

Endoscopic Middle Ear Surgery in Children

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KEYWORDS

• Middle ear surgery • Pediatric otology • Cholesteatoma • Tympanoplasty

KEY POINTS

- Permeatal access to middle ear is restricted by the narrower width, but facilitated by the shorter length in younger children.
- In many cases it is the curvature of the ear canal instead of the age of the child that governs endoscopic access. Totally endoscopic middle ear surgery can be completed successfully, even in infancy.
- Endoscopic visualization of the recesses of the middle ear allows a less invasive canal wall up approach that is ideally suited to children.
- The retrotympanum is a common location for cholesteatoma in children and benefits from endoscopic removal.
- Residual cholesteatoma rates can be reduced with endoscopic inspection and dissection.
- Removal of cholesteatoma from the medial epitympanum can be completed endoscopically without disarticulating an intact ossicular chain and so improve hearing outcome.



Videos of **Endoscopic Techniques in Children** accompany this article

INTRODUCTION

The wide-angle view from the tip of a rigid endoscope provides advantages to the otologist in many aspects of pediatric care, ranging from assessment of the ear drum in clinic to minimally invasive access to the hidden recesses of the temporal bone during surgery. In clinic, the recording of endoscopic images improves accuracy in monitoring changes in tympanic membrane retraction.¹ In surgery, endoscopes are used for inspection (eg, to reveal occult remnants of cholesteatoma) but, more importantly, they can be used with angled instruments and laser to remove disease from under hidden recesses without destructive bone removal. The child benefits from the consequent reduction in residual cholesteatoma² and gain in hearing from more frequent ossicular preservation.³ An intact canal wall approach is generally favored for pediatric cholesteatoma surgery⁴ and the endoscope is an invaluable asset in the combined

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approach through ear canal and mastoid. Although access is more challenging in the smaller pediatric ear canal, totally endoscopic middle ear surgery through the canal is still appropriate in many cases, avoiding the disadvantage to the child of an external incision. The opportunities and methods for application of endoscopes to pediatric middle ear surgery are outlined in this article.

The principle advantage of a totally endoscopic surgical approach for the child is avoidance of an external incision. For the surgeon, the avoidance of a small endaural incision or of a cosmetically placed incision just behind the postauricular sulcus might seem a small advantage. However, the universal expression of relief and pleasure on the faces of parents and children on learning that it has been possible to avoid an external incision indicates that this is perceived as a significant benefit by the patient. In addition to the psychological and cosmetic benefits, more tangible advantages include the possibility of a shorter hospital stay (same day discharge can be anticipated) and faster return to the physical sports in which many children participate. These benefits are outweighed by the principles of achieving a safe dry ear, and the functional importance of an intact tympanic membrane and ossicular chain. Therefore, selection of a totally endoscopic permeal approach has to be considered carefully and not allowed to compromise the primary objectives of surgery.

The advantages to the otologist of endoscopy are clearly demonstrated throughout this issue and center around the panoramic view of the middle ear cleft that endoscopy provides. The extent to which an endoscope is used in the ear of a child depends not just on the condition of that child's ear but also on the availability of resource and experience of the otologist. With appropriate circumstances, a full range of otologic procedures can be completed in part or totally with endoscopy. The tools required are, in the main, no different from those used in adults because the middle ear and tympanic membrane approximate to adult size at birth.⁵ By starting with sinonasal endoscopes and conventional middle ear instruments, the surgeon can gradually develop the skills and experience that may then justify procurement of more specialized instruments. These in turn will facilitate development of greater expertise. So, although in the first instance the endoscope may simply be used for inspection in clinic or intraoperatively, with time it will supplement, and in some cases ultimately supplant, the microscope for pediatric middle ear surgery. This article is based on experience using the endoscope increasingly in pediatric middle ear surgery over the last decade and outlines the potential scope of pediatric otoendoscopic practice, steps for appropriate case selection, procedural tips for children's ears, and discussion of the place of endoscopy in comparison with microscopy in pediatric ear surgery.

