Surgery for otosclerosis is simple in concept, yet good outcomes rely on successful execution of the fine details and the avoidance of complications. There are many descriptions of operative procedures for otosclerosis in the literature, including those by this author.1 These generally describe the basic elements of the operation in a sequential manner but do not focus on the particular critical points that are high risk for complications, nor do they describe how to avoid certain pitfalls. This chapter discusses the times during surgery in which the potential for complications is higher and proffers some thoughts on how to avoid them. Table 8–1 considers the potential difficulties as well as some solutions.

The procedure described here is the laser stapedotomy, which itself reduces the probability of complications relative to conventional stapedotomy. The reader is referred elsewhere for a description of the laser stapedotomy procedure and the basic procedural steps.1 This chapter focuses on specific areas of preparation and technique to avoid complications.

### Preoperative Preparation

The old saying “An ounce of preparation is worth a pound of cure” is extremely pertinent to avoidance of complications in stapes surgery. Preparation of the microscope, laser parameters, and patient as well as instrument care and surgical team training are extremely important in reducing complications. Many complications become more probable as a result of inadequate preparation before the first incision is made. The safety of an airplane flight does not begin with takeoff: it begins with the design of the airplane, the training of the support crews, the adequacy of maintenance systems, fuel checks before takeoff, and a well-trained and rested pilot. It is the surgeon’s responsibility to oversee all aspects of the preparation. The reader is encouraged to review the sections on preoperative preparation in the referenced chapter at the end of this article.

### Patient Positioning, Draping, and Comfort

The patient’s head should be positioned to the surgeon’s side of the table so the surgeon does not add further stress by operating with outstretched arms. I prefer not to use a headrest, allowing the patient’s head to be dropped back with the chin turned toward the contralateral shoulder. This positions the external canal optimally and facilitates the entire procedure.

Another bit of patient preparation that provides comfort to the sedated patient is the use of a draping bar and face fan. After prepping the auricle and periauricular area, a drape is placed over the area with the auricle exteriorized through the hole in the drape. This drape is placed over an L-shaped bar that is fixed in the rail attachment of the operating table (Fig. 8–1). Attached to the bar is a small, low-volume desk fan that provides a cooling breeze to the patient’s face during the procedure. The plastic drape forms a canopy, allowing the patient to see from under the drape and reducing the feeling of claustrophobia, and provides a...
visual pathway for the circulating nurse to confer with the patient during the procedure, if needed.

### Analgesia and Hemostasis

Adequate analgesia and hemostasis are extremely important in stapes surgery. Any significant bleeding while working in the oval window is an invitation to disaster. To optimize hemostasis in the canal, use 2% xylocaine with 1:20,000 epinephrine solution in a classic quadratic injection and follow that with a special anterior canal injection. The anterior canal injection is done by orienting the bevel of a 1.5 in., 27 gauge needle parallel to the anterior canal bone, inserting it below the skin and slowly injecting a small amount of the solution so that it migrates toward the anterior sulcus area (Fig. 8–2). This not only provides analgesia to the medial third of the anterior canal wall (a must in tympanoplasty) but also tends to reduce the bleeding sometimes encountered in the medial portion of the inferior leg of the tympanomeatal incision.

Although it may seem to be a trivial part of the procedure, the tympanomeatal incision is an important part of avoiding complications. The appropriate incision helps prevent a short flap situation (described in later text) but, possibly more importantly, can provide better hemostasis throughout the operation. Through as large an oval-beveled speculum as possible, incisions defining the flap are created. The initial incision is made with a sickle knife just lateral to the inferior annulus of the
A second incision is made with a 2 mm round canal knife beginning at the lateral extent of the initial incision and extending in a curvilinear manner, first posteriorly and then anterosuperiorly until it terminates ~2 mm above the pars flaccida. This second incision is made in multiple small segments beginning inferiorly. Each segment is composed of an initial crushing application of the knife into the canal skin and a subsequent cutting action that connects that small segment with the previously cut segment. The crushing portion of this action seems to impart additional hemostasis, particularly in the thicker vascular strip area. An additional advantage of making this in multiple small segments is that it eliminates the tendency of the tissue to tear.

### Prevention of the Short Flap

Although not a complication of catastrophic proportions a short tympanomeatal flap can add potential risk to the procedure as well as increased time to correct it. These occur by not allowing adequate canal length on the tympanomeatal flap in the area where the scutum is to be curetted. The maximum flap depth should be at ~10 o’clock on the annular clock (right ear) and should be ~4 mm to accommodate for the bone removed to visually access the oval window area. Should the tympanomeatal flap not cover the curetted scutal area, it can be corrected by placing a piece of temporalis fascia medial to the short flap and bridging it to the posterior canal bone.

