Introduction
It is widely accepted that cholesteatoma almost invariably requires surgical management. There has been ongoing debate regarding the optimal technique since intact canal wall or canal wall up (CWU) mastoidectomy was developed in the decade following the widespread introduction of the operating microscope in 1953. At the time of the national comparative audit of mastoid surgery overseen by the Royal College of Surgeons of England in 1991, 80% of procedures performed by participating surgeons in England and Wales for cholesteatoma were canal wall down (CWD) and 9% were CWU. Choice of technique depends on factors relating to the surgeon, the patient and the disease process. A plethora of literature cites the benefits and pitfalls of CWU, CWD and CWU with mastoid obliteration/canal wall reconstruction techniques. This article aims to review the arguments for and against CWU versus CWD surgery for cholesteatoma by addressing a number of factors which are affected by the technique performed.

Repeat operations
CWU surgery can provide very limited exposure (see below), particularly in cases with poorly developed zygomatic root cells and a low tegmen. A second look procedure is generally advocated 9 to 12 months after the primary surgery to remove any residual or recurrent cholesteatoma, which may not be seen behind the anatomically normal canal wall, or to confirm its absence. Reconstruction of the hearing mechanism may also be performed at the second look procedure. Conversely the aim of the CWD technique is to perform one-stage surgery. Recurrent disease can be seen more easily in an outpatient setting owing to the communication of the mastoid cavity with the external auditory canal. Hence revision surgery can be reserved for cases of established recurrence and the total number of procedures required is lower. CWD surgery should therefore be considered in frail patients or those with significant comorbidity who are not thought to be fit enough for more than one operative procedure. Similarly it is beneficial in patients who are unlikely to attend for follow up or in areas where healthcare provision is poor.

Abstract
There has been fierce debate regarding the optimal surgical technique for the management of cholesteatoma for over 50 years. Choice of technique depends on factors relating to the surgeon, the patient and the disease process. Much literature has been devoted to the benefits and pitfalls of canal wall up and canal wall down techniques and their respective effects on measures such as number of operations required for disease eradication, adequate surgical access, complications, residual/recurrent cholesteatoma, hearing outcomes and long-term follow up. This article aims to review the pros and cons of canal wall up versus canal wall down surgery for cholesteatoma.

Keywords
Mastoidectomy, canal wall up, canal wall down, cholesteatoma, hearing.
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Nevertheless revision surgery is not uncommon after CWD procedures. Osborn et al published a retrospective review of 420 children who underwent 700 procedures for cholesteatoma. Revision surgery was required in 51% of CWU and 21% of CWD procedures. Despite the higher rate of revision surgery in CWU cases they believe that CWU surgery is preferable due to better audiometric outcomes and easier post-op care. Other proponents of CWU surgery in children argue that serial general anaesthetics are often required to remove dressings and perform aural toilet during the early postoperative period following CWD surgery such that the total number of procedures performed is no less for the CWD technique. CWD revision rates should also be interpreted in light of when they were published – in the past in the UK many patients had chronic discharge post CWD surgery without revision. This has changed over the past 20 years and as a result revision rates for the CWD technique may be higher than earlier literature would lead one to believe. A new approach in the assessment of postoperative cholesteatoma is the use of non-echo planar diffusion weighted magnetic resonance imaging to detect recurrent disease. This is useful as an adjunct to second look surgery but as yet is not reliable enough to replace it, though it may play an increasing role in reducing second look rates in the future.