RANGE OF ENDOSCOPIC INTERVENTIONS

It is conceivable that the scope of endoscopic applications in pediatric otologic practice will increase in the future. A wide range of interventions is currently available.

Preoperative and Postoperative Assessment

Short (6 cm) rigid endoscopes are very useful for image-capture for patient and parental education, monitoring tympanic membrane retraction, and for careful preoperative planning. Insufflation adapters allow endoscopic assessment of adherence of retracted areas (**Fig. 1**, **Video 1**). The clearer optics of the 4 mm scope are preferable for most children, though the 2.7 mm scope is occasionally necessary for the narrower meatus of young children. Although angled endoscopes can help to visualize the depths of a retraction pocket, in practice it can be difficult to get the endoscope sufficiently close to a child's tympanic membrane to be able to see deeply into a pocket.



Fig. 1. Endoscopic video of the right tympanic membrane during insufflation of the ear canal. Part of the retracted pars tensa elevates with reduction in ear canal air pressure, but a section remains adherent to the promontory by the round window niche. Of note, the deeply retracted pars flaccida is not mobile, consistent with the different ventilation pathways and mechanisms of disease in pars flaccida retraction and cholesteatoma. (Data from Marchioni D, Alicandri-Ciufelli M, Molteni G, et al. Selective epitympanic dysventilation syndrome. *Laryngoscope* 2010;120:1028.)

Any skin contact of the endoscope within the bony meatus is painful and likely to preclude further cooperation.

Intraoperative Inspection

The rigid endoscope is used by many otologists to inspect the retrotympanum or other hidden areas after microscope-guided dissection of cholesteatoma. This intervention has the potential to lower residual disease rates significantly.^{6,7} For thorough inspection, curved suckers must be used to clear blood from these areas.

Tube Insertion

Endoscopy provides excellent visualization for tube insertion, which is helpful for teaching and in settings in which a microscope is not available ([Video 2](#)). It is not practical in the youngest or syndromic children with narrow ear canals.

Tympanotomy

Elevation of a tympanomeatal flap and insertion of an angled endoscope provides a good view of the middle ear cleft and under the ossicular chain for assessment of conductive hearing loss and residual cholesteatoma. The availability of thin, angled endoscopes (eg, 1.7 mm 30°) makes it possible to achieve limited inspection of the middle ear cleft through a myringotomy.

Tympanoplasty and Cholesteatoma

The full range of tympanoplasty techniques is used in pediatric tympanoplasty.⁸ A simple patch myringoplasty or a butterfly graft is ideal for tympanostomy tube site perforations. Underlay or lateral onlay techniques can both be completed endoscopically for larger pediatric perforations. The endoscope is especially beneficial in

surgery for tympanic membrane atelectasis because direct visualization for elevation of the retraction from the retrotympanum is provided.

As foreseen by Tarabichi,⁹ the endoscopic approach remains most valuable in tympanoplasty and cholesteatoma surgery (see later discussion).

Other

Petrous apex lesions and perilymph leak are rare in children but can be approached endoscopically. Endoscopic visualization of the Eustachian tube¹⁰ and cochlea¹¹ may prove valuable in future.

CASE SELECTION

As in all aspects of surgery, good results can only be anticipated from appropriate case selection. It can be hard to determine preoperatively whether an entirely endoscopic approach will be possible, or even appropriate, in any given pediatric patient. Therefore, it is important to obtain consent for an external incision in case it is needed. Several variables influence the likelihood of a successful, totally endoscopic approach.

Morphology of the External Auditory Meatus

The width, length, and tortuosity of the ear canal, particularly the bony portion, determine the feasibility of endoscopic access. A meatus narrower than the 4.5 mm speculum is likely to resist an endoscopic permeal approach. The bony meatus is narrower in young children, restricting access for instruments alongside the endoscope; however, it is also shorter, which increases the angulation and range of movement achievable. A deep anterior recess or prominent hump on floor of meatus can significantly impede access, though bone can be removed with curettage to improve access if necessary. Piezoelectric bone removal may prove effective (see the article by Badr-El-Dine and colleagues elsewhere in this issue), but drilling of bone is limited by the challenges of clearing irrigation fluid and spray. As shown in (Fig. 2), individual configuration of these proportions is more important than age in determining access and totally endoscopic middle ear surgery can be completed successfully even in infancy. The author's personal experience includes, for example, the identification and successful patching of a traumatic round window perilymph leak in a two-and-one-half year old child totally endoscopically (Video 3).

