Transcanal Endoscopic Management of Cholesteatoma

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KEYWORDS

• Cholesteatoma • Endoscopy • Ear endoscopy • Surgical management
• Surgical approaches • Anatomy

KEY POINTS

- The endoscope offers a new perspective of cholesteatoma and related surgical procedures by increasing the surgeon's understanding of that disorder and its progression through the temporal bone.
- Rediscovering the ear canal as the access port for cholesteatoma surgery is the main story and the main advantage of endoscopic ear surgery. This approach allows a more natural and direct access to and pursuit of cholesteatoma within the middle ear cleft.
- Endoscopic Technique allows better access to the tympanic cavity, the birthplace of cholesteatoma, and allows the surgeon to identify the cause for any selective atelectasis or poor ventilation.
- The Endoscope allows better access for the tympanic cavity for removal of cholesteatoma especially within the retrotympanum, the anterior attic, anterior mesotympanum, and eustachian tube.
- The endoscope is of limited use within the mastoid cavity proper and disease within the mastoid is best eradicated using traditional microscopic approaches.

Videos on transcanal endoscopic removal of cholesteatoma, endoscopic "Open Cavity" approach to cholesteatoma, endoscopic lateral canal approach to cholesteatoma and the isthmus ventilating the attic accompany this article at http://www.oto.theclinics.com/

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INTRODUCTION

Although it has been 2 decades since the first use of operative endoscopy for the exploration of old mastoid cavities, the endoscope is used infrequently in the day-to-day surgical management of ear disease around the globe for several reasons.[1] The role of the endoscope as defined by many prominent otologists is so marginal that most surgeons have not felt compelled to master newer techniques and instrumentation for its use.[2–6] In effect, the use of the endoscope did not significantly benefit either the patient or the surgeon. In addition, most physicians have focused on the use of smaller diameter endoscopes for ear surgery, which is frustrating and eliminates the main (and possibly the only) advantage of endoscopy (the wide field of view provided by the endoscope is greater than that of the microscope). Our first experience of using the endoscope in ear surgery was in 1993 during years of practice in the United States. In recent years, it has replaced the microscope as the instrument of choice for use in middle ear surgery.[7–10] The endoscope offers a new perspective of cholesteatoma and related surgical procedures by increasing the surgeon's understanding of that disorder and its progression through the temporal bone. Clinicians who use the endoscope during ear surgery realize how the microscope and its limitations have colored the clinical perception of cholesteatoma and have dictated its management (Videos 1–3).

HISTORY

The introduction of the binocular operating microscope, which was a landmark event in the development of modern otology, clearly changed the scope and character of ear surgery. Despite continuous technical improvements, however, basic optical principles and their limitations have remained the same over the last the decades. The use of the endoscope in various surgical procedures was extrapolated to otologic surgery, and the diagnostic and photographic use of that instrument in the examination of the tympanic membrane and the ear canal has been widely publicized.[2] Transtympanic middle ear endoscopy was initially reported by Nomura[3] and Takahashi and colleagues.[4] Poe and Bottrill[5] used transtympanic endoscopy for the confirmation of perilymphatic fistula and the identification of other middle ear pathologic conditions. Kakehata and colleagues[11–13] used microendoscopy and transtympanic endoscopy for evaluation of conductive hearing loss and inspection of retraction pockets. Thomassin and colleagues[1] reported on operative ear endoscopy for mastoid cavities and designed an instrument set to be used for that purpose. Badr-el-Dine[14] and El-Messelaty and colleagues[15] reported on the value of endoscopy as an adjunct in cholesteatoma surgery and documented a reduced risk of recurrence when the endoscope was used. The reduction in residual disease was further confirmed by Yung[16] and Ayache and colleagues.[17] Abdel Baki and colleagues[18] reported on using the endoscopic technique to evaluate disease within the sinus tympani. Mattox[19] reported on endoscopy-assisted surgery of the petrous apex. Magnan and Sanna,[20] Bader-el-Dine and colleagues, El-Garem and colleagues,[21–23] and Rosenberg and colleagues[24] reviewed the role of the endoscope in neuro-otologic procedures. McKennan[6] described second-look endoscopic inspection of mastoid cavities achieved through a small postauricular incision. More recently, Presutti and colleagues[25] and Marchioni and colleagues[26] described primary transcanal endoscopic ear surgery using a similar approach to the experience reported here.

INSTRUMENTATION

In the procedures described in this article, 4-mm wide-angle 0-degree and 30-degree Hopkins II telescopes that were 18 cm in length were most often used. More recently, a smaller 3-mm endoscope with a similar field of view to the 4-mm endoscope is being used. Other smaller diameter scopes were used sparingly. Video equipment consisted of a 3-chip video camera and a monitor. All procedures were performed directly off the monitor and were recorded. Instruments used in conjunction with routine microscopic ear surgery are shown in **Fig. 1**.

DISCUSSION

The rationale advantages and limitations, and the technique and long-term results of endoscopic transcanal management of limited cholesteatoma, endoscopic open cavity management of cholesteatoma, and expanded transcanal access to the middle ear and petrous apex are discussed in the following sections.

Rationale for Endoscopic Ear Surgery

Acquired cholesteatoma is usually a manifestation of advanced retraction of the tympanic membrane, which occurs when the sac advances into the tympanic cavity proper and then into its extensions, such as the sinus tympani, the facial recess, the hypotympanum, and the attic.[27] Only in advanced cases does a cholesteatoma progress further to reach the mastoid cavity proper. Most surgical failures associated with a postauricular approach seem to occur within the tympanic cavity and its hard-to-reach extensions rather than in the mastoid.[28,29] Therefore, the most logical approach to the excision of a cholesteatoma involves transcanal access to the tympanic membrane and tympanic cavity and the subsequent step-by-step pursuit of the sac as it passes through the middle ear. Mainstream ear surgery has usually involved the mastoid and the postauricular approaches because operating with the microscope through the auditory canal is a frustrating and almost impossible process.

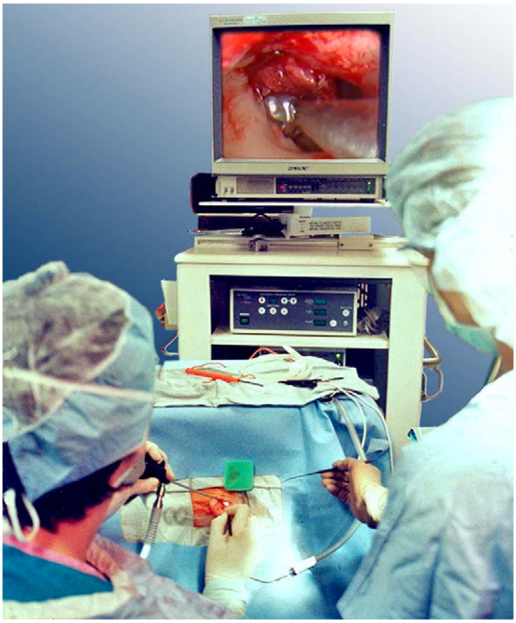

Fig. 1. Operating room setup. The surgeon is operating while watching the monitor, which is positioned across the operating room table. The surgical assistant also has a clear view of the monitor.

