Chapter 9

Surgical Solutions for Conductive Hearing Loss in Children

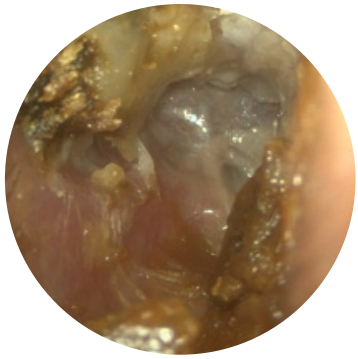
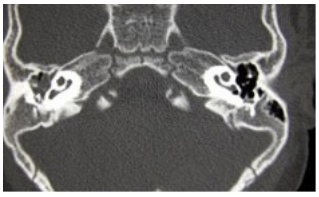
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There is something beautiful about all scars of whatever nature.'
~Harry Crews

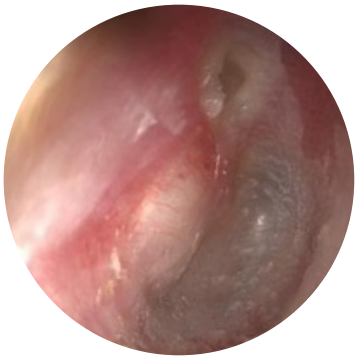
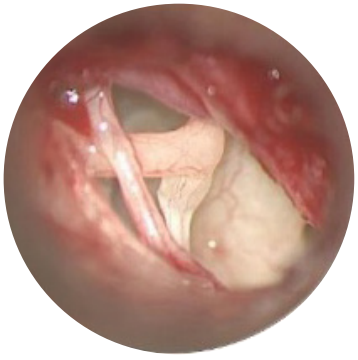
Introduction

Conditions leading to conductive hearing loss often require surgical intervention performed by an ear, nose and throat (ENT) surgeon. While the procedures themselves fall within the ENT surgeon's scope, it is important for hearing healthcare professionals (HHPs) to understand the underlying conditions and the surgical approaches used, and to work collaboratively with the surgeon to ensure optimal patient outcomes. This chapter also addresses the benefits of wax removal, which, although not strictly surgical, can improve hearing and support overall ear health. Table 9.1 lists the medical conditions most commonly associated with conductive hearing loss (CHL).

Table 9.1: Medical conditions commonly causing CHL

Condition causing CHL	Degree of CHL	Depiction of conductive condition *(all images are of Right ears)*
Cerumen *(earwax)*	Variable, depending on the extent of obstruction; typically 5–40 dB HL	
Canal atresia *(image shows CT scan of ear with atresia)*	Typically maximal: up to 60 dB HL	

Condition causing CHL	Degree of CHL	Depiction of conductive condition *(all images are of Right ears)*
Otitis Media with Effusion (OME) *(image shows retraction of tympanic membrane with OME)*	Variable: none to 30 dB HL, typically 20–30 dB HL	
Perforated tympanic membrane *(image shows antero-inferior 'central' perforation of tympanic membrane)*	Variable depending on the size and site of the perforation: less than 30 dB HL	
Ossicular chain discontinuity/fixation *(image shows retracted and tympanosclerotic tympanic membrane with erosion of incus long process which fails to meet the stapes head)*	More than 30 dB HL	

Condition causing CHL	Degree of CHL	Depiction of conductive condition *(all images are of Right ears)*
Cholesteatoma *(image shows pars flaccida/'attic' tympanic membrane defect with cholesteatoma visible behind the posterior-superior tympanic membrane)*	Variable depending on the pathology: none to greater than 30 dB HL	
Tympanosclerosis *(image shows extensive tympanosclerosis of the tympanic membrane)*	Very rarely causes CHL – only if it fixates to part of the ossicular chain	
Stapes fixation *(Image of the middle ear with the tympanic membrane lifted to show the incudostapedial joint being crossed by chorda tympani nerve)*	Variable depending on the fixity	

The surgical interventions for CHL which will be discussed are:

- Cerumen (earwax) removal and desquamated skin removal from the ear canal
- Meatoplasty
- Canalplasty
- Ventilation tubes ('grommets')
- Tympanoplasty/Myringoplasty
- Ossiculoplasty
- Surgical repair of hearing as part of cholesteatoma surgery
- Stapedioplasty (stapedectomy/stapedotomy)
- Eustachian tube (ET) dilation

Cerumen Removal

Total blockage of the ear canal with cerumen and desquamated skin of the ear canal is rare, and soundwaves only need a tiny opening in the ear canal to reach the tympanic membrane (TM). Thus, even a large amount of earwax should not cause noticeable hearing loss (HL). Cerumen plays a protective role in the external auditory canal and is typically moved outward by the canal's natural epithelial migration and jaw movements. However, this self-cleansing mechanism does not always prevent buildup, and cerumen impaction is a common clinical problem.