Indication for Surgery

As in adults, the commonest applications for endoscopic middle ear surgery are likely to be in tympanic membrane perforation and acquired cholesteatoma.⁹ Acquired cholesteatoma commonly arises from the pars tensa in children (Fig. 3), more so than in adults.¹² Therefore, it frequently extends into the retrotympanum. Cholesteatoma in this area is ideally suited to endoscopic surgery.^{13–15} However pediatric cholesteatoma more commonly extends deeply into the mastoid,¹² beyond the limits of what is readily achievable with a totally endoscopic permeal approach. Canal wall up surgery is widely favored in children⁴ and an endoscopic permeal canal wall down approach to pediatric cholesteatoma would not currently seem an appropriate option. So, if cholesteatoma can be removed via an endoscopic permeal atticostomy, reconstruction of the canal wall defect with cartilage would be appropriate. The size of canal defect achievable with curettage endoscopically is likely to be adequately covered by a tragal graft. Larger cholesteatomas still require an open approach with drilling of the mastoid cortex.

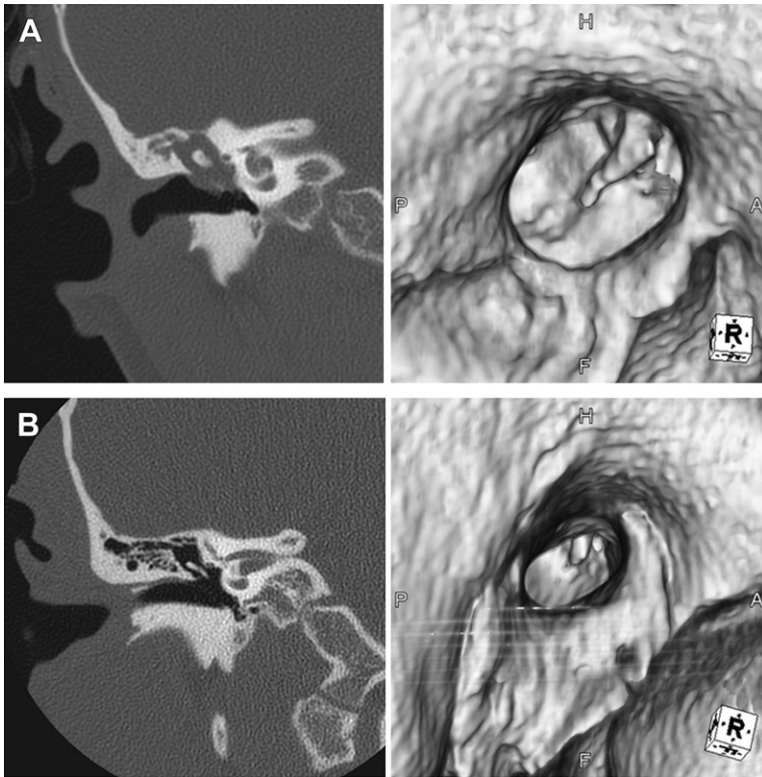


Fig. 2. CT images of the right temporal bone in (A) a four-year-old child and (B) a 14-year-old child. Left panels show coronal sections through the ear canal. Right panels show multiplanar reconstruction looking through the canal to the malleus handle. The ear canal of the younger child is clearly shorter, which allows good freedom of movement for instruments in permeal surgery. Uncharacteristically, the canal is narrower in the older child, showing that the proportions of the individual are more important than age in determining feasibility of permeal endoscopic access.