Access
Cholesteatoma may be removed piecemeal and left behind in areas of the temporal bone which are poorly visualised during surgery. Hulkka and McElveen demonstrated in a prospective randomised blinded temporal bone study that the CWD approach is significantly superior to CWU in visualising middle ear subsites, specifically the sinus tympani, posterior crus of stapes and lateral epi tympanum (the Eustachian tube opening could be observed equally well in both approaches). Exposure of such subsites is particularly difficult in CWU procedures in the presence of a low-lying tegmen, contracted sclerotic mastoid and anterior sigmoid sinus. These anatomic factors may be assessed preoperatively on a CT scan to aid choice of approach. Alternatively a CWU procedure can be performed and the canal wall removed intraoperatively if the exposure is not good enough to adequately remove the cholesteatoma. Surgical techniques have been developed whereby the canal wall is temporarily removed to provide the exposure achieved with CWD surgery followed by canal wall reconstruction and/or partial mastoid obliteration with a variety of materials to attain the benefits of CWU surgery. This enables single stage surgery in up to 90% of cases. The small cavity mastoidectomy, which comprises a ‘front to back’ approach (attico-antrostomy) in order to limit the size of the cavity to the extent of the disease, combines the open cavity technique with a relatively trouble free mastoid cavity although it is technically demanding. More recently the use of middle ear endoscopy has improved visualisation in CWU techniques leading to a reduction in, but not eradication of, residual cholesteatoma. The KTP (potassium titanyl phosphate) laser has also been shown to be a useful adjunct in cholesteatoma eradication. The ability to deliver energy through a flexible fibre means that it can be used around corners in areas which are otherwise difficult to clear of disease. Hamilton showed that the rate of residual cholesteatoma can be significantly reduced in CWU surgery by using the KTP laser to remove disease adherent to and adjacent to ossicles and to heat the surface of bone and soft tissue (apart from the facial nerve) from which cholesteatoma has been elevated, thus denaturing any residual microscopic but viable epithelium.

Complications of surgery
The rate of major complications reported in the national comparative audit of mastoid surgery was 7% for CWD, 4% for CWU and 6% for CWD with obliteration procedures. Dead ear and facial nerve palsy only occurred in CWD surgery. This may relate to the disease extent, experience of the surgeon and other factors and cannot simply be attributed to the technique itself.

Residual/recurrent disease
Residual cholesteatoma is that left behind at the first procedure, either intentionally, for example over a lateral semicircular canal fistula, or (usually) inadvertently. It occurs following CWU or CWD down procedures, most commonly in the areas which are difficult to visualise as detailed above (epitympanum and posterior mesotympanum) and therefore tends to be more prevalent in CWU surgery as a result of poorer intraoperative exposure. Recurrent cholesteatoma is primarily a problem of the CWU procedure and arises from posterior superior retraction pockets. The figures cited in the literature for residual and recurrent disease are extremely variable, which may be for several reasons. First, it is difficult to distinguish between the two unless the same surgeon has performed both the primary and second look/revision procedure and for this reason residual and recurrent disease will be discussed further as a single entity. Second, the residual/recurrent rates published for CWU versus CWD surgery in many series may not really be comparable as there may be a tendency to perform CWU surgery for small cholesteatomas and CWU surgery for much more extensive disease. Third, the technique used most often by a particular surgeon is usually that at which he/she is most accomplished. The single most important factor responsible for failure of CWD surgery is poor execution of the procedure resulting in a residual infected mastoid cells, high facial ridge, stenotic canal/meatus, bony overhangs preventing the cavity from self-cleaning and therefore promoting the disease process and failure to isolate the mastoid cavity from the Eustachian tube orifice and middle ear. CWD procedures tend to have lower residual/recurrent rates of cholesteatoma. As an example of results from a large otology practice, Karmarkar et al published a retrospective analysis of 433 primary cholesteatoma cases over a 7 year period. Recurrent/residual disease was present in 12.4% of CWU cases and 42% of CWD cases. The figures are somewhat different for cases of extensive cholesteatoma only; a series of 87 cases demonstrated recurrence in 70% of cases 10 to 13 years after a primary CWU procedure compared to 15% of cases following CWD surgery. The procedure must therefore be tailored to the disease severity for optimum results.

Hearing
As for residual and recurrent disease rates, there is wide variation in published hearing outcomes with CWU and CWD surgery. Hearing thresholds were improved following...
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30% of CWU procedures and 12% of CWD procedures in the national comparative audit of mastoid surgery – a statistically significant difference. Thresholds were worse after 13% of CWD and 8% of CWU procedures (not significant). Once again however, hearing outcomes were unknown in 40% of cases, so these results do not necessarily give us a clear picture. Hearing is generally thought to be worse following CWD than CWU surgery due to: 1. Changes in the resonance of the middle and external ear due to the mastoid cavity and 2. A shallower middle ear cleft and therefore reduced middle ear volume. Whittimore et al performed a cadaveric temporal bone study on the acoustic effects of changes in the volume of the middle ear air space resulting from CWU and CWD procedures and found that as long as the middle ear space is aerated and has a volume of more than 0.7 m³ there should be less than 10 dB difference between CWU and CWD hearing outcomes. Many other factors apart from the surgical approach affect hearing results including granulations, infection, status of the tympanic membrane, method of hearing reconstruction and Eustachian tube function, which are evident in some of the following publications.