If the ear canal is plugged tightly with earwax, cerumen impaction or earwax blockage, it can cause CHL of up to 48 decibels (dB) (Narayanan, Raman and Chong 2019). Removal can be achieved by syringing, mechanical removal with a Jobson-Horne probe, suction under microscopic or endoscopic visualisation or a combination of the above. Various syringing systems exist, ranging from a simple 50ml syringe with a luer lock and cannula through purpose-designed syringes to devices which pump water automatically. Removal is useful to provide good visualisation of the eardrum. Cerumen removal can generally be performed by a trained audiologist, nurse, general practitioner or ear, nose and throat (ENT) surgeon.

Syringing should always be performed gently, using body-temperature water (37 degrees Celsius) to prevent discomfort and vertigo from caloric (temperature-related) effects. Prior to syringing, one should ensure that there is no history of a perforation of the TM or grommet insertion – in which case syringing is contra-indicated. One should then establish the

confidence of the child and explain what is going to be done. Prior softening of the wax may be necessary or useful. As wax is water-soluble, ordinary water or dilute hydrogen peroxide (1.5%) is as effective as commercial preparations. The parent or caregiver can be given a dropper bottle and asked to instil the water/peroxide, jiggling the pinna or tragus for about 20 minutes prior to syringing.

The principles of the technique include:

- Having unrestricted access to the ear.
- Providing good light (possibly with a headlamp)
- Pulling the pinna backwards to straighten the ear canal
- Filling the canal gently with water before syringing more firmly
- Patience – allowing the combination of the dissolving action of the water as well as the mechanical water flow to loosen the wax
- Placing a container under the ear to catch the water

Meatoplasty and/or Canaloplasty

A narrowed, closed (stenosed) or undeveloped (atretic) bony ear canal (EAC), or a similarly affected cartilaginous external auditory meatus (EAM), can impede sound transmission to the eardrum directly or indirectly by promoting cerumen obstruction. These ear canal conditions may also make the fitting of a hearing aid (HA) problematic.

When such EAM/EAC narrowing or atresia is congenital, it may be associated with anomalies of the middle ear and/or inner ear which may contribute to HL – conductive and/or sensorineural. Mild or moderate cases of EAM/EAC narrowness can be improved by relatively simple surgical techniques. A narrow EAM can be widened by resection of obstructive cartilage and the transposition or interdigitation of small skin flaps – as, for instance, in the technique of M-Meatoplasty (Mirck 1996). A narrow bony EAC can be widened by drilling of the ear canal, splitting or 'barn-dooring' the EAC skin and grafting the resulting gap with fascia.

Severe congenital anomalies, as are found in atresia or microtia, represent a far more difficult problem for surgical reconstruction (Jahrsdoerfer and Hall 1986). Expert surgeons with significant experience report that even in their hands the results are often unsatisfactory, both in terms of hearing outcomes and in the health and stability of the newly-created ear

canals. It should only be considered by surgeons who are expert in this area and in cases where the radiology (CT and MRI) is favourable (McKinnon and Jahrsdoerfer 2002). A preferable solution is to address the often-associated cosmetic aspects of the pinna with surgery or a prosthesis, and to leave the EAC stenosed in favour of a bone-anchored hearing solution (Chapter 11).

Ventilation tubes ('tympanostomy tubes'/'grommets')

Ventilation tubes (VTs) may be indicated for insertion into the eardrums of children with otitis media with effusion (OME). OME is common enough to be called an 'occupational hazard of early childhood' (Rosenfeld 2004) by the American Academy of Otorhinolaryngology: Head and Neck Surgery (AAO-HNS), as 90% of children have OME before school age (Tos 1984) and they develop, on average, four episodes of OME every year (Mandel et al. 2008). Most episodes of OME resolve spontaneously within three months, but at least 25% of OME episodes persist for ≥3 months (Rosenfeld and Kay 2003) and 5% to 10% of episodes last ≥1 year (Stool et al. 1994; Williamsonet al. 1994). The prevalence and persistence of OME in children with Down Syndrome or cleft palate, however, is much higher, ranging from 60% to 85% (Flynn et al. 2009; Maris et al. 2014).