When congenital cholesteatoma is detected sufficiently early, it may be confined to the mesotympanum and supratubal recess, or extend a short distance into the medial epitympanum (**Fig. 4**). A totally endoscopic permeal approach is ideally suited to such lesions. Placement of an angled endoscope in the anteroinferior mesotympanum provides visualization for access to the supratubal recess and anterior surface of the processus cochleariformis from which congenital cholesteatoma most commonly arises (**Video 4**). Long, angled instruments or the KTP laser may be necessary for removal of matrix from these sites without disruption of the ossicular chain (**Video 5**).³

The use of endoscopy for staged second-look procedures has been advocated.^{16,17} This is certainly feasible for disease that was entirely accessible through the ear canal initially. However, access to the mastoid via a small stab incision is unlikely to provide adequate visualization of occult residual disease in many cases because of the tendency of the mastoid cortex to regrow in children, and because the cavity is often filled with obstructive scar tissue. Although ossiculoplasty can be completed endoscopically, precise positioning of total ossicular replacement prostheses is challenging with a one-handed technique, especially within the confines of a pediatric

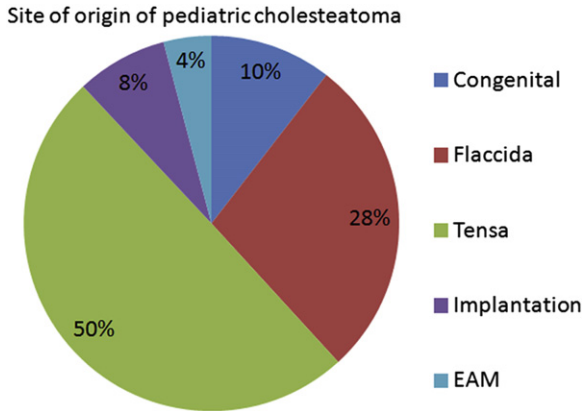


Fig. 3. Proportion of cholesteatomas arising at different locations. In contrast to adult series, pars tensa cholesteatoma is nearly twice as common as that arising from the pars flaccida. Prospectively acquired data from a consecutive series of 267 children with cholesteatoma at the Hospital for Sick children. (Data from James, 2012, unpublished data.)

meatus. With an intact stapes and eroded incus, the author favors cartilage tympanoplasty over incus interposition or partial ossicular replacement prosthesis, to achieve good hearing results and prevent recurrence of pars tensa retraction.¹⁸

Extent of Pathologic State

When considering a totally endoscopic approach for repair of tympanic membrane defects (with or without cholesteatoma) the location of the perforation must be considered in relation to the tortuosity of the ear canal, regarding ease of access. Also, the size of the child's tragus must be compared with the size of the perforation, with edges stripped, if tragal perichondrium or cartilage is to be used for the repair because it may be too small to close a large perforation. Consent for use of other donor sites or materials would then be required.

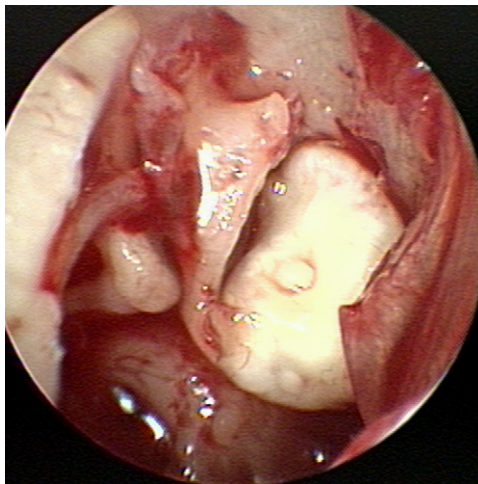


Fig. 4. Intraoperative image during endoscopic surgery for congenital cholesteatoma of the right ear. The tympanic membrane has been elevated off the malleus handle to provide access for removal of the lesion.