Advantages and Limitations

The view during microscopic surgery is defined and limited by the narrowest segment of the ear canal (**Fig. 2**). This basic limitation has forced surgeons to create a parallel port through the mastoid to gain keyhole access to the attic, the facial recess, and the hypotympanum (**Fig. 3**). In contrast, transcanal operative endoscopy bypasses the narrow segment of the ear canal and provides a wide view that enables surgeons to look around the corner, even when a 0-degree endoscope is used (see **Fig. 2**). Another anatomic observation that supports transcanal access to the attic, which is the most frequent site of cholesteatoma,[30] is the orientation of the ear canal in relation to the attic. **Fig. 4** shows a coronal computed tomographic (CT) section through the temporal bone, which reveals that an axis line drawn through the ear canal ends in the attic rather than the mesotympanum. The only structure that is in the way is the scutum, and its removal allows wide and open access to the attic, which is the natural cul de sac of the external auditory canal. Rediscovering the ear canal as the access port for cholesteatoma surgery is the main story and the main advantage of endoscopic ear surgery. This approach allows more natural and direct access to and pursuit of cholesteatoma within the middle ear cleft. In contrast, traditional approaches to the attic and facial recess have provided primarily keyhole access through postauricular mastoidectomy, and many surgeons use the ear canal to access the anterior part of the attic, even during postauricular tympanomastoidectomy. Other areas, such as the hypotympanum and sinus tympani, are minimally accessible even with extensive postauricular mastoidectomy. The wide view provided by the endoscope enables minimally invasive transcanal access to all those areas and facilitates the complete extirpation of disease without the need for a postauricular approach or incision.

Transcanal Endoscopic Anatomy of the Tympanic Cavity

As discussed earlier, the transcanal endoscopic approach provides a new way of looking at the anatomy of the tympanic cavity and, more specifically, the cholesteatoma-bearing areas of that cavity. The endoscope also allows a better

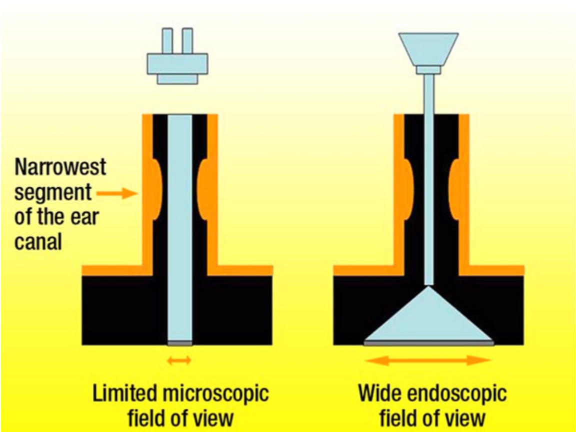

Fig. 2. The view from the microscope during transcanal surgery is defined and limited by the narrowest segment of the ear canal. In contrast, the endoscope bypasses this narrow segment and provides a wide view that allows the surgeon to look around corners, even when the 0-degree scope is used.

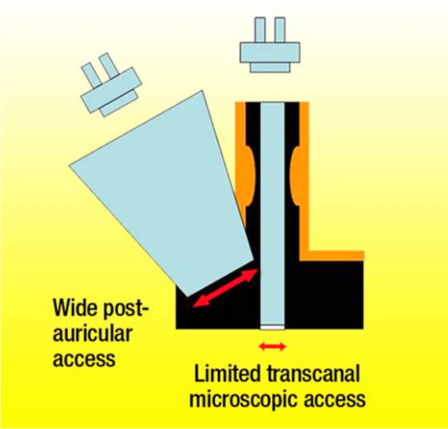

Fig. 3. The limited view provided by the microscope during transcanal procedures has forced surgeons to perform postauricular mastoidectomy, in which a port parallel to the attic is created after a considerable amount of healthy bone has been removed to enable anterior keyhole access to the attic.

understanding of the ligaments and folds of the middle ear and how they affect ventilation of these different spaces. This section highlights the anatomy of some areas and reviews the concept of the epitympanic diaphragm, which plays an important role in the pathophysiology of attic cholesteatoma.[31–33]

Facial recess

Using the transcanal endoscopic approach, the facial recess becomes an accessible and shallow depression on the posterior wall of the tympanic cavity (**Fig. 5**). In contrast, the postauricular posterior tympanotomy provides keyhole access to this important area. The pyramidal eminence, along with the vertical segment of the facial nerve, forms the medial wall of the recess and helps to mark the depth of the vertical segment of the facial nerve in that area. The bony annulus that forms the lateral wall of

Fig. 4. A coronal CT section of the temporal bone shows that an axis line drawn through the ear canal ends in the attic rather than the mesotympanum. This almost universal anatomic orientation enables a natural transcanal access to the attic.

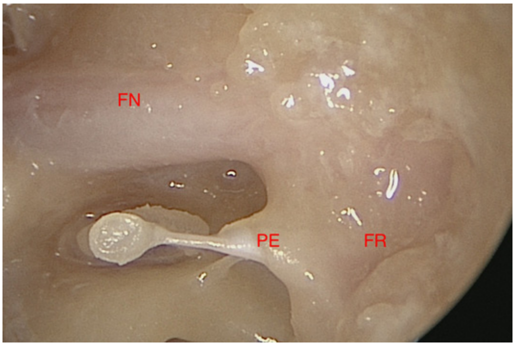

Fig. 5. Left ear. Endoscopic view through transcanal endoscopic access after minor removal of bone; the facial recess (FR) is shallow and more of a flat depression, more or less at the same level as the pyramidal eminence (PE) and the vertical segment of the facial nerve (FN).

the recess can be taken down safely as long as the pyramidal eminence is continuously observed. The relationship of the bony annulus to the vertical segment of the facial nerve is variable moving inferiorly beyond the pyramidal eminence, and great care should be taken when removing bone from the inferior/posterior aspect of the ear canal and bony annulus.

Retrotympanum When observing the anatomy of the retrotympanum, it is useful to start by identifying the footplate and the round window. The footplate is located within the posterior sinus that extends around it and posterior to it. The round window is located within the sinus subtympanicum that extends posterior and inferior to it. In between these 2 sinuses lies the sinus tympani (**Fig. 6**). It is a useful exercise during surgery to start superiorly with the posterior sinus and the footplate, and move inferiorly, identifying the ponticulus, the sinus tympani, the subiculum, and ending up with the sinus subtympanicum where the round window is located (**Fig. 7**). Inferior to that is the hypotympanum, which is separated from the sinus subtympanicum by the finiculus (**Fig. 8**).

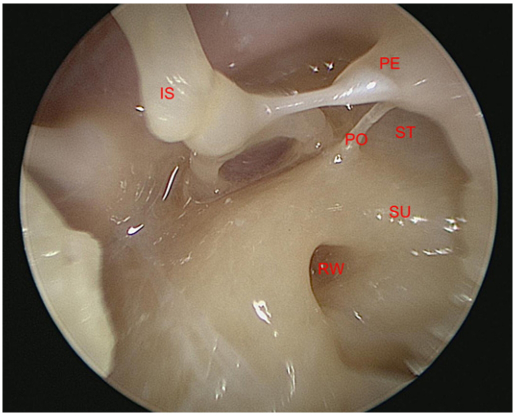

Fig. 6. Left ear: View of the retrotympanum. IS, incudostapedial joint; PE, pyramidal eminence; PO, ponticulus; RW, round window; ST, sinus tympani; SU, subiculum.