The HL associated with OME varies considerably (Fria, Cantekin and Eichler 1985), typically ranging from mild to moderate CHL (Moore, Hartley and Hogan 2003), although some children may have no detectable HL. In light of the above, the AAO-HNS has produced guidelines on OME (Rosenfeldet al. 2016) and ventilation tubes (Rosenfeldet al. 2022). These guidelines include the following recommendations:

- Determine if a child with recurrent acute otitis media (AOM) or with OME of any duration is at increased risk for speech, language or learning problems because of baseline sensory, physical, cognitive or behavioural factors (Table 9.2).
- Use pneumatic otoscopy for diagnosing OME in a child.
- Obtain tympanometry measures in children with suspected OME for whom the diagnosis is uncertain after performing (or attempting) pneumatic otoscopy.
- Manage the child with OME who is not at risk with watchful waiting for three months from the date of effusion onset (if known) or three months from the date of diagnosis (if onset is unknown).

- Obtain an age-appropriate hearing test if OME persists for three months or longer or, alternatively, for OME of any duration in an at-risk child.
- Take note that the ENT will offer bilateral tympanostomy tube insertion to children with bilateral OME for three months or longer, and who also have documented hearing difficulties.
- Be aware that tympanostomy tube insertion should not be performed in children with recurrent AOM who do not have middle ear effusion (MEE) in either ear at the time of assessment for tube candidacy. Bilateral tympanostomy tube insertion should be offered to children with recurrent AOM who also have unilateral or bilateral MEE at the time of assessment for tube candidacy.
- Perform an adenoidectomy as an adjunct to tympanostomy tube insertion for children with symptoms directly related to the adenoids (adenoid infection or nasal obstruction) or, alternatively, in children aged four or older to potentially reduce future incidence of recurrent otitis media or the need for repeat tube insertion.

The procedure of insertion of VTs is generally very simple: under general anaesthetic, a small incision is made in the TM. The middle ear effusion is evacuated using suction. The particular VT chosen is then inserted into the defect created in the TM (Figure 9.1). Different types of VTs can be used, and they typically remain in the TM for varying periods before spontaneously extruding. Typically, one chooses a short duration of VT initially, and reserves longer duration tubes for recurrent/resistant cases. Very long-term/permanent tubes (for example, 'T-tubes') should be avoided in children.

Figure 9.1: (a)

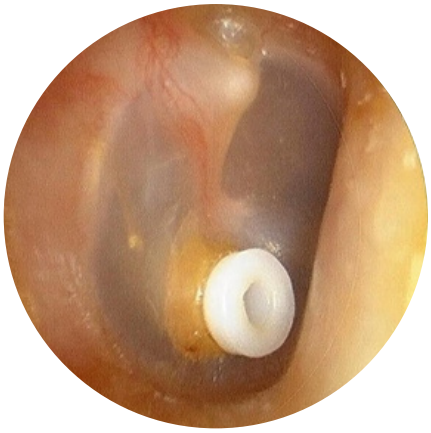


Figure 9.1: (b)



Figure 9.1: (a) ventilation tube in a right TM
Figure 9.1: (b) examples of ventilation tubes (with a paper clip shown for size reference) suitable for use in children include 'Reuter bobbins' – plastic and titanium – and 'Umbra Minor' tubes

The complications of VT insertion are mild and rare. Insertion may be followed by otorrhoea (9%) which is easily resolved with ear toilet and the use of antibiotic/steroid eardrops (for example, Cilodex®). The lumen of the tube may become obstructed with dried mucus or blood. The tubes may be extruded prematurely, and the OME may recur. Rarely, when the tubes are extruded, they may leave a perforation in the TM (2%) (Kay, Nelson and Rosenfeld 2001). It is recommended that the AAO-HNS guidelines be followed, and that the children receiving VTs be followed up six-monthly until extrusion of the VTs.

Adenoidectomy is often performed with VT insertion when there is reason to believe that enlargement or infection of the adenoids may be contributing to ET dysfunction, recurrent otitis media or obstruction of nasal breathing. The adenoidectomy procedure involves a general anaesthetic, the use of a curette to scrape out the adenoids (lymphoid tissue in the nasopharynx above the soft palate) and then visualisation with a mirror endoscope to see they are properly removed and to control bleeding. Adenoidectomy should not be performed on a child with a cleft palate as this may result in palatal incompetence.

