The Journal of Laryngology & Otology

cambridge.org/jlo

Surgical treatment of chronic ear disease in remote or resource-constrained environments

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Abstract

Background. Surgery for chronic suppurative otitis media performed in low- and middle-income countries creates specific challenges. This paper describes the equipment and a variety of techniques that we find best suited to these conditions. These have been used over many years in remote areas of Nepal.

Results and conclusion. Extensive chronic suppurative otitis media is frequently encountered, with limited pre-operative investigation or treatment possible. Techniques learnt in better-resourced settings with good follow up need to be modified. The paper describes surgical methods suitable for resource-poor conditions, with rationales. These include methods of tympanoplasty for subtotal wet perforations, hearing reconstruction in wet ears and open cavities, large aural polyps, and canal wall down mastoidectomy with cavity obliteration. Various types of autologous ossiculoplasty are described in detail for use in the absence of prostheses. The following topics are discussed: decision-making for surgery on wet or best hearing ears, children, bilateral surgery, working with local anaesthesia, and obtaining adequate consent in this environment.

Review Article

Mr M C F Smith takes responsibility for the integrity of the content of the paper

Cite this article: Smith MCF, Huins C, Bhutta M. Surgical treatment of chronic ear disease in remote or resource-constrained environments. *J Laryngol Otol* 2019;**133**:49–58. https://doi.org/10.1017/S0022215118002165

Accepted: 1 October 2018
First published online: 19 December 2018

Key words:
Low-Income Population; Global Health; Hearing Loss; Otitis Media, Suppurative; Tympanic Membrane Perforation; Cholesteatoma; Tympanosclerosis; Myringoplasty; Tympanoplasty; Ossiculoplasty; Ear Ossicles; Ear, Middle; Autografts; Otologic Surgical Procedures; Mastoidectomy; Mastoid Obliteration; Mastoid; Ear; Surgery; Nepal; Cambodia

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Introduction

There are many practical issues affecting the provision of ear surgery in resource-poor and remote settings in low- and middle-income countries. The surgical techniques described here are largely limited to the treatment of chronic suppurative otitis media, the main burden of ear disease in these settings. The senior author has worked in resource-poor settings in Nepal on a regular basis for over 35 years, both in regional and peripheral remote settings. The other authors have experience of similar work over shorter periods of time, mainly in Cambodia. All have additional experience in various countries, including India, Pakistan and Uganda. All have a particular interest in global health and otology.

We will not attempt to describe all possible permutations of middle-ear and mastoid procedures for chronic suppurative otitis media. These are well described elsewhere.[1] The following is a discussion of techniques that may be utilised for chronic suppurative otitis media in situations with limited facilities, and which are suitable to teach to those working in these environments. The aim is to treat as many patients as possible with the highest rate of success, minimal risk and least financial cost. A rationale for these approaches will be explained and as far as possible the evidence discussed. Emphasis is laid on conditions that may be encountered more often, or at a later stage, in resource-poor settings.

Facilities that are routinely used in developed world hospitals such as facial nerve monitoring and high quality pre-operative imaging are unlikely to be available.

Pre-operative care

Surgical decision-making

This is often complex. Bilateral disease and bilateral mixed hearing losses are common and are difficult to mask audiometrically. This may make it difficult to decide which ear to operate on first. Audiometry in remote areas and in noisy environments may be unreliable and patients may not understand the test. A 512 Hz tuning fork is essential, and clinical assessment by voice testing and a Barany noise box (for severe losses) are very useful.

The better hearing ear may be the side most likely to provide safe treatment, and to give the best hearing outcome or most economic benefit, especially when this may be the only chance of treatment for this patient. The lack of pre-operative care such as micro-suction, the limited opportunity for a conservative management trial, and the lack of imaging or other investigations such as bacteriology and pathology further complicate decision-making. When in doubt, ask the patient which ear troubles them most.

On occasion, bilateral surgery may be appropriate; for example, underlay repair of a large perforation on one side, with a small transcanal procedure for a small perforation on the other side. When treatment options for an individual are limited by geography and finance, even bilateral mastoid surgery, staged over a few days or weeks, may be

appropriate. It requires well-informed agreement, and discussion of risks and post-operative care, between the experienced team and the patient.

Surgical conditions and extent of disease

Although all degrees of chronic ear disease will occur in the community, it is likely, in a setting where treatment has not been widely available, that a high proportion of those presenting will have advanced disease or significant hearing loss. More perforations are subtotal, more middle ears are inflamed and granular, more ossicles are eroded or fixated by tympanosclerosis, more patients have post-aural scars from abscesses, cholesteatomas are bigger, and more structures are eroded or exposed. Visiting surgeons should be prepared for difficulties they may have encountered infrequently, and be ready to adapt their techniques to these challenges.

Imaging

Pre-operative computed tomography (CT) and follow-up magnetic resonance imaging (MRI) scans are now considered obligatory in many developed world centres, particularly for cholesteatoma assessment. Scans, including high-resolution CT of the temporal bones, are available in some low- and middle-income countries, but do increase costs, and may make little difference to the surgery. One should critically consider why a scan is needed and what information is required before requesting it. A lateral oblique plain mastoid X-ray alone can be useful. It will show the degree of pneumatisation, localise the sigmoid sinus and demonstrate the level of the tegmen. It will not give detailed information, such as potential erosion of the lateral semi-circular or facial nerve canals.

Pre-operative clinical checks, of facial nerve function or a fistula sign for example, should be recorded. One should examine for old surgical or post-aural abscess scars. In the absence of imaging, one should proceed with surgery cautiously, expecting that any possible complication may be encountered and being ready to deal with it.