Size and location of the lesion are also important considerations when planning totally endoscopic cholesteatoma surgery. False negative and false positive identification occurs with CT and MRI so these devices cannot always predict the extent of the disease. Completion of a totally endoscopic approach when the child and parents are prepared for an external approach will be welcomed more warmly than the opposite scenario! Although pediatric cholesteatoma has a reputation for being more extensive than adult disease, the condition certainly can be detected while still small and, in the author's region, a high proportion are localized only to the epitympanum and mesotympanum within reach of totally endoscopic access.^{3,4}

Reconstruction

Before embarking on a totally endoscopic approach to cholesteatoma or perforation, consideration must be given to the method of tympanic membrane reconstruction. The tragus is the optimum donor site for endoscopic ear surgery because the incision for access can be hidden on the posterior surface. Although the tympanic membrane approximates to adult size at birth, the tragus is considerably smaller in children, so it may prove may be inadequate for larger perforations. If a larger graft is required than that provided by the tragus, consent for an alternative graft may be required (see later discussion). Furthermore, use of an external incision reduces the principle benefit of the incisionless permeal approach: use of a postaural or endaural incision for access and donor site should be considered, with or without the benefit of an endoscope.

TECHNICAL TIPS FOR ENDOSCOPIC PEDIATRIC MIDDLE EAR SURGERY

Although the principles and specifics of the endoscopic approach to the ear are the same of children and adults, the following points are considered especially pertinent to the application of this technique to children.

1. Reduce bleeding. This is one of the highest priorities in endoscopic middle ear surgery.
 - a. Canal infiltration. Injection of bupivacaine with 1:200,000 adrenaline helps to reduce bleeding. 1:100,000 adrenaline solution has been reported to cause transient tachycardia without any less bleeding in adult sinus surgery¹⁹; therefore, it is perhaps better avoided in children's surgery. A better view is achieved by slow injection so as to avoid blebbing and minimize the number of puncture sites because these bleed slightly. Infiltration of the superior canal wall is easiest because the skin is thicker and not adherent to the tympanic ring, but the most attention is required where a flap is to be raised.
 - b. Care to avoid abrasion of the meatal skin with the tip or shaft of endoscope or instruments is of importance in the narrow pediatric meatus.
 - c. Controlled hypotension. Successful completion of tympanoplasty and subannular tube insertion has been reported in children under local anesthesia.^{20,21} However, in the author's practice to date, children receive general anesthesia. Communication with the anesthetist to provide optimal conditions is important. Anecdotally, a heart rate of less than or equal to 80 beats per minute and blood pressure in the order of 80/35 mm Hg generally seem to provide good conditions. The services of a pediatric anesthetist help to ensure that this is done safely.
 - d. Epinephrine-soaked cotton balls. Cotton wool balls can be trimmed for small spaces and unlike synthetic foam, conform to the required shape. They are useful for retraction of the tympanomeatal skin flap (either under it to push it away from the bone or placed on the everted edge of the flap).