Tympanoplasty/Myringoplasty

Correctly-speaking, the term 'tympanoplasty' means surgical repair of the tympanum – the entire middle ear, comprising the TM or 'myrinx'; the spaces of the middle ear, in particular the mesotympanum; and the ossicular chain. 'Myringoplasty' is the repair of the TM alone – but this term is seldom used. In common usage, 'tympanoplasty' is the term used for the repair of the TM. The indications for, and aspects of, tympanoplasty may therefore include any of the following:

- Closure of a perforation of the TM (myringoplasty).
- Repair/reinforcement of a retraction of the TM.
- Repair of the ossicular chain ('ossiculoplasty').
- Removal of disease from the middle ear (for example, cholesteatoma).

Myringoplasty

The procedure 'freshens' the edges and undersurface of the TM and places a graft underneath to support epithelial growth across the defect. Various graft materials have been used, with temporalis fascia, cartilage and perichondrium being most commonly favoured. The surgical techniques used vary too: The approach can be post-aural (behind the ear), end-aural (incision down the ear canal) or trans-canal (incision at the bottom of the ear canal). A microscope or endoscope can be used, and the graft material can be placed and secured in various ways. The site and size of the perforation may determine these choices by the surgeon.

The quoted success rate in the literature for closure of the TM varies significantly, from about 60% to 90%. Factors believed to influence the success rate of closure include the size and position of the perforation, the experience of the surgeon, the age of the patient and the graft material used (cartilage appears to have a slightly better success rate than fascia (Lajdam et al. 2023). There is much debate about a minimum age before performing tympanoplasty. While most surgeons would prefer to wait until six or eight years of age, this is not a hard and fast rule. Considerations affecting the decision include not only the age of the child but also the status of the other ear, whether there is a problem with recurrent otorrhoea, whether swimming is an issue, etc.

In terms of outcomes, successful closure of a perforation alone gives only a modest improvement in hearing – mean improvement of the order of 8 dB HL. Some residual CHL remains as the repaired TM is not normal. Nevertheless, this improvement can make a significant difference to the patient. There are furthermore the added benefits of having a closed eardrum with no/low risk of otorrhoea, and an ear which is more amenable to HA use. Myringoplasty also has a low complication rate.

Myringoplasty for repair/reinforcement of a retraction of the TM

Retraction of parts of, or the entire TM, with consequent loss of the sturdy fibrous layer and atelectasis of the TM, is believed to be the consequence of persistent ET dysfunction. It varies considerably in extent, from mild retraction of a portion of the TM to complete retraction of the entire TM ('adhesive otitis media'). There may be associated erosion of variable portions of the ossicular chain. The HL is also variable, from a conductive loss of greater than 30 dB HL if the ossicular is eroded, to no HL at all – as indeed may be the case even in an adhesive otitis media. There is no conclusive evidence that VT insertion can prevent or reverse TM retraction. Nevertheless, surgeons often insert VTs and thereafter monitor patients closely, provided that there is no ossicular erosion causing HL or TM retraction severe enough to raise concern for cholesteatoma development.

Reinforcement myringoplasty with excision of and/or support of the atelectatic portion of the TM is performed similarly to standard myringoplasty. Additional considerations would include attention to ET function, careful dissection of any adherent retracted TM off the ossicular chain or promontory of the middle ear, repair of the ossicular chain if eroded (ossiculoplasty, see below) and the use of cartilage as a sturdier graft material.

Retraction of the TM can be managed either by observation or by reinforcement of the TM with cartilage. Considerations in this decision include:

- Whether there is visible discontinuity of the ossicular chain
- Whether there is a CHL
- Whether the retraction looks as if it is progressing and is at risk of becoming cholesteatomatous

Ossiculoplasty

Defects of the ossicular chain can be congenital or acquired, and involve fixation, disarticulation due to trauma or discontinuity due to erosion. Ossicular chain defects causing CHL include:

Congenital: (rare)

- Fixation: Ossicular malformations
- Discontinuity: Ossicular malformations, congenital cholesteatoma

Acquired:

- Fixation: Tympanosclerosis (rarely affects the ossicles)
- Discontinuity
- Disarticulation: Head injury, surgical (rare, except when deliberate in cholesteatoma surgery)
- Erosion: Retraction of TM, chronic otitis media including cholesteatoma

The most common site of erosion of the ossicular chain is the delicate lenticular process of the incus, followed by erosion of the delicate stapes superstructure. Extensive cholesteatoma may cause osteitis and erosion of the more robust body of the incus and malleus. The principles of ossiculoplasty involve either re-establishment of the continuity of the ossicular chain or creation of an alternative conductive mechanism from the malleus handle or the TM to the stapes (superstructure (SSS) or footplate). The materials used in ossiculoplasty include the patient's own ossicles, homograft ossicles (ossicles from other human beings), cortical bone, cartilage or manufactured ossicular prostheses (currently usually made of Titanium) and, more recently, bone cement (for example, Ketac Cem®).