Children

The minimum age for middle-ear surgery such as drum repair has long been debated. In resource-poor regions, there are some special considerations. The general health of the child and resistance to infections (vitamin or protein-calorie deficiency should also be considered), chronic upper respiratory tract infection (the 'mucoid dripping nose'), or glue ear in the other ear may militate against success.[2] In contrast, a child with bilateral subtotal perforations and conductive hearing loss should not be denied surgery that could profoundly affect educational prospects. The child with a chronically draining ear and deteriorating hearing, who is at risk of complications or ostracism by peers, must be considered, even when the results may be less reliable. Re-perforation rates in children with temporalis fascia grafts may be higher than in adults;[3] however, the use of cartilage grafts may reduce that risk.[4–6]

Consent issues

Written and verbal consent should always be obtained. In cases of illiteracy, a thumbprint may suffice. Information may need to be imparted appropriately to the educational level but not paternalistically. Minor language groups make communication difficult, even for locals. Medical concepts that are understood in high-income and well-educated societies may be alien to the situation and culture. Lack of formal education does not remove the individual's right to make an informed decision. In many communities, decisions are only made with reference to family or others in authority. Questions about the procedure, options and risks should be answered truthfully and accurately.

Medical fitness for surgery

Outcomes of treatment for chronic suppurative otitis media in those with chronic disease, such as immune disorders, positive human immunodeficiency virus (HIV) status, diabetes, or in smokers, are poorer. In a Western, high-income population on adequate highly active antiretroviral therapy, general surgical outcomes were similar to those with negative HIV status.[7] It seems likely that surgical outcomes will be less reliable in patients without access to adequate HIV treatment. The literature is variable on this matter, with some claiming no relationship between HIV status or cluster of differentiation 4 count and the outcome for a variety of general surgical procedures, whilst most find worse outcomes. This was not felt to be sufficient to refuse necessary surgery.[8,9] We could not find any literature on the outcomes of ear surgery in those with HIV infection, treated or untreated.

Planning anaesthesia

There are pros and cons of general and local anaesthesia. Well-controlled and monitored hypotensive general anaesthesia may not be possible or safe. Without this, there may be poor control of bleeding and no consistent depth of anaesthesia.

It is possible for the surgeon to administer local anaesthetic and then perform the surgery. For more complex procedures, or those that become complicated per-operatively, and in children or anxious adults, it is preferable to have an anaesthetist present.

Whilst almost any ear surgery can be performed under local anaesthesia, surgeons need to be constantly aware of patient responses. When the patient moves, alters their pattern of breathing or otherwise indicates pain, they must immediately be injected with local anaesthetic with adrenaline (before soft tissues are stripped away from bone). Alternatively, topical anaesthetic-soaked cotton wool should be applied, whilst moving to another area of the ear for a while. Sedated patients may suddenly rouse to a pain stimulus, and lack self-control. Effective use of time is important so that the local anaesthetic does not stop working, particularly in scarred or very inflamed ears where anaesthesia may not spread, or last long. Cold-water irrigation whilst drilling, stapes manipulation, or suction near a labyrinthine fistula should all be avoided, and may lead to sudden vertigo or even vomiting. Drilling close to dura may produce meningeal pain, which will require topical anaesthesia. Drill noise via bone conduction may be very loud and alarm the patient, unless forewarned. Good communication with the anaesthetist is important; for instance, they should be informed if there has been stapes manipulation or if an area of the ear appears poorly anaesthetised.

Set-up and equipment

The requirements for a basic clinic and ear surgery operating theatre set-up in a remote location are detailed in the online

https://doi.org/10.1017/S0022215118002165 Published online by Cambridge University Press

supplement. This includes a photograph (Figure 1 in the Supplementary material 1, available online) of the operating table and hardware, and detailed lists of equipment including surgical instruments.

These suggestions have been tried and tested at multiple ear camps and in resource-constrained locations in Nepal. Local requirements may differ.

Surgical techniques

Tympanoplasty

Wet ears

When possible, a course of pre-operative antibiotic and steroid eardrops, and perhaps oral antibiotics, may be used. In the senior author's practice, if there is pulsatile discharge from the middle ear, surgery will be delayed, at least a few days, and reviewed after a course of antibiotic and steroid drops and oral antibiotics. If the discharge has reduced and does not pulsate, the surgery will proceed. Sometimes there is dramatic improvement even after 2–3 days of treatment.

It is not necessary for all perforations to be dry before surgery; indeed, ears that are not dry are those most in need of intervention. The results of tympanoplasty in wet ears have been shown to be close to those in dry ears.[10,11] Swollen bleeding mucosa may, however, make the surgery technically more difficult.

In the presence of active cholesteatoma, it is usually impossible and inappropriate to try to make the ear dry before surgery.

In the past, when there was chronic perforation with discharge, it was common to perform cortical mastoidectomy at the same time as myringoplasty. Studies have not shown any benefit of this.[12] In our practice, we perform cortical mastoidectomy only for persistently discharging revision cases.

Small perforations

Pinhole perforations can be surprisingly troublesome, with recurrent infection. Some act as grommets to ventilate the middle ear. If there is an effusion in the other ear, it may be inappropriate to close a perforation unless the ear persistently discharges.

Two reliable techniques use cartilage, which is often more robust than the traditionally used temporalis fascia.[1,5] A graft pushed through the perforation onto a bed of Gelfoam® in the middle ear, placed through the perforation, is one method. Another is the so-called 'butterfly' cartilage graft.[13] This works well when the perforation has clear tympanic membrane borders, and is not close up against the annulus or the malleus handle. A disc of tragal cartilage and perichondrium, usually 4 mm in diameter, is deeply scored around its margin, and then fitted like a grommet into the perforation. It should have good overlap around the margins.