- e. Bleeding generally becomes less of a problem once the drum has been lifted. In some cases significant patience with control of bleeding is required to get to this point.
2. Shave hairs. The hairs of even young children may extend well into the narrow pediatric external auditory meatus (EAM). The clarity of the visual field is easily impaired by a smearing of the smallest trace of wax or blood from these hairs across the lens of the endoscope as it is passed into the ear. Rudimentary trimming of these hairs (eg, with small curved iris scissors) minimizes this problem. There is no need to shave them flush to the skin (eg, with a scalpel) because resultant skin abrasion may provide an additional source of bleeding into the field.
3. Choice of endoscopes. For many surgeons, this may be limited by the range of scopes available in the operating room for other purposes. Resources allowing, a full selection of 0°, 30°, 45°, and 70° scopes of different diameters might be ideal, but few would be used regularly. As a minimum, a 4 mm 0° scope is good for initial assessment of the tympanic membrane and will allow adequate access for raising the tympanomeatal flap in most children. For surgery within the mesotympanum and epitympanum, a narrower angled scope is required. The 30° 2.7 mm scope is effective, but the newer 3 mm scopes have vastly superior optics for illumination and clarity. A 45° angle generally provides a more useful field of view for retrotympanic and epitympanic access. A 70° scope is occasionally useful for examining the under surfaces of structures such as the medial surface of the incus though the tympanic recess or the medial surface of the pyramidal eminence in the subpyramidal recess. Unlike the 30° and 45° scopes, the 70° does not give a view of structures lying directly in front of the tip of the scope so extra care is required to avoid ossicular trauma. Optimal length of the endoscope is between 11 and 20 cm, according to the surgeon's preference. If it is too short, movement of instruments is impaired by the head of the scope and camera; if it is too long, it becomes difficult to stabilize the scope.
4. Additional instrumentation. Acquisition of dedicated equipment can transform the surgeon's ability to complete pediatric surgery endoscopically. The following have been found to be very beneficial:
 - a. Curved or angled instruments (eg, Thomassin set, Storz, Germany)
 - b. KTP laser plus filter (see the article by Badr-El-Dine and colleagues elsewhere in this issue)
 - c. High-definition camera and monitor.
5. Stabilizing the endoscope. It is generally easier for the surgeon to hold the endoscope instead of using an assistant or mechanical scope holder for the following reasons, which are especially relevant in the smaller pediatric ear:
 - a. Movement of the scope allows the surgeon to optimize his or her view for the specific task in hand.
 - b. The position of the scope can be adjusted to follow safe insertion and removal of instruments from the ear, and to allow optimum angulation and movement of instruments within the ear.
 - c. It is likely that the surgeon's ability to associate proprioceptive feedback from small movements of the scope with corresponding changes in the field of view aids three-dimensional appreciation of the anatomy. This sensory feedback may be particularly advantageous in the small confines of the middle ear cleft in comparison, for example, with endoscopic anterior skull base surgery in which a four-handed approach is often used.
 - d. Two-point stabilization of the scope helps to give a very stable visual field. The shaft of the scope rests firmly on the side of the opening of the EAM. The

surgeon's elbow or forearm can be rested on the arm or back rest of the chair or on an adjustable stand. It should be noted that too much pressure from the surgeon's arm resting on the chest of a child can increase bleeding by obstructing venous return.²²

6. Tympanic membrane reconstruction.

The tragus provides the optimum donor site for perichondrium or cartilage because the incision for access is well hidden within the meatus. Both cartilage and perichondrium are thinner and more delicate than in adults, so additional care is required to avoid damage during harvest. The cartilage is often an optimal thickness for tensa reconstruction without the need for shaving. The curve of superior edge of the tragus often matches the curve of the posterior annulus. This is ideal for reconstruction: if intact perichondrium is harvested on both sides of the graft, it can reflect off the convex (usually the anterior) surface and kept in continuity around the superior edge of the graft. Perichondrium can then be draped up the posterior wall of the EAM so providing good stability for the graft.

Other autografts: other donor sites can be used, though this does reduce the benefit of having no external incision that is otherwise achievable with a totally endoscopic approach.

Other materials: Allograft (eg, AlloDerm; LifeCell Corporation, Branchburg, NJ, USA), xenograft (eg, Gelfoam; Pfizer Inc, New York, NY, USA), or synthetic materials (eg, Epidisk; Medtronic Xomed Inc, Jacksonville, FL, USA) may be used as adjuncts to facilitate or support tympanic membrane repair without recourse to an external incision. Of these, AlloDerm in particular can be used for reconstruction of larger defects or revision surgery after previous use of the tragus as a donor site.

TOTALLY ENDOSCOPIC OR ENDOSCOPE-ASSISTED MIDDLE EAR SURGERY?