### Prevention of Tympanic Membrane and Canal Skin Perforations

A not uncommon complication of otosclerosis surgery is perforation of the tympanic membrane upon elevation of the tympanomeatal flap. Most common among inexperienced surgeons, it occurs from trying to elevate the skin flap and annulus from the bone rather than separate the skin flap from the canal bone and separate the fibrocartilaginous annulus from the bony annular sulcus. By pushing on the soft tissue with a round knife or elevator one can slide over the annulus and penetrate the knife or elevator into the tympanic membrane just anterior to the annulus. This can be easily avoided by never taking the knife off the bone surface. The flap will naturally elevate when it is separated. If one always keeps the knife on the bone surface, develops the separation on a relatively broad front, and never allows soft tissue beneath the blade, one cannot perforate the tympanic membrane. The important point is to recognize the annulus and annular sulcus, depress the knife edge into the sulcus, and separate the fibrocartilaginous annulus from the sulcus. Should a tympanic membrane perforation occur, inject a small amount of analgesic solution into the lower temporalis fascia area, harvest a small piece, and place it medial to the perforation. Bring it onto the bony posterior canal wall and bolster it with a small amount of Gelfoam® in the posterior tympanum.

### Prevention of Damage to the Chorda Tympani Nerve during Tympanomeatal Flap Elevation

The chorda tympani nerve is susceptible to damage during several phases of the operation. The first is related to the “elevation” of the tympanomeatal flap already described. This tends to occur when the most advanced separation of the tympanomeatal flap is near the iter chordae posterius from which the chorda tympani nerve emerges to enter the middle ear space. This location is variable but is located at ~10 o’clock on the annular clock (right ear). Therefore, it is best to approach the first below that area at 8 or 9 o’clock, elevate the annulus from its sulcus, interrupt the mucosa, and then carefully continue the dissection superiorly into the region of the chorda tympani. If the chorda is not apparent at that point, it is advantageous to go above that area to 11 o’clock, separate the mucosa, and locate the chorda as it emerges from behind the manubrium. Place a small pick between the
chorda and the tympanic membrane just posterior to its emergence from behind the manubrium and gently pull the instrument laterally. This usually separates the chorda from the tympanic membrane, bringing its pathway to the annular area into view.

To limit the deleterious effect of stretching the chorda tympani nerve, as is sometimes necessary, to gain better visual and instrument access to the oval window area it is helpful to first separate the nerve from its attachment to the medial surface of the manubrium. Then slowly stretching the nerve distributes the effect over the entire middle ear portion of the nerve rather than only that section between the manubrial attachment and the iter chordae posterius.

The next phase of the operation in which the chorda is more susceptible to damage is during the curette reduction of the scutal margin. The risk in this phase can be mitigated as described following here.

**Prevention of Damage to the Chorda Tympani Nerve and Incus during Scutal Curettage**

Although little has been said about the details of scutal curettage, it is a part of stapes surgery in which complications can occur. Inadequately accomplished, it can reduce effective viewing of the oval window area, which can result in additional complications. However, the two risks directly associated with reduction of the scutal margin while curetting are damage or section of the chorda tympani nerve and disarticulation of the incus. These risks can be reduced by the following techniques. Most importantly, always use a sharp curette. A dull curette is a risk factor. Although it is always tempting to curette first along the scutal edge, one can reduce the risks by first curetting a groove just lateral to the edge (Fig. 8–3). By doing so the heavy bone mass is attacked without having the curette partially in the middle ear. This reduces the likelihood of the curette slipping under heavy pressure and disarticulating the incus. By completing the groove first and then removing the edge, less instrument pressure is needed while the curette is near the incus (Fig. 8–4). Should the incus be disarticulated, inject the postauricular area (2% xylcaine with 1:100,000 epinephrine), perform a posterior atticotomy to reestablish its connection to the stapes and to the articular facet of the malleus, pack it in place with Gelfoam, close the ear, and return in 1 year. Proceeding with stapedotomy (or stapedectomy) with a compromised incudomalleolar joint will give disappointing results. Although it may be a little embarrassing to explain the need for a subsequent operation, remember patients retain you to improve their hearing, not to do an operation and hope for the best.
Protection of the chorda tympani nerve is fostered by always rotating the curette away from the chorda tympani, being mindful that the back side of the curette could crush the chorda tympani as it turns. If the chorda tympani continues to be directly in the visual pathway to the oval window, it is sometimes necessary to delicately remove its bony covering on the canal side, elevate the nerve from its channel, and then, with the small end of the curette, remove the bone medial to the chorda tympani.