Other methods such as a fat plug, which is less reliable, or permeatal underlay grafting, which takes longer and is more technically demanding, are also effective. Patients should be instructed not to blow their nose forcefully (such as in the common habit in some countries of obstructing one nostril and blowing hard onto the ground), for two weeks.

Subtotal perforations

Discharge is often intermittent. Climate and season may influence this. Repair requires adequate visualisation of the entire annulus. The graft should be placed medial to the malleus handle, to avoid drum lateralisation.[3] The latter causes conductive hearing loss and is difficult to correct.

Subtotal perforations commonly develop from atelectasis, so there may be squamous epithelium in areas such as the hypotympanum, facial recess, and promontory or incudostapedial joint. All of this must be removed, or elevated to lie lateral to the tympanic graft. Cartilage provides additional support to an accurately placed temporalis fascia graft.

The fascia graft should be well anchored under the anterior annulus. One effective method is to pull a tail up through a small sub-annular tunnel or 'buttonhole'. A canal incision is made a few millimetres lateral to the annulus, just inferior to the anterior malleolar ligament. A subcutaneous tunnel is developed from the incision inwards, between annulus and bone, to enter the middle ear just lateral to the Eustachian tube. The fascia graft edge is pulled up into the tunnel to anchor it. Cartilage 'petal' grafts are placed behind the fascia for additional drum support (Figure 2 in the Supplementary material 2, available online).

Grafting of drum, cartilage and other materials

Long-term graft stability is important in economically deprived areas, where recurrent upper respiratory infections and water exposure may be common. Temporalis fascia is the most widely used material for grafting the drum, and usually provides good closure, at least in the short term.[14] Unfortunately, recurrent perforation is common in the long term.[15]

Some use other autologous materials such as fascia lata.[16] Whilst this is more substantial, it requires a separate and sometimes painful wound on the thigh and is not widely used. Heterologous materials such as dura or animal collagen can be used, but these are expensive and not easily available. They may additionally be associated with cultural issues in some countries.

It has been shown that cartilage grafting (up to about 1 mm thickness) of the tympanic membrane does not adversely affect hearing. Long-term hearing outcomes are equivalent between cartilage and fascia.[5] Tragal composite grafts, with the cartilage left attached to the perichondrium, have been shown to obtain better therapeutic effects (in regard to closure rates and hearing improvement) when grafting larger perforations, in comparison to temporalis fascia or perichondrium alone.[17,18] In cases with poor middle-ear ventilation, which includes almost all cholesteatoma cases, cartilage also resists retraction pocket formation. It is essential to fit cartilage accurately to areas where recurrent retraction is most common, including the postero-superior segment of the drum and exposed attic.

Cartilage sources

Conchal cartilage is removed as part of meatoplasty, and so is readily available. It is usually thick and can be sliced, with limited tendency to curl.

Cartilage from the canal floor may already be exposed by a post-aural incision and can be sliced, with very little tendency to curl. It may have fibrous suture lines (fissures of Santorini) limiting the size of any single sheet.

Cymbal cartilage has a concave shape. In terms of thickness, it is similar to tragal cartilage. A good-sized disc can be taken, and, when chamfered around its perimeter on the concave side, will make a good flat disc for total drum repair.

Tragal cartilage can provide an excellent sheet for drum or attic repair. It is frequently used with an attached wide rim of perichondrium.[1,18]

https://doi.org/10.1017/S0022215118002165 Published online by Cambridge University Press

Myringitis

When this granular inflammation of the drum surface fails to respond to water avoidance and topical agents (such as vinegar (acetic acid[19]), chemical cautery, or antibiotic-steroid ointments or drops), it may need excising and grafting, as for a perforation. Recurrence may remain a problem.[3]

Florid myringitis affecting all the deep canal skin and thickening the drum may be treated by widening the canal and meatus,[20] excising the affected skin and surface of drum, and then accurately lining it with split skin grafts. Recurrence is common and it is unwise to promise sustained correction of hearing. Over years, such ears normally become dry, with a grossly thickened featureless drum and conductive hearing loss.

Ear tuberculosis

Tuberculosis (TB) of the ear is usually associated with pulmonary TB. It causes pale granulation tissue, sometimes multiple tympanic perforations, and is associated with surgical failure.[21] A diagnosis of TB may be made from the patient's history, by remembering the possibility and obtaining granulation samples for histological analysis; culturing takes many weeks.

Tympano-mastoidectomy

Acute ears and some complications

Acute mastoiditis in children may settle with intravenous antibiotics (with or without myringotomy). Occasionally, failure to settle will require simple cortical mastoidectomy. In most such cases, the cortex is intact. If there is a post-aural abscess, it usually develops through a very small defect in the cortex. This abscess may be aspirated with a needle.

Post-aural abscesses in older children and adults usually arise from cholesteatoma. If an incision and drainage procedure is performed, it should be made clear that definitive surgery (tympanomastoidectomy) should take place very soon, with transfer to a specialist hospital if necessary.

If the patient is septic or has an extensive abscess such as a Bezold abscess, they should be systemically stabilised before definitive mastoid surgery.

Facial palsy that is iatrogenic or caused by disease is only relatively urgent. If decompression or repair is required, the second opinion of an experienced surgeon should be considered, and, if necessary, transfer to another hospital. Immediate complete facial palsy persisting for more than 24 hours after ear surgery requires rapid referral or re-exploration, possibly for nerve decompression or grafting.

Intracranial complications will need immediate systemic antibiotics and neurological monitoring, with definitive ear surgery for underlying disease (usually cholesteatoma) as soon as access to a suitable surgical facility is available and the patient is stable.