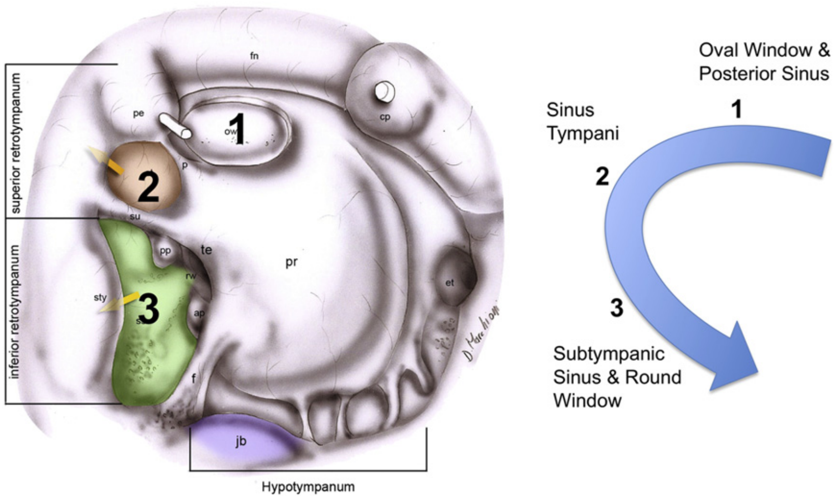

Fig. 7. The retrotympanum in a right ear. It is useful to start superiorly at the oval window and move inferiorly: from the posterior sinus, then the sinus tympani, the sinus subtympanicum, and the hypotympanum. Fn, facial nerve; jb, jugular bulb; p, ponticulus; pr, promontory; sty, styloid prominence; su, subiculum; te, temen of the round window.

Attic The attic forms a compartment that is distinct and separate from the mesotympanum both anatomically and in terms of aeration. Attic retraction pockets present often as an isolated finding with normal ventilation and findings within the mesotympanum. The concept of the epitympanic diaphragm had been advocated and advanced by many clinicians, histologists, and pathologists.[31–33] However, this concept did not make much of an inroad on the clinical side because of the difficulty in communicating and understanding the difficult anatomy. The endoscope allows a much better understanding of the anatomy of the attic and the reason that this area is distinct and separate from the rest of the middle ear in terms of ventilation.

The attic is a reasonably busy place with the bulk of the ossicular chains and many suspensory ligaments and folds. In the lateral attic, the lateral incudomallear and the

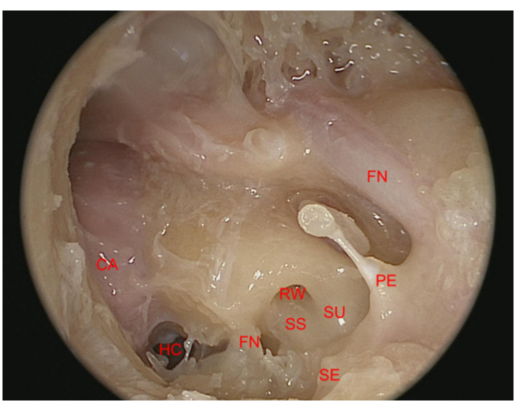

Fig. 8. Left ear: the tympanic cavity with special attention to the retrotympanum. CA, carotid artery; FN, facial nerve; FN, finiculus; HC, hypotympanic air cell; RW, round window; SE, styloid eminence; SS, sinus subtympanicus; SU, subiculum.

lateral mallear folds form a lateral wall that does not allow for ventilation of the attic via the mesotympanum laterally (**Fig. 9**). The anterior part of these lateral folds forms the medial wall of the Proussak space. The anterior attic is often separated from the anterior mesotympanum and the eustachian tubes by the tensor tympani folds. There are 2 main variations of this structure. The first is an almost horizontal orientation where the folds attach to the tensor tendon posteriorly and to the tympanic wall anteriorly close to the anterior tympanic spine (**Figs. 10** and **11**). The second is when the supratubal recess is well developed and it pushes the folds almost to a vertical position (**Fig. 12**). The attic and the supratubal recess are 2 distinct areas anatomically and developmentally. Anatomically, the supratubal recess is often a smooth-walled cavity; in contrast, the attic wall has numerous tags and excrescences. These 2 areas are separated by the transverse crest, a semicircular bony ridge that starts at the medial wall of the attic, runs across the roof, and then the lateral wall of the attic (**Fig. 13**). Its medial limb starts from the area of the cochleariform process and forms the cog, a commonly recognized surgical term, and a bony protrusion on the medial anterior attic wall (see **Fig. 13**).[34]

Developmentally, the middle ear spaces are formed from 4 pouches or sacs (saccus anticus, saccus medius, saccus superior, and saccus posticus) that bud out from the eustachian tube.[35] The attic is formed from the saccus medius, which divides into 3 saccules, anterior, medial, and posterior. The supratubal recess may be formed by the saccus anticus. The anterior saccule of the saccus medius meets the slower growing saccus anticus at the level of the semicanal of the tensor tympani, thus forming the horizontally lined tensor tympani fold. The space thus formed above the tensor fold and anterior to the tensor tendon is the anterior attic compartment.[36] Alternatively; the saccus anticus may occasionally extend upward to the tegmen, pushing the tensor fold into an almost vertical position and in the process, forming a well-developed supratubal space.[36] The expansion from the bony eustachian tube to form the supratubal recess begins at a late fetal stage and continues throughout childhood.[37] By contrast, growth of the tympanic cavity, the attic, and the mastoid antrum is virtually complete by birth.[38]

In the presence of an intact tensor fold, there is a fully formed diaphragm that separates the attic from the mesotympanum (**Fig. 14**). This diaphragm is formed by the lateral incudomallear and mallear folds laterally and the tensor folds anteriorly. The only ventilation port is through the anterior and posterior isthmus. The anterior isthmus is the area in between the incudostapedial joint and the tensor tympani tendon

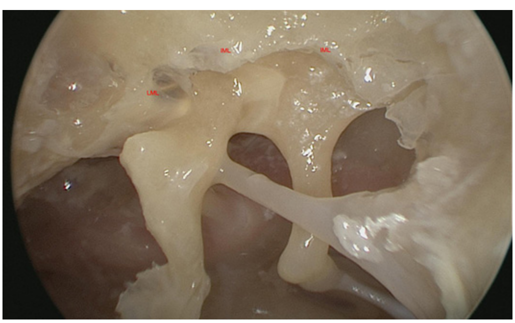

Fig. 9. Left ear: the lateral attic is closed off from the mesotympanum by the lateral incudomallear and mallear ligament. Not the relatively straight insertion line of the lateral incudomallear ligament (IML) and the downward sloping insertion line of the lateral mallear ligament (LML).

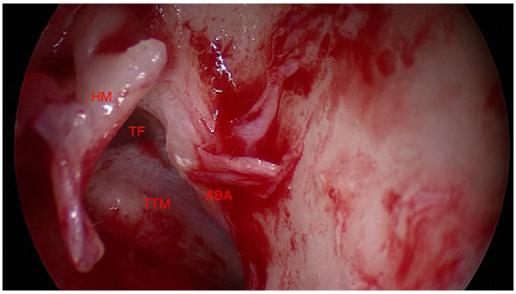

Fig. 10. Right ear: poorly developed supratubal recess in a surgical case. Using a 70° endoscope and looking up and backward. The tensor fold in these settings is almost a horizontal structure. ABA, anterior bony annulus; HM, handle of malleus; TF, tensor fold; TTM, tensor tympani muscle.

(**Fig. 15**).[32] The posterior isthmus is the area posterior to the incudostapedial joint and is often extremely narrow and has many other structures such as the chorda and the pyramidal eminence. So the anterior isthmus, or the isthmus is the main point of attic ventilation with a long channel that extends medial to the ossicles and then superior to the ossicles to ventilate the lateral and anterior attic (**Fig. 16**). This long channel is also populated by other partial folds and suspensory ligaments that provide other opportunities for impaired ventilation.