**Confirmation of Disease**

Although not by definition a complication, inadequate confirmation of disease can result in a poor outcome and be disappointing to both patient and surgeon. It is important to immediately eliminate three potential problems that could mimic the diagnosis of stapedial otosclerosis: malleus fixation, incus fixation, and round window obliteration by otosclerosis. This is best done immediately after fully reflecting the tympanomeatal flap before any manipulations are done in the middle ear. A quick inspection of the round window can usually eliminate the round window closure diagnosis.

Stapes mobility is best assessed by applying pressure medially on the lower end of the long process of the incus while observing the stapes. A thinner stapes may move in the superior inferior axis with a fixation of the footplate; therefore, the movement in a medial lateral axis is the most important. Should the movement be equivocal, focus on the annular ligament while palpating the incus or the posterior crus of the stapes. Even small amounts of movement of the footplate evoke a light reflex in the stapes annular ligament.

Carefully palpating the medial surface of the manubrium of the malleus should reveal the possible diagnosis of malleus fixation. After assessing all three ossicles should malleus fixation be the diagnosis, the differential between malleus head fixation, tensor, tympani tendon and anterior malleolar ligament calcification comes into play.

To evaluate the anterior malleolar ligament, extend the anterior-superior extent of the tympanomeatal incision anteriorly another 3 mm and elevate the canal skin and pars flaccida, fully revealing the neck of the malleus and the short process (Fig. 8–5). Then, with a sharp 30 degree stapes pick, make an incision in the upper portion of the posterior periosteum of the manubrium (Fig. 8–6). Using the same pick elevate the periosteum from the upper manubrium and short process (usually there is a small cartilage “cap” on the bony short process — elevate this off with the periosteum). A curved, double-edge sickle knife is useful in elevating the anterior periosteum. These maneuvers should reveal...
the anterior malleolar ligament (Fig. 8–7). Palpate the ligament. If it is calcified and retarding malleolar movement, place a small piece of Gelfoam behind it as a beam blocker and use the laser (laserscope KTP/532 laser: 3 W; 100 msec pulses) to vaporize the central portion of the ligament (Fig. 8–8). If both the tensor tympani tendon and the anterior malleolar ligament are unaffected, the likely source is the fixation is the malleolar head. In this case, inject the postauricular area with local analgesic, slightly adjust the conscious sedation, advise the patient that there will be drilling noise, and perform a posterior atticotomy. Use the laser (KTP/532 4 W; 100 msec pulses) to vaporize the bridge of bone usually found between the anterior-superior surface of the head of the malleus and the superior attic wall (Fig. 8–9). Placing a small piece of

FIGURE 8–7 Separation of the tympanic membrane from the upper manubrium reveals the anterior malleolar ligament.

FIGURE 8–8 The laser is used to vaporize the calcified anterior malleolar ligament.

FIGURE 8–9 Malleus fixation by a bony bridge to the anterior superior attic wall is vaporized.
Silastic sheeting into the created space is advisable to thwart potential refixation. It is not necessary to disarticulate the incudostapedial joint if only the laser is used to free the malleus. Should a drill be used, however, it is advisable to section the joint, place a pad of Gelfoam in the void, free the malleus, remove the Gelfoam, reapproximate the lenticular process onto the head of the stapes, and pack in place with Gelfoam.

Incus mobility is more difficult to assess but can be done by directly palpating the incus and finding it fixed with clear mobility of the stapes and malleus. Incus fixation alone is more infrequent than stapes or malleus fixation, but it does occur. Should incus fixation be determined to be the diagnosis the procedure is similar to that already described for malleus head fixation, with attention directed to the incus fixation.

Avoiding the Short Prosthesis

A poor result can occur as a result of poor measurement of the distance between the footplate and the medial surface of the incus. In laser stapedotomy it is desirable to have the prosthesis protrude \( \frac{1}{3} \) to \( \frac{1}{2} \) mm below the lateral surface of the footplate. Therefore, it is advisable to add about \( \frac{1}{2} \) mm to the measured distance when selecting the prosthesis. If the distance is equivocal, it is best to err towards the longer prosthesis because a slightly longer prosthesis will still be effective for hearing improvement and will cause no vertigo problem unless it is excessively oversized and impinges on the saccule (~1.8 mm from the medial surface of the footplate). A prosthesis of inadequate length may well become displaced out of the fenestra and result in the need for revision.