Polyps

Enormous polyps protruding from the meatus may be seen. Simple polypectomy is inadequate. They usually develop from squamous chronic suppurative otitis media and this should be surgically addressed at the same time. Traction on the polyp risks damage to the ossicular chain, inner ear or facial nerve. A post-aural approach is made, then a bony canalplasty for exposure of the polyp neck. This is then divided at drum level. This is followed by the clearance of underlying disease and reconstruction. There may be extensive bleeding from the remaining polyp until it is cleared.

Incisions

Besides endoscopic surgery, which will be discussed later, and very limited disease, most cholesteatoma surgery is performed via a skin incision. Most procedures can be conducted through an endaural incision; all procedures can be carried out via a post-aural incision. As the disease process may be worse than first estimated, especially in the absence of imaging, and efficient and safe use of time is important under these anaesthetic conditions, we think it is best to adopt a post-aural route in most cases, and most local surgeons in resource-poor settings use this approach.[1] A post-aural approach gives wide access to the entire mastoid cortex down to the tip, and to the anterior margin of the drum.

Canal wall down cholesteatoma surgery

As cholesteatoma normally starts in the middle ear or attic, it makes sense to use a front-to-back approach, following the disease, and therefore limiting cavity size. An atticotomy or atticoantrostomy may avoid the need for modified radical mastoidectomy. If the traditional back-to-front approach is used (dating from when a hammer and gouge were used), then an unnecessarily large cavity becomes inevitable in every case.

Widening the canal or removal of the canal wall facilitates removal of cholesteatoma from those areas that are notorious for residual disease. For example, access to and visualisation of the facial recess, sinus tympani, and anterior epitympanum is much easier.

The rates of residual and recurrent disease are much lower with canal wall down than canal wall up surgery. Where there is residual disease, it is usually in the middle ear, meaning that the obliteration of a cavity is relatively safe. Residual disease is likely to become visible in a cavity, breaking through the obliterative material, rather than causing an intracranial complication. Recurrent pockets going back out of sight into the mastoid cannot occur in canal wall down surgery.

Occasionally, there may be little or no remaining healthy canal skin. Small 'pinch' split skin grafts harvested from relatively hair-free areas behind the pinna can be placed on bare bone, ideally lapping against any remaining vascular soft tissue margins. When larger amounts of split skin are required, it is best to take a formal graft from the thigh or inner side of the upper arm.

Cavities should be smooth, and without sumps and areas that are difficult to clean. Minimising or obliterating cavities, and making extra-large meatoplasties, help a great deal. A small meatus with a large cavity should be a thing of the past. Meticulously retaining good skin flaps to reflect back into the ear canal or cavity helps regain normal skin and wax migration pathways. The aim is a self-cleansing ear or at least one where an inexperienced person can clean the cavity.

When there is a recent or chronic mastoid fistula, this and its tract should be excised as part of a post-aural incision. When large defects in the tegmen or bone of posterior fossa are identified, squamous epithelium can normally be dissected free, leaving the dura intact. Granulations on the dura can often be stripped off and the dura lightly drilled with a diamond burr to reach a healthier surface. A large sheet of cartilage from the concha or helix can then be placed over the exposed dura and under the bone margins. If the dura is also opened, a large plug of muscle should first be placed through the defect.

When the lateral sinus is involved, a needle may be inserted. If no blood is obtained, then after widely exposing

https://doi.org/10.1017/S0022215118002165 Published online by Cambridge University Press

the sinus it may be incised. Inform the anaesthetist and be prepared to immediately put the patient's head down to prevent air embolus. Keep two pieces of ribbon gauze impregnated with antibiotic ointment in readiness. If there is heavy bleeding, be ready to compress and plug each end immediately. After cleaning the area, insert large muscle plugs to replace the gauze pieces. If a clot or abscess is encountered in the sinus lumen, it may be cleaned until a light flow of blood is seen at each end. It should then be plugged as before with soft tissue covered by cartilage, followed by a wide-based soft tissue flap. However, recent literature suggests that this classic approach is now excessive in the era of more effective antibiotics; simply aspirating the sinus for any pus and clearing the infected tissue surrounding the sinus may be adequate, and will allow recanalisation of the thrombosed sinus.[22,23]

Labyrinthine fistulae should be watched for throughout surgery. A pre-operative history or positive fistula test finding may forewarn of danger. The epithelium should be lifted with great care from the lateral canal and other at-risk sites; suction should not be applied directly. If a bony fistula is identified, leave the matrix in place until the operation is complete. A small piece of fascia should be available in readiness. Subsequently, the epithelium should be peeled off with care under high magnification – using a small cotton wool ball can help separate it from the usually thickened membranous labyrinth. The area should be covered with the fascia and bone pâté, and the cavity obliterated to provide thermal insulation.

Facial nerve exposure caused by bone erosion or cholesteatoma, or iatrogenic due to drilling, may be encountered anywhere along its intratemporal course. It is the senior author's practice to carefully peel off any matrix; if there appears to be any damage to the nerve sheath, the bony canal is decompressed a few millimetres each side of the dehiscence. The exposed section is then covered, without pressure, as for a fistula. Intravenous dexamethasone is administered per-operatively, and possibly again that evening and the following morning.

Canal wall up mastoidectomy and staging

Canal wall up mastoidectomy, also called combined approach tympanoplasty, has the advantages of: allowing the normal anatomy of the ear canal and depth of middle ear to be retained, preventing potentially troublesome otorrhoea from mastoid cavities,[24] faster healing, and potentially enabling the easier fitting of a hearing aid if needed. However, it has the disadvantages of: necessitating second-look surgery to check for residual cholesteatoma behind the intact wall, and high rates of both residual and recurrent cholesteatoma. Combined approach tympanoplasty surgery has not been shown to improve hearing results.[24] When residual disease is found, a third examination (or more) may be required.