Basic Techniques and Management Algorithm

There are 3 basic approaches to the endoscopic management of cholesteatoma that echo the principles and lessons learned from traditional tympanomastoid surgical procedures. These are:

1. Transcanal management of limited cholesteatoma
2. Open endoscopic management of cholesteatoma
3. Extended transcanal approach to cholesteatoma

Although preoperative planning based on high-resolution CT and endoscopic examination is important, the decision is finally made in the operating room and patients needs to understand the range of possible interventions. The first question to be answered is whether the ear canal is an adequate port for the complete removal

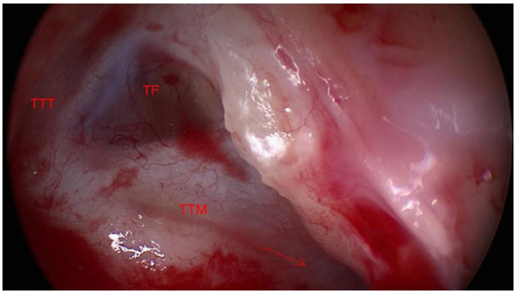

Fig. 11. Right ear: close up view of the tensor fold (*arrow*) seen in **Fig. 32**. TF, tensor fold; TTM, tensor tympani muscle bony encasement; TTT, tensor tympani tendon inserting on the neck of the malleus.

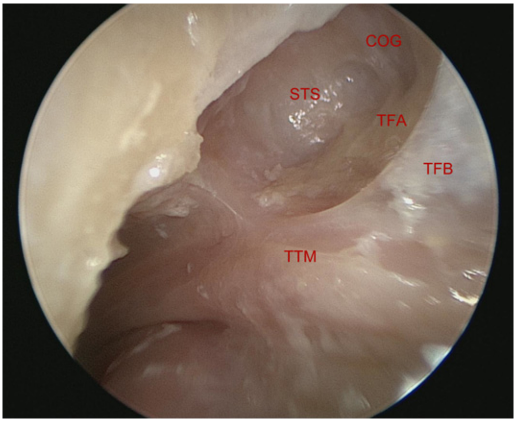

Fig. 12. Left ear: the anatomy of the tensor fold in a specimen with a well-developed supratubal recess. The tensor fold is composed of 2 segments, a vertical part that attaches to the cog and a horizontal part that forms a partial floor of the supratubal recess. COG, the surface of Sheehy's cogs, which separate the supratubal recess from the anterior attic; STS, supratubal recess; TFA, the vertical segment of the tensor fold, which, when complete, closes off the attic from the eustachian tube; TFB, the horizontal segment of the tensor fold that forms a partial floor of the supratubal recess anteriorly; TTM, tensor tympani muscle's bony encasement.

of cholesteatoma. If the answer is yes, then a wide tympanomeatal flap is elevated, atticotomy is performed, the sac is identified, and pursued along with removal of overhanging bone, basically all the steps involved in the section on endoscopic management of limited cholesteatoma. If the answer is no, then the ear canal access is improved through an extended transcanal approach by removing the skin and enlarging the canal.

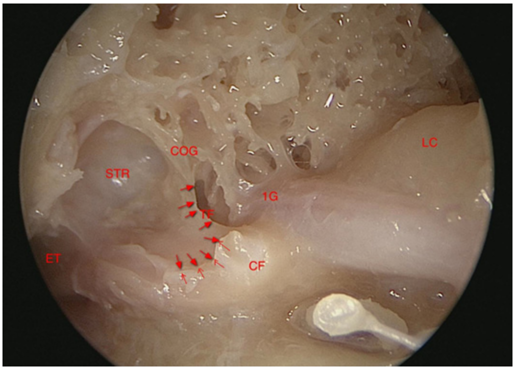

Fig. 13. Left ear: the tensor tendon is transected and the handle of the malleus is removed, as well as the anterior spine, anterior mallear ligament, and the corda tympani. Note the distinction between the smooth wall of the supratubal recess and the numerous tags and excrescences of the anterior attic. 1G, first genue of the facial nerve and neighboring geniculate ganglion; CG, cochleariform process; COG, Sheehy's cog; ET, eustachian tube; LC, lateral semicircular canal; STR, supratubal recess; TM, remnant tensor fold. Solid arrows, insertion point of the completely removed horizontal segment of the tensor fold; thin arrows, insertion point of the partially removed vertical segment of the tensor fold.

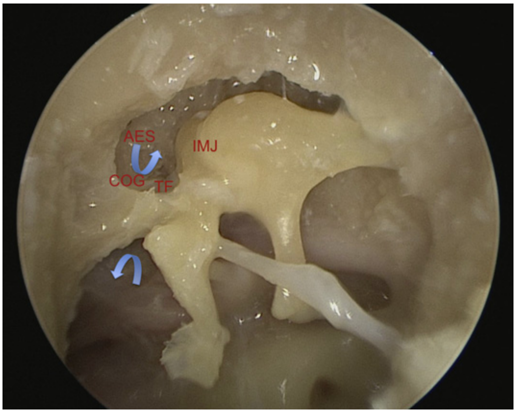

Fig. 14. Left ear: the anterior attic is separated from the supratubal recess and the eustachian tube by the tensor fold, so there is no direct communication or ventilation anteriorly between the attic and the eustachian tube.

The issue of the mastoid needs to be addressed. A limited cholesteatoma that extends to the aditus antrum can be completely removed through a transcanal approach. If the mastoid is involved, then a decision needs to be made whether the disease can be addressed through a postauricular mastoidectomy or whether it can be exteriorized by endoscopic open cavity management of cholesteatoma with aggressive bone removal superiorly and posteriorly all the way to the mastoid cavity proper (**Fig. 17**).

Endoscopic Transcanal Management of Limited Cholesteatoma

The attic (especially its anterior part) is poorly visualized via traditional approaches. An endoscopic approach enables the surgeon to retrace the sac, starting from the mesotympanum and continuing through its twists and turns around the ossicles and ligaments. This improved access also facilitates better preservation of the ossicles while

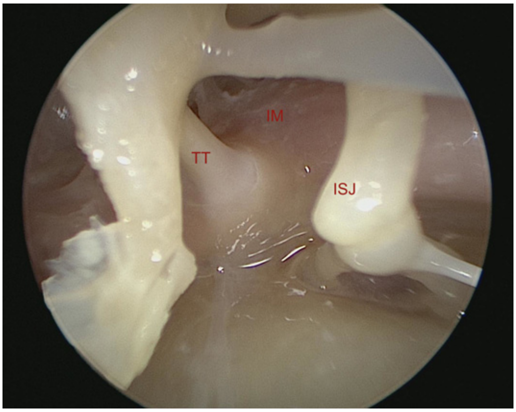

Fig. 15. Left ear: IM, the isthmus forms the only pathway for attic ventilation in the presence of a complete tensor fold. ISJ, incudostapedial joint; TT, tensor tympani tendon.

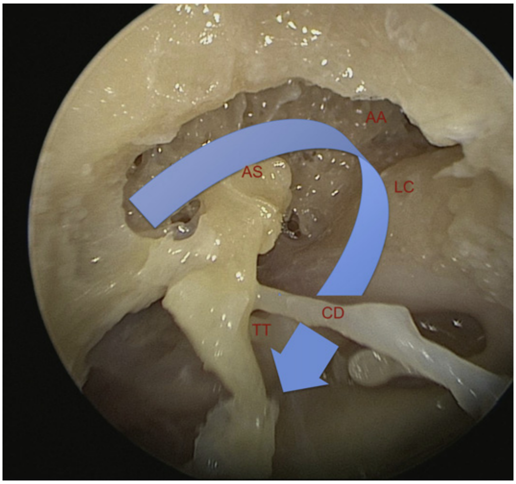

Fig. 16. Left ear: the incus has been removed to demonstrate the long narrow channel for ventilation of the attic through the isthmus, medial attic, and the upper attic.

ensuring complete removal of the matrix in toto rather than piecemeal and through different access ports.

Technique

A wide posterior tympanomeatal flap is elevated. The sac is then pursued under direct vision, and the bony rim is curetted or drilled just enough to enable dissection to continue under direct vision. Appropriate ossicular chain work is performed, and the attic defect is closed by means of a composite tragal graft.