As stated in the introduction, the extent to which individual surgeons choose to use the endoscope in pediatric middle ear surgery will depend on several factors. The surgeon's training, preference, and experience are the most influential factors. Some surgeons rely predominantly on the endoscope alone in children as well as in adults. Currently, the author predominantly prefers to use both the endoscope and microscope in most middle ear surgery and switches from one to the other according to need. Occasional cases, such as tympanoplasty or exploratory tympanotomy, are performed endoscopically without availability of the microscope. The endoscope is almost always used for dissection of tympanic retraction or cholesteatoma from out of the retrotympanum (Video 6). In this area it is vastly superior to the microscope (Video 7) and can help to significantly reduce the likelihood of residual disease in this otherwise challenging area.² Excessive bleeding or an unusually tortuous meatus are the only barriers to the benefits of endoscopy at this site. Endoscopy is nearly always used in preference to the microscope for clearance of cholesteatoma from underneath an intact ossicular chain, either through the ear canal, through the mastoid, or both. A two-handed approach with the microscope is easier when drilling bone to clear irrigation fluid and bone dust, so the microscope is usually used when a magnified view is needed in the mastoid. However, even within the mastoid the endoscope can provide advantages over the microscope in providing a more complete view (Fig. 5). An anteriorly-placed sigmoid in a typically sclerotic pediatric mastoid can block the straight-line view required for microscopy; therefore, endoscopy can be invaluable when removing cholesteatoma from the medial epitympanum under intact ossicles or from a deep sinus tympani via the retrofacial approach (Fig. 6; Videos 8 and 9). Although total ossicular replacement is possible endoscopically, it is

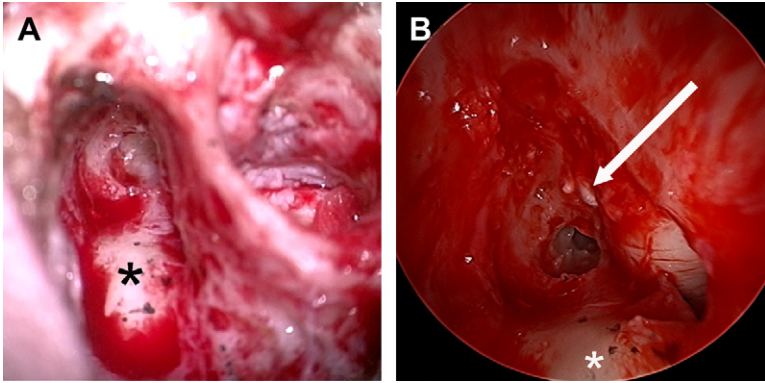


Fig. 5. Intraoperative images of the right epitympanum through the mastoid at the second stage of intact canal wall surgery. (A) Microscope view revealing no sign of residual cholesteatoma. (B) View with 45° endoscope revealing pearl of residual cholesteatoma above the superior wall of the ear canal (*arrow*). The undersurface of the tympanic membrane cartilage graft is also seen. An asterisk marks the same location on the lateral semicircular canal in both images.

often much easier to obtain optimal prosthesis or graft placement with two hands. It can be advantageous to have a microscope available for this purpose, depending on the surgeon's experience with endoscopy.

In summary, availability of both endoscopy and microscopy for most cases is advisable in pediatric middle ear surgery until confidence from an adequate experience with endoscopy has been achieved. This allows the advantages of each tool to be used when required. In the experience of most surgeons that use endoscopy in the middle ear, reliance on the microscope for middle ear surgery decreases with increased endoscopic experience.



Fig. 6. Axial CT scan of the right temporal bone. Deep extension of cholesteatoma between the posterior semicircular canal and facial nerve (*arrow*). The sigmoid sinus (*asterisk*) limits retrofacial access with the microscope, but not the endoscope.

SUMMARY

The endoscope is of great value in pediatric middle ear surgery. It has clear advantages over the microscope for visualization and instrumentation in the hidden recesses of the retrotympaanum and medial epitympaanum that have long been recognized.^{23,24} It facilitates more conservative surgery and some cases can be completed entirely endoscopically, avoiding the requirement for a postauricular incision. This is always greatly appreciated by children and their parents, and makes same-day discharge more feasible. Morphology of the pediatric ear canal and extent of disease often prevent an entirely endoscopic approach. In such cases, the endoscope is still often invaluable, allowing more frequent preservation of the ossicular chain and intact canal wall. Reduced rates of residual cholesteatoma and improved hearing thresholds can be anticipated with this approach. The learning curve for endoscopic middle ear surgery is long, even for surgeons experienced in microscope-guided middle ear surgery. Advances in instrumentation may allow more to be done more easily in future.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at <http://dx.doi.org/10.1016/j.otc.2012.10.007>.

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