In some centres, the cortical cavity is obliterated; this reduces the rate of recurrence but necessitates effective MRI to check for residual disease. Specialised MRI (non-echo planar, diffusion-weighted imaging) scans are becoming more common and more accurate in identifying residual and recurrent disease. However, they lack adequate sensitivity and specificity when using lower resolution scanners and software, and without expert reporting. As there is a considerable likelihood that patients will not return for second or subsequent procedures, combined approach tympanoplasty is not normally undertaken for squamous disease in resource-poor environments.

In all cases of middle-ear surgery, the question arises as to whether ossiculoplasty should be performed at the primary operation, or staged. The argument is that once the ear is stable, ideally with a good aerated middle ear, then the results will be more favourable. However, no one wants two operations where one will suffice. Patients may be unable to bear the burden or cost of staged procedures. The results of ossiculoplasty are almost the same in wet and dry ears, and at primary or secondary procedures.[25,26] If it fails the first time, there is still the option to try again when the ear has settled. Ossiculoplasty is easier in a dry, stable middle ear, but that is no argument for not attempting at the first stage, if performed carefully and safely. Many patients will accept long-term conductive hearing loss, rather than submit to a second operation. A hearing aid is not always the answer in a low-income environment, and bone-anchored aids are not widely available. Many patients have bilateral disease and eventually have bilateral hearing loss. We attempt to maximise hearing whenever possible.

Cavity obliteration

Mastoid cavity care is problematic in remote areas. It makes sense to minimise the need for it by obliterating the cavity.

Before cavity obliteration, absolute attention must be given to all the well-recognised characteristics of a 'good' canal wall down mastoidectomy. These include: complete clearance of disease from the middle ear and mastoid; adequate exposure of the anterior epitympanum, facial recess, sinus tympani and Eustachian tube; and removal of all cholesteatoma at these sites. One should be particularly careful in children, where the cholesteatoma is often invasive of many air cells. The ear canal floor should be lowered to avoid a sump. For extensive disease, the cavity should be saucerised, skeletonising the sigmoid sinus and removing the mastoid tip down to the digastric ridge, so that the soft tissues and pinna move medially and reduce the cavity size.

When the disease has been clearly seen and removed, and obliteration of a small or large cavity is planned, there is no absolute necessity to lower the 'facial ridge' (which may also reduce surgical risk to the facial nerve). The final cavity will then be no more than a moderately widened ear canal, with evidence suggesting a low (2 per cent) residual or recurrence rate for cholesteatoma.[27]

Techniques of cavity obliteration are many. The senior author favours the collection of clean bone pâté from the mastoid cortex during initial drilling. A large wet cotton ball is placed in the ear canal to avoid squamous epithelium or infected material mixing with the pâté. The cortex is drilled with a large cutting burr, using limited irrigation. As a pile of moist bone dust builds, it is scooped up with a periosteal elevator and placed in a gallipot. Once an adequate quantity has been collected, and before any cholesteatoma is encountered, this is put to one side and kept slightly moist with a few drops of saline. Collecting devices can be purchased that are placed in the suction tubing, but these are unlikely to be available in this environment.

Some surgeons soak the bone with Betadine® or antibiotic solution; we have found that to be unnecessary. Others have shown reduced infection rates with 48 hours of intravenous (IV) antibiotics and a subcutaneous Penrose drain.[28]

The pâté is packed tightly into the cavity, tamping down hard by suction through wet cotton wool, so that bone particles lock together. This reduces the incidence of depressions forming in the pâté later.[29] This is then entirely covered by a

https://doi.org/10.1017/S0022215118002165 Published online by Cambridge University Press

jigsaw of cartilage pieces. Additional small amounts of bone pâté are placed around to the edges of the cartilage pieces, to minimise the risk of any long-term retraction pocket formation. Particular care is taken to obliterate the anterior attic, where retractions are prone to occur. A superiorly based musculo-periosteal temporalis or periosteal (middle temporal) flap,[29] with or without an inferiorly based post-auricular soft tissue flap, is placed in the cavity, over the cartilage. The posterior edge of the underlay temporalis fascia graft used for drum repair is then laid back over the flaps.

Meatoplasty

The importance of an adequately wide meatoplasty cannot be over-emphasised in remote locations. Visiting surgeons from higher income countries often underestimate this.

Once the tympanomastoidectomy has been completed, a large conchomeatoplasty is made. The skin flap or flaps (depending on the favoured technique) arising from this are placed into the cavity over the grafts. No skin should be sacrificed. It is essential that sufficient cartilage is excised from the conchal bowl, so that the skin flap lays back freely into it (without the need for securing sutures). The meatus must be large, even though the eventual cavity will be small because of saucerisation and obliteration. This makes access for cleaning easier and safer, and the cavity more likely to self-clean. It also provides good ventilation and drying. Obliteration provides insulation over the lateral canal and labyrinth, so that cold will not cause thermal vertigo.

Regarding meatoplasty technique, many options have been described. We detail the favoured method of the senior author, used over many years, in the online Supplementary material 2. The advantages of this are: conchal cartilage harvesting; the retention of underlying soft tissue to help line the cavity; and a single, long, random-pattern vascular flap, which can be placed to reach and overlap cavity obliteration grafts. The long flap, running uninterrupted from deep in the canal to the meatus, promotes normal epithelial migration and a self-cleansing canal. Regarding the potential disadvantages, the wide meatus may be a cosmetic issue and may affect hearing aid fitting.

Blind sac closure

In end-stage ear disease, where multiple attempts to obtain a dry ear have failed and often there is no residual hearing, then the ear can be sealed. After wide mastoidectomy, exenterating all residual squamous and as much as possible all mucosal disease, the Eustachian tube is sealed. Some use bone wax; however, this may not be available and can act as a foreign body. Thus, bone pâté and a muscle plug can be packed into the tube. Remember the proximity of the internal carotid artery when working in this area. The cavity is obliterated as before, or with abdominal fat. The external auditory meatus is everted and sealed in layers that include conchal or tragal cartilage.