Results

Seventy-three ear procedures were performed on 69 patients; 65 of those individuals underwent unilateral surgery. The results of preoperative CT scanning of the temporal bone, which was performed on 46 ears, suggested cholesteatoma with the presence of bony erosion in 26 ears. Seven ears showed evidence of total opacification of the middle ear and mastoid air cells (without bone erosion), and isolated opacification of the middle ear and attic was evident in 11 ears. The results of audiologic testing showed an air-bone gap of 20 dB or more in 51 ears. The transcanal endoscopic approach was adequate for the removal of disease in all patients. There were no iatrogenic facial nerve injuries. Bone thresholds were stable; ie, no change of 10 dB or more was noted in average bone conduction thresholds at 500, 1000, 2000, or 3000 Hz. In 24 ears, the cholesteatoma was dissected from the malleus head and the body of the incus, both of which were preserved. The incus or its remnant was removed in 49 ears, and the head of the malleus was removed in 43 ears. Primary ossicular reconstruction was performed in 38 ears and was delayed in 17 ears. Follow-up was performed at 43 months, on average. Revision for recurrent and clinically evident disease was performed on 5 ears. In 8 ears, a revision procedure was performed to correct a failed ossicular reconstruction or a persistent perforation. In 1 of those reconstruction failures, a small incidental pearl attached to the underlayer of the tympanic membrane was noted. Moderate-to-severe retraction in other areas of the tympanic membrane was evident in 28 patients, none of whom required further intervention.

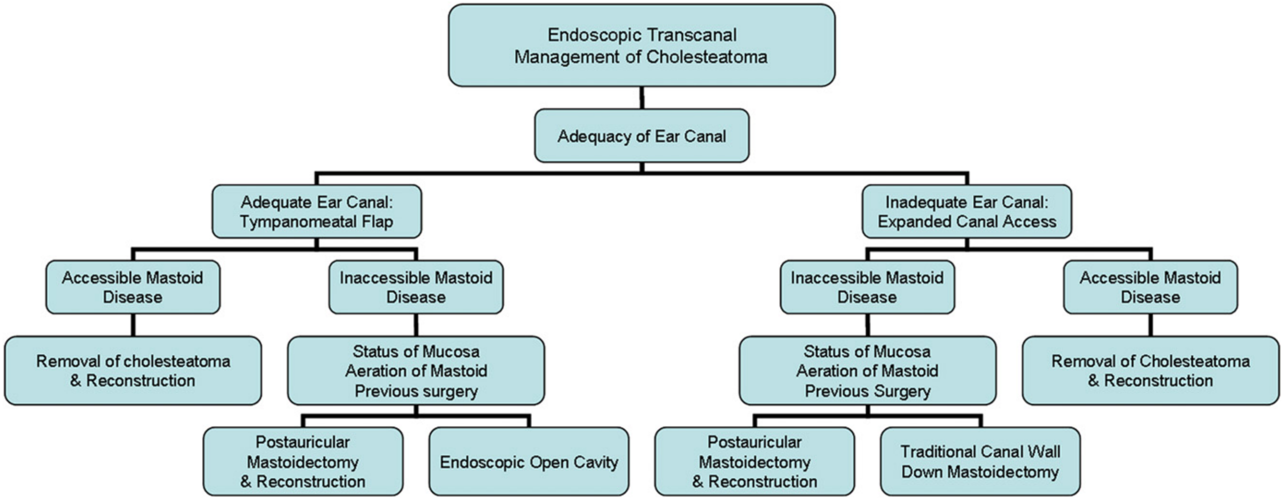

Fig. 17. The management algorithm for endoscopic transcanal management of cholesteatoma.

Case presentation: endoscopic transcanal approach

The initial evaluation of a 46-year-old man with a long-standing history of problems showed severe retraction bilaterally and some granulation tissue and drainage from the right ear. After a week of medical treatment, his right ear showed clear evidence of severe retraction and debris within the cholesteatoma sac (**Fig. 18**). An endoscopic transcanal approach was undertaken, a wide tympanomeatal flap was elevated, and the middle ear was entered (**Fig. 19**). A wide atticotomy was performed with a curette (**Fig. 20**). The cholesteatoma sac was identified; it extended to the lateral attic and was pulled downward laterally to the body of the incus and medially to the removed scutum (**Fig. 21**). Another process of the sac had rotated posteriorly and medially around the incudostapedial joint and the superstructure of the stapes and had advanced medially to the long process of the incus (**Fig. 22**). The sac was pulled out completely and was deflected (**Fig. 23**). It was evident that the sac had eroded the incudostapedial joint (**Fig. 24**). A prosthesis was used to reconstruct the ossicular chain (**Fig. 25**). A piece of tragal composite graft with excess perichondrium was used to reconstruct the attic defect (**Fig. 26**). The tympanic membrane defect was reconstructed with a perichondrial underlay graft, and the tympanomeatal flap was repositioned (**Fig. 27**). The patient experienced an uneventful postoperative course. One month after the procedure, his tympanic membrane was intact, his hearing was good, and he returned to duty.

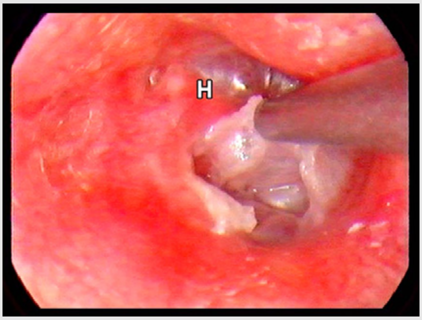

Fig. 18. Right ear: note the retraction and cholesteatoma. H, handle of malleus.

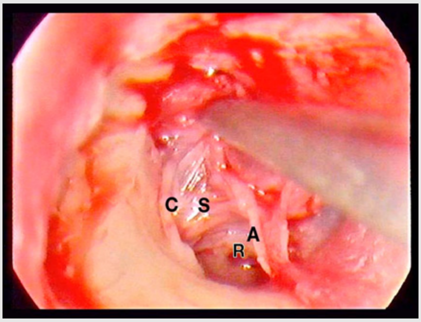

Fig. 19. Right ear: the tympanomeatal flap has been elevated, the middle ear has been entered, and the cholesteatoma sac has been exposed. A, annulus; C, chorda tympani; R, round window; S, cholesteatoma sac.

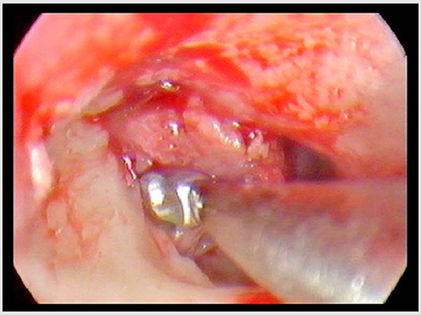

Fig. 20. Right ear: a wide atticotomy is performed with a curette.

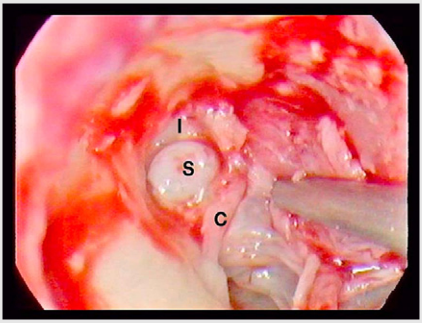

Fig. 21. Right ear: the sac (S) has been pulled down from the attic, lateral to the body of the incus, and medial to the scutum. The body of the incus (I) can be seen. The chorda (C) forms a collar around the neck of the sac.