If erosion of the lenticular process of the incus occurs, the traditional approach has been the remodelling of the patient's incus to connect from either the malleus handle or the TM to the head of the stapes, or the use of a PORP (partial ossicular replacement prosthesis). A recent innovation is the use of bone cement capable of reconstructing absent bone, to reconstitute the long process/lenticular process of the incus (Demir et al. 2019). One such cement, Ketac Cem®, was created for dental work but is very successful and robust in this application. This adheres to the principle that reconstructing the long process of the incus produces the best results.

Surgical Repair as Part of Cholesteatoma Surgery

In cholesteatoma surgery, the principles of myringoplasty and ossiculoplasty, as described above, generally apply. The difference is that disease removal is a priority prior to the process of reconstruction. In such cases, an intact ossicular chain will need to be disarticulated. When the cholesteatoma is superficial to the various components of the ossicular chain, it may be possible to preserve the ossicularchain. . In this case movement and manipulation of the ossicular chain should be minimised to avoid sensorineural hearing loss (SNHL). If much manipulation is anticipated, it might be wise to temporarily disarticulate the incudo-stapedial joint prior to the operation. There is debate as to whether ossiculoplasty should be undertaken during the initial cholesteatoma surgery or be delayed until the second stage. However, most clinicians prefer to do this during the initial surgery, particularly in children. Reasonable improvement in hearing can be obtained. In a series of cases where reconstruction took place during primary surgery, an overall air bone gap improvement of at least 7 dB was obtained (Wilson, London and Shelton 2013; Eliçora et al. 2017).

Stapedioplasty (stapedectomy/stapedotomy)

Stapedioplasty (also known as stapedectomy/stapedotomy) is a relatively common procedure in adults, owing to the 0.3 – 0.4 prevalence of development of otosclerosis in early adulthood. It is very rarely indicated and performed in children because of the rarity of stapes fixation in the young. Stapedectomy/stapedotomy/stapedioplasty is an operation performed for a fixed stapes bone in the oval window (most commonly, otosclerosis). The crura (arms)/ superstructure of the stapes bone are carefully removed (often using a laser) and a small hole (stapedotomy) is made in the stapes footplate. A piston-like prosthesis is secured onto the long process of the incus so that movements of the ossicular chain are transmitted through the piston to the fluid of the inner ear.

Eustachian tube (ET) dilation

It is generally accepted that most middle ear problems originate from inadequate ventilation due to poor ET function, which is common in children as their ET is of smaller dimension and more exposed to the recurrent upper respiratory tract infections of childhood. The frequency of these problems diminishes with age and generally settles by age eight. Children with a

cleft palate and Down Syndrome, where the ET is negatively affected, have a far higher prevalence of middle ear problems.

Until recently the problem of inadequate ET ventilation of the middle ear was circumvented using ventilation tubes, and the ET was considered too inaccessible for intervention. There is now some evidence that balloon dilation of the ET may resolve middle ear problems attributed to ET insufficiency in a certain percentage of adult patients (Anand et al. 2019), although the improvement is only in the region of 60% (64% improvement in tympanometry), and many experts remain sceptical.

The concept of ET dilation in children is even more controversial, but there are some series showing subjective benefit and some significant objective improvement. Although there are no prospective randomised control trials, a systematic meta-analysis of the literature concluded that ET balloon dilation ± tympanostomy tube placement may produce outcomes that are comparable to tympanostomy tube placement in the treatment of recalcitrant OME in the paediatric population. Furthermore, the procedure was found to be safe, with the most common complication being epistaxis (nosebleed). Acclarent Inc. received clearance in December 2023 from the U.S. Food and Drug Administration (FDA) for use of their ET balloon dilation system in the treatment of children between the ages of eight and seventeen. Nevertheless, this more complex and uncertain procedure should be weighed against the far simpler one of myringotomy and placement of a ventilation tube.

Conclusion

Procedures on, or surgery to, the ear are often required to resolve CHL. If outer- or middle ear conditions leading to CHL are suspected in children, they should be referred to an ENT surgeon for further management. It is important that HHPs establish a referral system and collaborate with ENT surgeons to ensure successful management of children with CHL.

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