Ossiculoplasty

Here, we describe autologous tissue ossiculoplasty techniques (see the Supplementary material 3, available online, which includes detailed explanations with diagrams and photographs of those techniques commonly used by the senior author in remote settings over many years). Although prostheses may be faster to use, they are usually not available, may be made from poor quality materials prone to extrusion and the results may be no better.

There are well-recognised limitations in outcome and long-term deterioration in results with all techniques and materials. We do not have good control of Eustachian tube function and middle-ear aeration. However, despite this, sometimes the results are good, and usually there is some degree of improvement in the air–bone gap. Routine practice with ossicular reconstruction should lead to better outcomes. For a patient with bilateral hearing loss, and no access to hearing aids and batteries, even a small gain may be invaluable.

In low- and middle-income countries, access to prostheses is poor, and costs are usually excessive. It is necessary to use what is available, such as ossicle remnants, cortical bone and cartilage. These will never extrude, even if the drum retracts around them. However, using autograft materials extends the operating time, as harvesting and refashioning such materials takes longer than using a prosthesis.

There may be a temptation to use items such as a Teflon™ grommet or a dummy prosthesis sizer as a prosthesis; however, these are unlicensed, not intended for implantation and likely to extrude. Some locally made, more economic prostheses are available in some countries; for example, Teflon stapes prostheses and titanium total ossicular replacement prostheses are obtainable in India.[30]

Grommets are generally available and low in cost; however, in their absence, it is possible to make them locally. Thin plastic tubing should be used, such as that from a butterfly IV cannula. A short length of tubing should be cut, heated at each end and pressed flat to create flanges, ensuring the lumen is patent.

The ideal ossiculoplasty material is an autograft ossicle. (Homografts should no longer be used because of the risk of transfer of prion and viral diseases.) Re-implantation of cholesteatoma is an important risk, but this is rare when caution is exercised.

When carving ossicle or bone, the ideal instrument to secure it is Derlacki forceps. These resemble Adson toothed forceps, but with more teeth and a screw to clamp it closed. (Many ossicles have been crushed or lost by using mosquito forceps.)

Check the integrity and mobility of the stapes footplate or the round window reflex before performing ossiculoplasty.

In most cases, we surround the prosthesis in the middle ear with ciprofloxacin-soaked gelatine sponge. If a dry sponge is used, it will expand and may disturb the reconstruction. If the facial nerve is exposed or at risk of oedema, a couple of drops of steroid such as dexamethasone may also be applied. (In some countries, combined quinolone with steroid eardrops are available.)

Congenital anomalies of pinna and ear canal

Reconstruction of microtia or canal atresia for cosmetic or hearing purposes is challenging in any environment. Although there may be family pressure, it is best to avoid these procedures, which may be multistage and are prone to serious complications. Moreover, the results are often disappointing. For bilateral cases, bone conduction hearing aids may be considered, if available. Recently inexpensive Bluetooth®-paired bone conducting devices have been developed for use by cyclists, and there is interest in repurposing these as a low-cost bone conduction device for other uses.

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Post-operative care

Suturing and cosmesis

One aim of any visiting surgical team must be to minimise work pressure on the local services. Avoiding skin sutures is one way to do this. Use permeatal approaches or subcutaneous absorbable sutures when possible. Graft donor sites from the tragus do not need sutures. Visible scars may affect the marriageability of young girls. Some ethnic groups are at greater risk of keloid scarring.

Wound closure and dressings

Gelatine sponge (Gelfoam) is commonly used in the middle ear and over the repaired tympanic membrane. It may help to maintain a middle-ear space during healing and to support underlay grafts. It may also protect the new drum externally until it has epithelialised. The sponge may be soaked with a non-ototoxic antibiotic such as ciprofloxacin. Gelatine may not be available or acceptable. There is no inexpensive, readily available substitute, though blood oozing into the field or antibiotic ointment on the drum may serve the same purpose.

The ear canal or cavity may be packed to help hold tissue flaps in position and reduce dead space for clots to accumulate. Ribbon gauze impregnated with an antiseptic or antibiotic ointment is commonly used. Examples would be ointments containing neomycin, polymyxin or bacitracin. Ointment is preferable to cream, as it is oily and not water-soluble. This type of packing is normally removed within two weeks. When surgery is conducted in remote areas, it is best not to leave packing material for non-specialists to remove. Tiny pieces of packing that are difficult to find should never be used, especially in children. When necessary, packs can be removed within 24 hours of surgery and replaced with antibiotic ointment. Alternatively, no ribbon packing may be needed, just ointment with or without gelatine sponge.

A head bandage may be left in place for some days, to protect the wound from dust and insects, and to absorb any exudate.

Patients and their carers should receive clear written and verbal information (in their language) about post-operative care and contact points in case of any problems. Mobile phones and the Internet are now so widely available that even patients in remote areas should be given contact details to enable them to reach the surgical team, or designated local experts with access to their medical records, for advice. Local community health workers should also be instructed and given the same information, so that they are not left feeling disempowered and unable to advise.

Patients should be supplied with adequate medication for the full post-operative period (e.g. they may need analgesics and a lengthy supply of eardrops). We provide written advice about wound care and water protection.

Antibiotic prophylaxis

Many studies have shown that antibiotic prophylaxis during or after ear surgery is unnecessary.[31] There is evidence to indicate that ears which are wet at the time of surgery have similar outcomes to dry ears.[10,11,25] However, these studies are generally from high-income countries. These patients may have relatively uninfected ears at the time of surgery, and their hygiene is better. Antibiotic abuse is common in low- and middle-income countries, and leads to loss of bacterial sensitivity. There are also problems with compliance in taking post-operative medication. There is a high incidence of counterfeit or low potency drugs in low- and middle-income countries.