Avoiding Fracture of the Lenticular Process

When using prostheses with receptacles to cradle the lenticular process, so-called bucket handle prostheses, it is important to avoid fracturing the lenticular process when sectioning the incudostapedial joint. There are several maneuvers that help reduce such occurrences. First, definitively locate the plane of the joint by palpating the incus, moving it in an anterior-posterior direction. There is a light reflex that occurs from the joint capsule that clearly identifies the plane of the joint. Using a sharp joint knife or sharp right-angle pick, carefully sever the joint capsule superiorly, inferiorly, and posteriorly. This will allow the joint to separate slightly and better allow the insertion of the joint knife into the joint. Insinuate the joint knife into the joint and rotate it slightly as it is further introduced into the joint until separation occurs (Fig. 8–10). This entire maneuver is enhanced by a slight lateral pressure on the incus applied with a no. 24 suction tip, which helps separate the joint. This technique will help avoid lenticular process fracture, which usually occurs when anterior pressure is applied with the joint knife without first incising the capsule or with the knife edge on the lenticular process rather than the joint plane. Should the lenticular process be fractured, it is advisable to use a prosthesis style that crimps on the lower long process of the incus rather than a bucket handle prosthesis.

Prevention of Facial Nerve Damage

Although damage to the facial nerve in stapes surgery is uncommon, it does occur. Awareness of the position and condition of the facial nerve is the first step in reducing the incidence of this complication. Prior to any activity in the vicinity of the oval window, it is advisable to study the facial nerve. Does it protrude into the window sufficiently to compromise access to the footplate? Is it dehiscent? Does it have a bifurcated pathway? Damage to the facial nerve may occur when the nerve has bifurcated and some of its fibers travel immediately inferior to the oval window. Vaporizing in the area of the inferior wall of the oval window (which is sometimes necessary with an overhanging facial nerve) with an unidentified bifurcated facial nerve can result in damage to the nerve. More commonly, the overhanging dehiscent facial nerve is more susceptible to damage
because it compromises the ability to fenestrate the footplate. In this situation the overhanging facial nerve and promontory techniques described elsewhere provide for creating a fenestra and reduce the risk to the facial nerve.

### Perilymph Protection

Many of the most severe complications of stapes surgery result from sudden perilymph pressure changes. These may result from rapidly applied pressure or aspiration of perilymph. Although these are less likely hazards in laser stapedotomy than in conventional manual stapedectomy, constant caution is necessary when working around the footplate area.

Hemostasis is necessary when working around the oval window. Persistent bleeding from a canal flap must be controlled with a micro bipolar cautery, laser cauterization, packing, or reinjection before any footplate maneuvers are attempted. Any bleeding from the oval window should be controlled. As one opens the tympanomeatal flap a drop or two of the canal injection solution can be dropped into the middle ear, which not only provides analgesia but may have some beneficial effect on reducing future bleeding. After such an application it is advisable to aspirate any pooling of the solution in the round window niche because any absorption through the round window membrane may result in temporary unilateral labyrinthine paresis with associated vertigo and vomiting.

Should bleeding occur from the oval window area it is advisable to place a small pledget of Gelfoam or cotton soaked with the canal injection solution into the oval window and wait a few minutes for the hemostatic effect. Bleeding points can also frequently be stopped with a slightly defocused KTP/532 laser beam of 2 to 3 W with 100 msec pulses if the bleeding source is clearly visible. Attempts to persist in footplate activity in the face of poor hemostasis are a recipe for complications. With an open footplate attempts to aspirate oval window blood present a higher risk of perilymph aspiration. This is especially true if special small suction tips of 24, 26, and 28 gauge are not available, so much so that if adequate hemostasis cannot be attained after several persistent attempts, it is best to stop the procedure, close the tympanomeatal flap, and come back 6 months later. As surgeons we want to finish the procedure, feel defeated and inadequate in such circumstances, and are uncomfortable about telling the patient that we backed out. The truth of the matter is that we are retained to provide a solution, not simply to do an operation. The real contract between the patient and the surgeon is for the surgeon, to their best judgment, to achieve the desired result and limit the probability of an adverse event.

