loss (Fig. 1.15). Therefore, measurement of the depth of the space to be bridged by the prosthesis (the undersurface of the footplate to the under surface of the long process) must be carefully assessed with a measuring instrument. The desired arrangement is represented by a prosthesis, which extends slightly beyond the fenestra. If the prosthesis is too long, then it may contact the utricular nerve and macula in the vestibule (Fig. 1.16). This contact can be...
detected intraoperatively by the patient’s response to depression of the incus under local anesthesia.

The most serious postoperative complication of stapedotomy/stapedectomy surgery is the formation of post-stapedectomy granuloma [2]. The granuloma may form in the oval window after the use of Gelfoam, adipose tissue, or other connective tissues. Although it had been reported more often with the use of Gelfoam than with connective tissue, it is generally felt to be a reparative granuloma to surgical trauma in the oval window region. It probably accounts for most unexplained sensorineural hearing losses after stapedotomy. The presence of a granuloma affecting labyrinthine function is usually detected within the first 2 weeks postsurgery by the appearance of sensorineural hearing loss, with a reduced word discrimination score and vertigo (Fig. 1.17). Sensorineural hearing loss with vertigo as a manifestation of mild
surgical serous labyrinthitis improves with postoperative time. If these symptoms persist or worsen with time after surgery, then they indicate a progressive labyrinthitis. Careful otoscopy at 1 week will reveal ear drum changes (edema, erythema) indicative of middle ear inflammation. However, audiologic demonstration of a significant loss in word discrimination is key to confirming the progressive nature of the labyrinthitis. Early recognition is important as surgical exploration and complete removal of the granuloma may salvage labyrinthine function (Fig. 1.18).

A perilymph fistula may occur along the prosthesis in the stapedotomy fenestra [8, 10]. The larger the space around the prosthesis in the fenestra, the greater the incidence for nonhealing of this space and leakage of perilymph, manifested by fluctuating sensorineural hearing loss and vertigo. This may occur at any time in the postoperative phase and is an indication for early
re-exploration with tissue repair of the fistula. The use of tissue (adipose, perichondrium, vein) to seal the perilymphatic compartment will reduce the incidence of oval window fistulae.

Experience with these complications allows the otologic surgeon to develop the ability to recognize and avoid them. It is hoped that this description of otosclerosis surgery will aid in prevention of these complications.

**COMPLICATIONS TO AVOID**

1. Avoid eardrum tears by elevation of the tympanic annulus.
2. Avoid incus dislocation by careful curettage of bony ear canal.
3. Avoid floating footplate when fracturing crural arch.
4. Precise measurement of footplate to incus distance to determine prosthesis length.
5. Seal large defects around piston with soft tissue to avoid perilymph fistula.

**Pearl**

- Small fenestra stapedotomy is preferable to total stapedectomy.
Fig. 1.16 This vertical section through the oval window region demonstrates the proximity of the utricular nerve and macula (arrowhead) to the stapes footplate (FP). O otosclerotic bone, F facial nerve.

Fig. 1.17 This series of audiograms document the preoperative (9 May 1967), 13 days post-stapedectomy (22 May 1967), and 1-month post–revision surgery (19 June 1967) of patient B.J., who underwent surgery for removal of a post-stapedectomy (granuloma) on 22 May 1967.
References


Fig. 1.18 Photograph of the specimen removed from patient B.J. Arrowhead marks the interface between gel foam (G) and granuloma (GR)
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