Our practice is to give a single dose of IV or intramuscular antibiotic at the time of surgery. Currently, we use ampicillin with cloxacillin (or co-amoxiclav) and gentamicin (vestibular ototoxicity from a single dose is rare, particularly when renal function is normal[32,33]).

It is also our normal practice to administer a single dose of IV dexamethasone at the start of the procedure, to ameliorate nausea and perhaps protect the cochlea.

Immediate post-operative care

There must be a designated recovery area, however simple, with adequately trained personnel observing. This should occur regardless of whether general anaesthesia or local anaesthesia with sedation was employed. Frequent observations of respiration and pulse, preferably with a pulse oximeter, should be made. Facial nerve function must be checked and recorded. Local anaesthesia may be responsible for early weakness, but should not be assumed to be the cause. Nausea or vomiting may require treatment. Persistent bleeding through a head bandage may require elevation of the head. Adequate analgesia should be readily available.

Once stable, the patient may be transferred to supervision by their relative or guardian. Most patients can leave the medical facility within a few hours.

Long-term post-operative care

Traditionally, patients with mastoid cavities are seen every 6–12 months for review and cleaning. However, this may be impractical in remote communities. A wide ear canal and obliterated cavity accumulate less debris, and can be cleaned under direct vision (perhaps with a head torch) by local health personnel. When possible, occasional review by an otologist is wise, to detect any recurrent or residual disease.

Record keeping

It is important to record the operative method and findings. In some countries, patients carry their own records. They should be routinely supplied with a copy of the operation notes, not a summary. These can be shown to any future surgeon. Revisions and recurrences are not uncommon in ear surgery cases. It is good patient care to provide these details. For example, if the patient presents elsewhere with severe conductive hearing loss, and fixation of the stapes was not recorded, it could lead to unnecessary re-exploration. Knowledge of an exposed facial nerve, high jugular bulb, labyrinthine fistula or other surgical difficulties will protect both the patient and surgeon.

Surgical outcomes and audit

Audit, especially prospective, should be routine. It provides evidence for: financial donors, learning and training opportunities, reflection on outcomes, research options, and best practice. Follow up is difficult in remote situations, but should be considered, and efforts made to plan this as part of the project.

We have kept records of the demographics, diagnosis and treatment for over 50 000 ear out-patient consultations in

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resource-limited sites in Nepal on a computer database created using Epi Info, a World Health Organization free resource. These have been analysed to inform local authorities and our own project proposals. In addition, we have recorded on paper all post-operative visits of patients treated surgically on remote ear camps in Nepal.

All patients receive a copy of their notes, including the operation notes, in a protective plastic folder. All patients have an identifier number on the notes because names and spellings vary when transliterated to roman script, and date of birth is frequently uncertain in some communities. At the immediate post-operative counselling sessions and in the printed notes that they are given regarding their post-operative care, patients and guardians are urged to retain the folder, and present it at any subsequent meeting with our or any other team. Although many fail to do so, we have been able to use these to analyse the results of about 10 per cent of 2642 patients operated on in 36 remote locations. These data are, of course, very limited and far from ideal, but have enabled us to examine some results.

We have tried arranging post-operative visits at fixed dates, but unfortunately many patients fail to attend. Our best follow-up rate was for planned return visits after 7 months, for which 72 per cent of patients attended; we had a lower rate for planned revisits to another site after 12 months, at 39 per cent. The surgical results for these two groups were comparable to those of the 10 per cent of all patients seen by chance at subsequent ear camps, with the average follow-up period of these being 1 year and 9 months (range, 2 months to 10 years). Considering that for many patients a visit would involve expense and many hours of walking over difficult terrain, the low follow-up rate is perhaps not surprising.

Cohort analysis findings

From the cohort mentioned above, of 2642 patients we saw 231 again at some point on repeat visits. Twenty-seven per cent of these had over three years of follow up. A total of 170 patients had an intact drum; 66 (28 per cent) had a perforation. However, only 23 patients (10 per cent) were thought suitable for revision surgery. (In the other cases, the operated ear was now the best hearing ear, dry, with only a trouble-free pinhole, or the patient was requesting surgery for the other ear). This survey was completed some years ago (2008); since then, and as result of these findings, we have universally used a two-layer graft for the drum, including cartilage, in all cases.

In this cohort, 39 ears were wet when re-examined (17 per cent); however, in most cases, this was due to limited areas of myringitis, which may respond to medical treatment. Most patients had not been seen by any ENT doctor or received aural toilet during the follow-up period.

Residual or recurrent cholesteatoma was identified in four cases (all were revised).

Hearing had improved (average air conduction at three mid-range frequencies) in 136 patients (78 per cent). This is lower than the 90 per cent of patients who had post-operative follow up at 7 or 12 months post-operation. Hearing remained similar to pre-operative levels in 34 patients (19 per cent) and was worse in 5 (3 per cent). Two patients had dead ears pre-operatively. There were no dead ears as a result of surgery.

One patient developed a partial facial palsy due to posterior genu injury; he underwent immediate decompression. Subsequently obtained information indicated that this palsy improved spontaneously.

As almost all of these patients had wet ears, with no pre-operative preparation, and often the patients had complicated findings such as granular atelectasis, lateral canal fistulae, granular exposed dura or exposed facial nerves, we are of the opinion that these results are acceptable, but with room for improvement.