Less hazardous, but still an area where caution is due, is the aspiration of perilymph off the surface of the footplate during the laser fenestration of the footplate. After one or two holes of the fenestral rosette pattern are made, perilymph will emerge from the vestibule and layer on the footplate. Persistence of this layer presents a disadvantage for creating the rest of the rosette. The layer reflects some of the laser energy, and the fluid has somewhat of a heat sink effect. Although one can persist and vaporize through a thin layer, it tends to diminish the effectiveness of future pulses. Therefore, it is advisable to remove this layer immediately prior to the next few laser pulses. This cannot be done safely with conventional larger suction tips such as 20 gauge and above. However, it can easily and safely be done by using smaller suction tips, especially 26 and 28 gauge tips. These tips are small enough to be placed in the oval window or even on the footplate posterior to the fenestration zone (Fig. 8–11). In addition to their size allowing this placement, they have less aspiration pull and markedly reduce the possibility of an inadvertent aspiration of perilymph and the consequent adverse effect on hearing. Again, this underscores the importance of preparation: having the appropriate suction tips in this instance could make the difference.

The other side of the coin in protecting the perilymph is avoiding pressure changes in the opposite direction: pulsion forces. These occur both during insertion of the prosthesis and in checking the prosthesis for adequate motion. Although both these maneuvers are necessary during the procedure, the potential negative effects can be mitigated. The prosthesis should be inserted in the fenestra very slowly to avoid a rapid
rise of pressure. Remember that in laser stapedotomy, as contrasted to conventional manual stapedectomy, the prosthesis–vein combination fits relatively tightly in the fenestra, and there is less chance for pressure increases to be dissipated around the prosthesis–vein assembly. Once the prosthesis is in place, it should be very lightly checked for mobility. Once mobility is confirmed, one should stop; there is no advantage to further proving it to yourself or showing other observers the motion.

One further point, thermal protection, is worth mentioning on protection of the perilymph. In laser stapedotomy the perilymph temperature can be elevated if the laser pulses used to fenestrate the footplate or to remove part of the promontory lip (promontory technique for overhanging facial nerves) adjacent to the inferior border of the footplate are made too rapidly. In both maneuvers, space the pulses by 5 to 10 seconds. Although there does not appear to be any objective persistent negative effect of too frequent a pulse sequence, it can cause nausea in the patient and disrupt the smooth execution of the operation.

### Avoiding the Binding Prosthesis

Occasionally, the configuration of the oval window architecture is too narrow for piston bucket handle prostheses. When this occurs, the prosthesis may be nicely on the incus, but palpation reveals it does not move readily. There are two things that are likely amiss. The first is a prosthesis that is sitting on the footplate and not in the fenestra. This can be checked by attempting to push the prosthesis anteriorly with a small 30 degree stapes pick. If there is resistance, it is probably within the fenestra; if it moves anteriorly, it likely represents a short prosthesis that is sitting on the surface of the footplate. If, after repositioning the prosthesis it continues to displace anteriorly, it should be replaced with a slightly longer prosthesis.

If the prosthesis is in the fenestra and still not moving easily, it is likely in apposition to the bone of the promontory in the inferior oval window space. In this instance, leave the prosthesis in place and use the KTP/532 laser to vaporize the bone contacting the prosthesis. If this is not possible, remove the prosthesis and vaporize the offending bone (KTP/532: 4 W; 100 msec pulses). Space the pulses about 5 to 10 seconds apart to reduce heat buildup. Then replace the prosthesis. Should this not be effective, change the prosthesis to a wire crimp-on piston type, which will not have this problem. Several of the newer bucket handle prostheses with a narrow shaft and terminal piston alleviate much of this problem.

### Preventing Tympanic Membrane Collapse onto the Incus and Prosthesis

This is a maneuver that may have some effect on later potential prosthesis extrusion. It is advisable to avoid having the tympanic membrane lie on the incus and the prosthesis. Therefore, attention should be directed to replacing the tympanomeatal flap fully back to its anatomical position and not allowing it to sag onto the incus. By carefully pulling up the posterior-superior part of the flap and packing it into place with a large pledget of Gelfoam, this potential late complication can be reduced.

### Conclusion

Laser stapedotomy for otosclerosis is an effective procedure and among the most successful operations in all fields of surgery. It is simple in concept, but its success depends upon careful preparation, continued assessment of the operative field, skilled execution of surgical techniques, and attention to the details of the procedure. This chapter provides suggestions for avoiding specific complications, which are part of the overall techniques more fully described in the chapter referenced at the end of this chapter.

### Reference