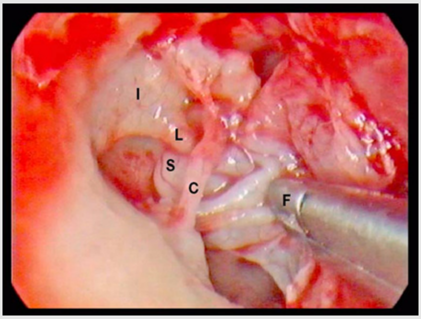

Fig. 22. Right ear: the sac has been completely pulled down from the area lateral to the body of the incus (I), but another process of the sac (S) has rotated posteriorly and medially around the incudostapedial joint and medial to the long process of the incus (L). Cuffed forceps (F) are used to pull the sac from underneath the chorda (C).

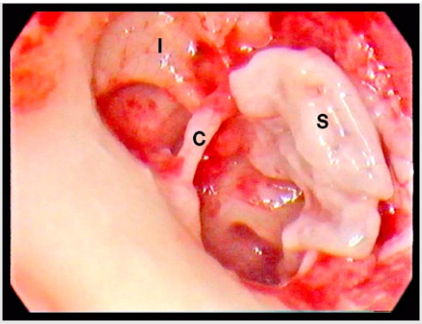

Fig. 23. Right ear: The sac (S) has been completely pulled out and deflected over the tympanomeatal flap with the incus (I) and the chorda (C) in view.

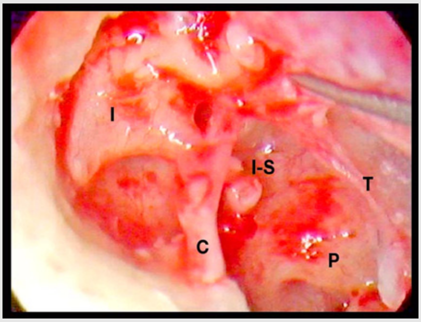

Fig. 24. Right ear: the sac is removed. The cholesteatoma has eroded the incudostapedial joint (I-S). The incus (I), the chorda (C), and the promontory (P) are clearly in view. The anterior edge of the tympanic membrane retraction (T), now a perforation, is also visible.

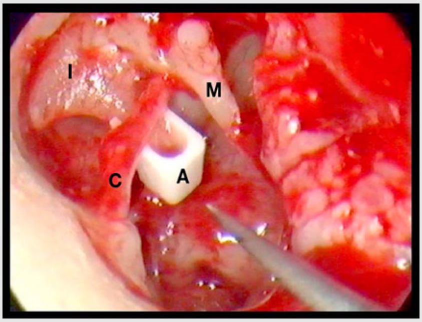

Fig. 25. Right ear: a prosthesis (A) is used to reconstruct the incudostapedial joint. The handle of the malleus (M), the incus (I), and chorda (C) are visible.

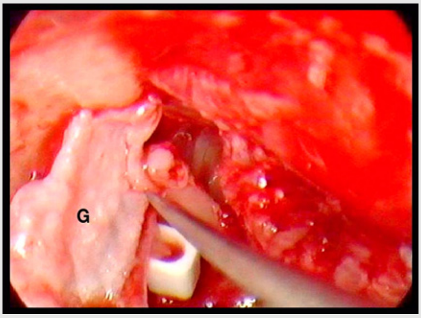

Fig. 26. Right ear: the attic defect is reconstructed by means of a composite tragal graft (G) with excess perichondrium to prevent retraction around the graft.

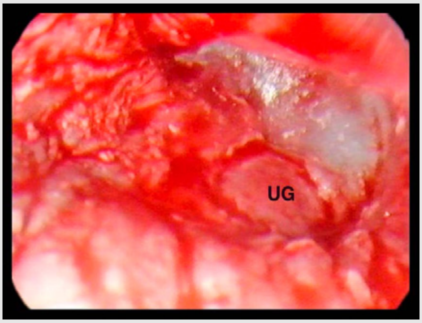

Fig. 27. Right ear: the tympanomeatal flap is repositioned over an underlay graft (UG) to reconstruct the retracted area of the tympanic membrane.

Endoscopic Open Cavity Management of Cholesteatoma

In canal wall down procedures, which have been viewed as the definitive treatment of cholesteatoma, all disease-containing cavities are exteriorized to provide natural aeration and direct access to the disease in the clinic setting. However, during the process of accessing the disease, large problematic cavities that require lifelong maintenance are created. In addition, unpredictable healing patterns, fibrosis, and closing of the meatus, which are common complications associated with postauricular canal wall down procedures, often prevent further ossicular reconstruction. Endoscopic techniques allow transcanal exploration of the disease-containing cavities without opening up areas that are not involved in the cholesteatoma. Such techniques enable the surgeon to approach and reconstruct the ear in a highly predictable fashion. This in turn creates a better framework for ossicular and partial tympanic membrane reconstruction.

The transcanal endoscopic approach opens up only diseased areas, preserves many healthy air cells, and leaves the cortical bone intact. It also allows for the creation of 2 independent cavities: the small reconstructed tympanic cavity that conducts sound in the middle ear and is small enough to be serviced by the usually dysfunctional eustachian tube, and the larger attic, antrum, and mastoid cavities, which are joined to the ear canal and are exteriorized (**Fig. 28**). Such an approach was described by Tos[27] in 1982. The main concern of many surgeons is the possibility of closing the open attic. That concern is driven by the results of traditional open surgery of the mastoid, in which damage to the cartilaginous portion of the ear canal produces a vicious circle: Trauma to the ear canal results in fibrosis and narrowing of the meatus, which forces the surgeon to design a more aggressive meatoplasty, which in turn results in more trauma, secondary fibrosis, and narrowing. A huge meatus must be created to compensate for that eventual fibrosis and narrowing. In contrast, the limited trauma to the cartilaginous ear canal caused by endoscopic surgery allows surgeons to avoid those complications and results in small, shallow, benign, problem-free cavities.

Technique

In endoscopic open cavity management of cholesteatoma, the wide posterior tympanomeatal flap is elevated as described earlier. A transcanal atticotomy is performed. The attic is then emptied from the incus and the head of the malleus. Aggressive bone removal is then performed to provide open endoscopic access into the attic and all the way posteriorly into the antrum. Tympanic membrane defects inferior to the horizontal segment of the facial nerve (including atelectatic areas) are

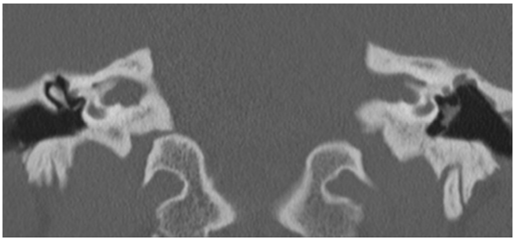

Fig. 28. Coronal CT views of a patient who underwent endoscopic open cavity management of a cholesteatoma in the left ear. Compare the normal ear to the left operated ear. The neotympanic membrane (NT) is reconstructed up to the level of the horizontal segment of the facial nerve (FN), and the attic is left open (OA).

Case presentation: endoscopic open cavity management of cholesteatoma

The patient was 41 years old with a retraction pocket and recurrent granulation tissue. **Fig. 29** shows the large attic retraction pocket after it was emptied of dermal debris. A wide tympanomeatal flap was elevated, and the thick vascularized sac can be seen after the atticotomy was extended (**Figs. 30** and **31**). The incus and the head of the malleus were removed after the incudostapedial joint was dislocated (**Figs. 32** and **33**). The anterior epitympanum was cleared of all disease. The remainder of the sac deep to the removed ossicles was removed after further widening of the atticotomy (**Fig. 34**). All disease was excised, and specific attention was paid to the attic and the tympanic cavity (**Fig. 35**). A prosthesis was used to reconstruct the ossicular chain (**Fig. 36**), and a composite cartilage graft was positioned on top of the prosthesis (**Fig. 37**). The tympanomeatal flap was divided longitudinally (**Fig. 38**). The inferior part was repositioned over the ear canal, the superior part was draped over the horizontal segment of the facial nerve (**Fig. 39**), and the attic was packed open.