We would suggest that using a computerised standard operation record (or at least scanning the written record) and then documenting post-operative findings whenever patients present, even in remote locations, would enhance our system, improve patient care and enable continuous audit. Regular return visits to the same site or a locally trained paramedic should also improve follow up.

A recent review of 216 primary ear surgical procedures (including cholesteatoma procedures), performed by 2 resident trainee surgeons at our base hospital in Nepal, identified 22 cases (10.2 per cent) with a perforation at one-year follow up.

A recent (2018) review was conducted of 60 mastoidectomy procedures with cavity obliteration performed by 4 surgeons (including 2 trainees) at our ear centre in Nepal. Follow-up duration was short, at six months to two years. Of the patients, 86 per cent had dry ears, 97 per cent had intact drums and 70 per cent had an improved average air conduction threshold on pure tone audiogram. (Some patients had near-normal hearing pre-operatively, but had to undergo ossicular chain reconstruction because of disease.) Residual cholesteatoma pearls were identified in two patients and were revised.

New developments and their appropriateness in remote settings

Endoscopic ear surgery

Endoscopes offer improved visibility and minimal access. They require a high-definition camera system, are fragile, expensive and cannot replace the microscope for all procedures. Infected granular ears that bleed are not ideal for endoscopic work. The two-dimensional view and the usual need to operate with only one hand may be technically challenging for those new to the technique. General anaesthesia is usually required. Endoscopes will become more widely used for limited disease, because of the improved visualisation of detailed anatomy and the reduced need for incisions.

Laser

Lasers, usually potassium titanyl phosphate or diode, may be used in otosclerosis and cholesteatoma surgery. Evidence of improved hearing results is scant. Lasers should be considered a luxury in resource-limited settings. Low wattage lasers are compact and their use may become more widespread. Light fibres are expensive and most are intended for single use only.

Discussion

The burden of ear disease and deafness in low- middle-income countries is well known. A large proportion of cases are chronic suppurative otitis media. Much of this is preventable or treatable.[34] It is a hidden problem, often considered low priority, despite significant morbidity and even mortality. The long-term social and economic costs are underestimated. Services to treat these needs are often underdeveloped, with few trained professionals. Some continents, such as Africa, are currently particularly lacking in services and trained personnel.[35,36]

https://doi.org/10.1017/S0022215118002165 Published online by Cambridge University Press

Those working in this field are the principal advocates for those affected. The World Health Organization has published a helpful review, which includes strategies to develop surgical services.[37]

The model of specialists visiting remote locations, either internally or from overseas, is one way to help meet some of the current needs. Once health services develop, and specialists are provided in centres outside of major cities and are running peripheral clinics, the need will reduce. Meanwhile, there is a place for peripatetic work in remote locations. A survey of otolaryngologists in Nigeria conducted in 2013 revealed that 60 per cent of their places of work performed no ear surgery; of the remaining 40 per cent, about 40 per cent of places offered only cortical mastoidectomy and about 30 per cent offered only myringoplasty.[38] Integration with national health programmes is ideal but is not always straightforward. Criticism of short-term surgical visits may be justified when they lack forethought and can do real harm to patients.[39,40]

There is little published practical advice on running services in remote centres with limited facilities. This paper describes the elements that we have found necessary to make the centres successful, including appropriate surgical techniques. Others have recorded their experiences in different places,[41–44] emphasising the need for repeat visits[45] and longer-term follow up of surgical outcomes.[46] Some have pointed out that volunteers are often relatively inexperienced residents or junior trainees, and that they are not tied in with local training programmes.[47]

The senior author has run over 50 ear camps from inception to the current day, and worked full time for over 15 years in resource-poor settings. The world and its needs are changing, communications have become ubiquitous, and although we are very far from 'making poverty history', there is significant infrastructure development in many countries. There is a growing political desire to take local responsibility, and not depend on outsiders or voluntary organisations. The need for international 'parachute' missions is diminishing, but partnerships and mutual support still have a place. At a recent international otology conference, more than 100 countries were represented.

There is a danger that higher income individuals in lower income nations will be able to access First World medicine and surgery, but the poor will remain under-served.[48] As the excellent 2017 review in *The Lancet* clearly describes,[49] improved primary healthcare is the most cost-effective way to reduce the prevalence of chronic suppurative otitis media. However, there remain those already affected or those that despite excellent healthcare still suffer middle-ear disease.

Conclusion

Ear surgery techniques used in resource-poor environments must be modified to meet the situation. In general, for extensive disease, meticulous canal wall down surgery, with cavity obliteration and wide meatoplasty plus primary autologous ossiculoplasty, may represent the best option. For less extensive problems, such as simple perforations, minimal access techniques like permeatal tragal composite graft myringoplasty may provide the best long-term outcomes for minimal morbidity. Equipment should be appropriate, affordable, and have the means for local repair and replacement of parts. Teaching, with the aim of passing on skills, and becoming redundant by regular long-term input, should be the target.

Improved primary healthcare of the ear, early treatment and referral will change the landscape. Close co-operation with, and respect for, local services and colleagues are essential for ultimate success. Audit and constant re-examination of the programme in the light of current circumstances and national medical development should be integral to any plan.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0022215118002165.

Acknowledgements. The authors acknowledge the friends and colleagues in many countries who have contributed to their experience. In particular, they wish to thank those in Nepal, India and Cambodia.

Competing interests. M C F Smith has associations with the International Nepal Fellowship (member), Ear Aid Nepal (chairperson) and Stiftung Ohrchirurgie Nepal (link person); these charities support medical work in Nepal, but the author receives no personal financial support. Charlie Huins and Mahmood Bhutta previously worked as visiting teaching fellows at the ENT Department of the Children's Surgical Centre, Phnom Penh, Cambodia, a position funded by the Kadoorie Foundation. They are not in receipt of any ongoing funding.

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