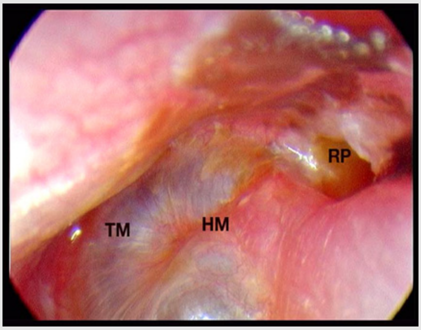

Fig. 29. Left ear: a large retraction pocket (RP) with evidence of recurrent prior episodes of infections and the formation of granulation tissue. HM, handle of malleus; TM, tympanic membrane.

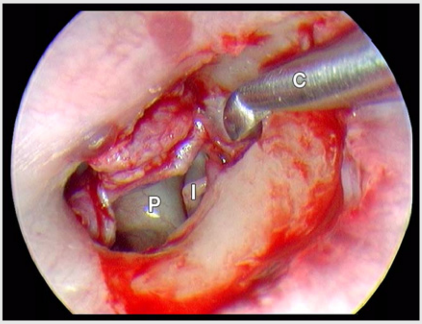

Fig. 30. Left ear: a wide tympanomeatal flap is elevated. The premonitory (P) and the incudostapedial joint (I) can be seen. A curette is used (C) to create the extended atticotomy.

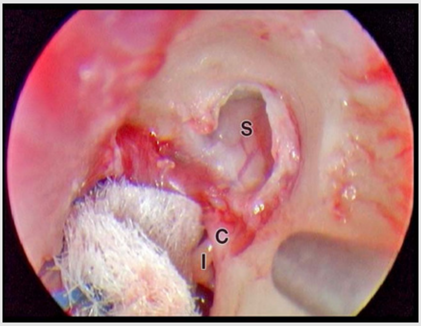

Fig. 31. Left ear: note the extended atticotomy at the thick sac (S), the chorda tympani (C), and the incudostapedial joint (I).

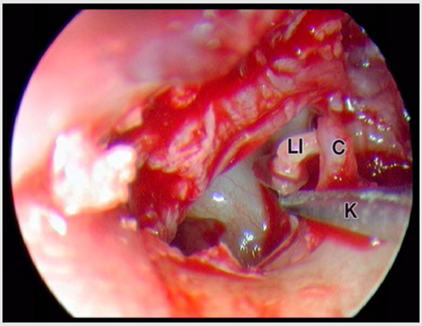

Fig. 32. Left ear: the incudostapedial joint (LI) is dislocated with a small round knife (K). C, chorda tympani.

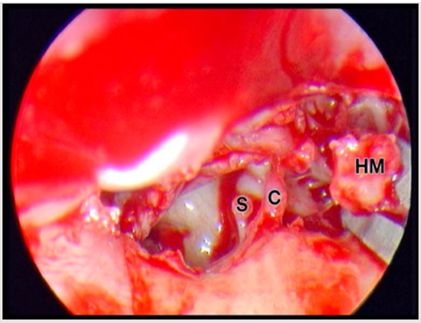

Fig. 33. Left ear: the incus has been removed, and the head of the malleus (HM) is extracted. Note that the head of the malleus is separated from the handle by means of a malleus nipper at a proximal site to preserve the ligaments stabilizing the handle of malleus. C, chorda tympani; S, stapes.

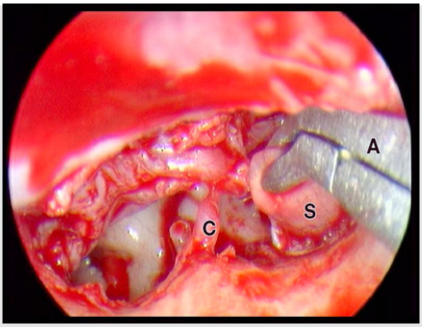

Fig. 34. Left ear: the thick sac (S) is being pulled with an alligator forceps (A). C, chorda tympani.

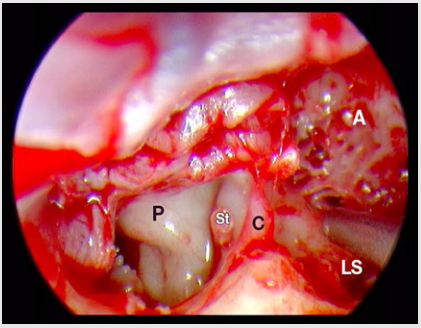

Fig. 35. Left ear: the sac has been removed completely. A, attic; C, chorda tympani; LS, lateral semicircular canal; P, promontory; S, stapes.

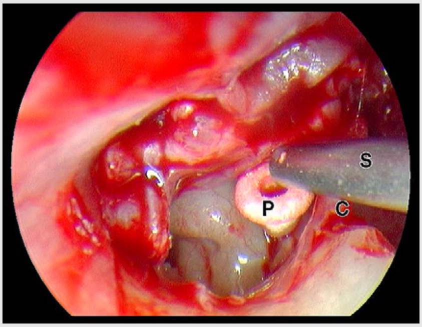

Fig. 36. The ossicular chain is reconstructed with the use of a prosthesis (P). C, chorda tympani; S, suction.

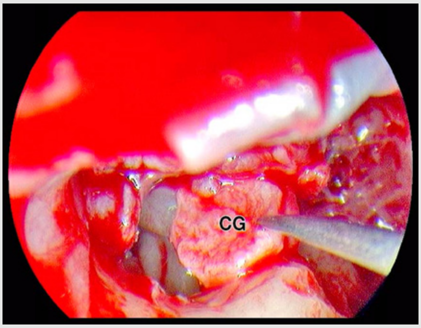

Fig. 37. Left ear: composite tragal cartilage (CG) is used on top of the prosthesis.

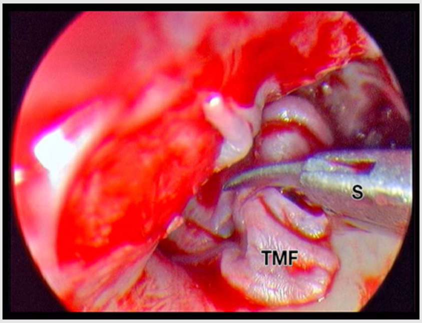

Fig. 38. Left ear: the tympanomeatal flap is cut longitudinally with middle ear scissors.

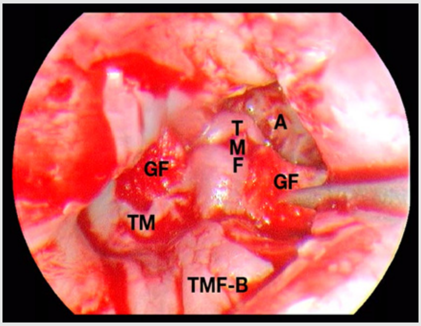

Fig. 39. Left ear: the inferior part of the tympanomeatal flap (TMF-B) is repositioned over the ear canal while the superior part of the tympanomeatal flap (TMF) is reflected over the horizontal segment of the facial nerve into the open attic (A). Small pieces of Gelfoam (GF) are used to pack the open attic and ear canal. TM, tympanic membrane.

reconstructed with a perichondrial graft, which is placed directly on, and up to, the horizontal segment of the facial nerve superiorly and on a bed of Gelfoam that is packed in the middle ear inferiorly. The ear canal and the open attic are then packed with Gelfoam. This technique should result in a small, closed, reconstructed tympanic cavity and membrane anteriorly and inferiorly (to service the impedance-matching function of the middle ear) and an open attic and antrum posteriorly and superiorly (see **Fig. 28**).

Results

Eighty-five ear procedures were performed on 78 patients. There were no iatrogenic facial nerve injuries. Bone thresholds were stable (stability was defined as no change of 10 dB or more in average bone conduction thresholds at 500, 1000, 2000, and 3000 Hz) except in 1 patient who presented preoperatively with depressed bone thresholds, vertigo, and a perilymphatic fistula. The mean follow-up was 32 months. Closure of the air-bone gap to within 20 dB was accomplished in 47 ears. Six ears required revision

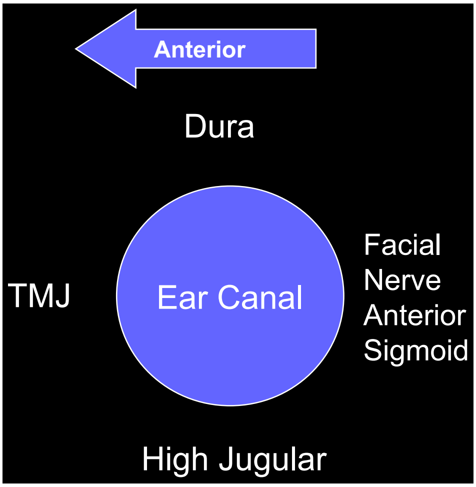

Fig. 40. Structures to be considered when enlarging the ear canal. TMJ, tympanomeatal flap.

Case presentation: expanded transcanal access to the middle ear and petrous apex

A 36-year-old man presented with a long-standing history of right hearing loss and dizziness. Examination showed an anterior whitish lesion behind the tympanic membrane (**Fig. 41**). Audiometry indicated a dead ear on the right, normal hearing on the left. CT of the temporal bone showed extensive petrous bone cholesteatoma eroding the cochlea and the carotid artery (**Fig. 42**). Using the expanded transcanal access technique, the vascular strip was preserved, the ear canal skin was removed, the fibrous layer of the tympanic membrane was preserved, and the ear canal was then enlarged (**Fig. 43**). The extensive cholesteatoma had eroded the bony encasement of the sinus tympani muscle and carotid and had eroded the middle and apical turns of the cochlea (**Fig. 44**). The cholesteatoma was completely removed from the apex of the petrous bone (**Fig. 45**).

Fig. 41. Right ear with an anterior whitish lesion behind an intact tympanic membrane.

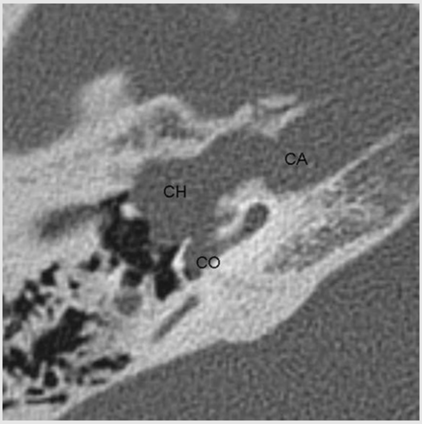

Fig. 42. Right ear: axial CT images of the temporal bone. CO, basal turn of the cochlea; CA, carotid artery; CH, cholesteatoma.

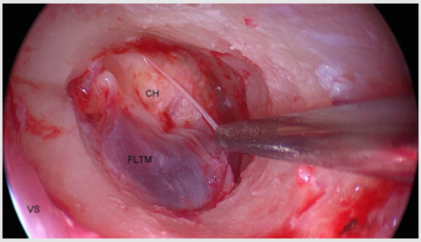

Fig. 43. Right ear: the skin of the ear canal is elevated in contiguity with the epithelial layer of the tympanic membrane with preservation of the vascular strip and then enlargement of ear canal. CH, cholesteatoma; FLTM, fibrous layer of tympanic membrane; VS, vascular strip.

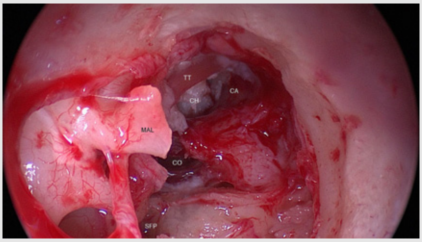

Fig. 44. Right ear: much of the cholesteatoma eroding the cochlea has been removed. CA, eroded carotid artery canal; CH, cholesteatoma in the petrous apex surrounding the tensor tympani muscle (TT); CO, the eroded middle turn of the cochlea; MAL, malleus with the handle transected; SFP, stapes footplate.

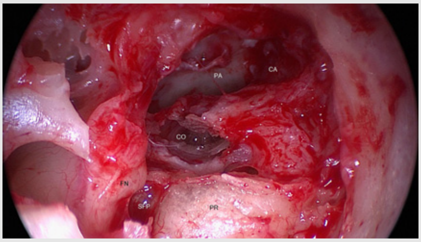

Fig. 45. Right ear: the view after complete removal of a cholesteatoma. CA, carotid artery; CO, eroded middle turn of cochlea; FN, dehiscent facial nerve; PA, petrous apex; PR, promontory; SFP, stapes footplate.

surgery, Four of the surgical failures resulted from complete closure of the open attic by a growth of overlying skin rather than by a step-by-step narrowing of the atticotomy. This complication was usually evident early in the postoperative course and was managed by re-excising the overlying skin in a simple procedure.

Expanded Transcanal Access to the Middle Ear and Petrous Apex

Although the use of the endoscope allows much expanded transcanal access to the middle ear compared with the microscope, the ear canal in some patients can be so limiting in size and angulation that adequate exposure is not possible. Addressing these limitations before addressing the disease is essential for performing adequate and safe endoscopic procedures. In addition, this approach provides wide access to disease within the anterior middle ear, eustachian tube, and the petrous bone.

Technique

After evaluation of the limiting elements in the ear canal in relation to location of the disease, a decision is made on whether to address these limitations. The location of disease and its extent is determined by endoscopic examination and review of CT of the temporal bone. Anterior middle ear, eustachian tube, and significant disease within the hypotympanum often require an expanded transcanal approach. When enlarging the ear canal, the surgeon needs to be keenly aware of critical structures that lie in close proximity (**Fig. 40**). The bony annulus, the line separating the ear canal from the middle ear, has tremendous variations[39] and all the structures that border the tympanic cavity proper should be considered when enlarging the ear canal. Posteriorly, the facial nerve and an anterior sigmoid should be condsidered.[40] Inferiorly, a high jugular bulb can come lateral to and border the ear canal.[41] Breaching the glenoid fossa anteriorly is usually a nonevent, but it can present a limiting factor.

The technique echoes that of Sheehy's lateral graft tympanoplasty. The skin of the ear canal is removed along with the epithelial layer of the tympanic membrane and the vascular strip is preserved. The ear canal is enlarged as needed. The annulus and the fibrous layer of the tympanic membrane are elevated either completely or partially to provide access to the areas of interest. Then all of the overhanging bony annulus is curetted and wide access to the middle ear is gained for removal of any disease. After the necessary ossicular chain work, the remaining part of the tympanic membrane is repositioned, a lateral graft is applied, and the skin of the ear canal is repositioned and packed in place.

SUMMARY

The story of endoscopic management of cholesteatoma is that of the rediscovering the ear canal as the most logical, direct, and natural access point to cholesteatoma within the mesotympanum, attic, facial recess, sinus tympany, hpotympanum, and eustachian tube. It offers a fresh outlook on this disease and changes the surgical treatment paradigm of cholesteatoma.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at http://dx.doi.org/10.1016/j.otc.2012.10.001.

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