Tos and Lau achieved significantly better postoperative hearing results with CWU than CWD surgery but the preoperative thresholds were also significantly better in the CWU group, demonstrating that disease severity and other confounding factors also affect hearing outcomes independent of the surgical procedure.

Kim et al found no significant difference in post-operative air-bone gap (ABG) between CWU and CWD (10.9 vs 13.5 dB) or in the proportion of patients with an ABG <20 dB (58.6% vs 68.4%) 3 months after ossiculoplasty. This study is notable for the fact that the authors have tried to exclude confounding factors by comparing CWU and CWD outcomes in patients with an intact tympanic cavity and stapes who had a staged ossiculoplasty at least 6 months after mastoidectomy. Nevertheless their follow up period is short.

Toner and Smyth published their comparison of patients who had CWU, CWD with reconstruction and CWD surgery with follow up of between 8 and 12 years. They found that the hearing benefit at one year (pure tone average (PTA) air conduction (AC) threshold) was greater in the CWU group, demonstrating that disease severity and other confounding factors also affect hearing outcomes independent of the surgical procedure.

Studies in children show great variability. Murphy & Wallis had similar hearing outcomes following CWU and CWD surgery in children. Osborne et al found hearing to be significantly better following CWU surgery (mean PTA 30 dB) than CWD surgery (mean PTA 45 dB) in their retrospective review of 420 children, independent of preoperative hearing levels and of the condition of the stapes.

It is also worth considering the Glasgow benefit plot and Belfast rule of thumb when comparing hearing outcomes. To achieve patient satisfaction in operations to improve hearing the ABG must be closed to less than 30 dB and/or to within 15 dB of the other ear; thus although a specific technique may improve hearing, if it does not meet these criteria then it may be clinically irrelevant to compare small differences in threshold achieved for each surgical technique.

Wet ears

A wet ear can have significant impact on the quality of life of patients following surgery for cholesteatoma. It may result in changes in lifestyle, such as adherence to strict water precautions and dependence on microsuction. Moreover, a wet mastoid cavity used to be considered ‘safe’ but this has been shown not to be the case; continued activity in the absence of cholesteatoma in a modified radical mastoid cavity can result in an intracranial abscess. The national comparative audit of mastoid surgery collected data on the status of ears between 3 and 15 months postoperatively, though it is noteworthy that it was unreported in 22% of cases. There was no significant difference between the number of dry ears with open and closed cavities but a statistically significant difference of 1.7% wet ears following CWD surgery and 10% following CWU procedures. In contrast Toner found no significant difference in the number of moist ears and the degree of wax accumulation following CWU, CWD and CWD with obliteration procedures. At the last consultation, 1 to 24 years after surgery, 95% of cavities were found to be dry and self cleaning after CWD surgery in a series by Kos et al. The status of the cavity is not only affected by the procedure performed, but also by the skill of the surgeon, cavity size, shape and extent of epithelialisation.

Hearing aids

Fitting a hearing aid is generally associated with fewer complications after CWU surgery than CWD surgery due to an anatomically normal external auditory meatus. CWD surgery requires a meatoplasty for adequate aeration of the cavity. A widened distorted meatus makes initial fitting of a mould more difficult and the cavity can subsequently become wet when the meatus is obstructed by a hearing aid mould.

Deformity

The meatoplasty performed can in some cases be sufficiently large as to visibly distort the meatus and area of the conchal bowl. The cosmetic aspects of the surgery should be considered when performing a meatoplasty.

Follow up

Immediate and long-term postoperative follow up is generally considered to be more intensive following CWD procedures since serial debridement is usually required, whereas the ear maintains its natural anatomy and heals more quickly after CWU surgery. Toner et al challenge this in their data on patients who had surgery for cholesteatoma with follow up of between 8 and 12 years. They found no significant difference in frequency of required follow up between CWU, CWD with obliteration and CWD procedures.

Khalil et al studied follow up in a group of patients after CWD surgery. They attended for follow up for removal of the clinical features of chronic cavity inflammation, to maintain the lining of the cavity in a healthy state and to assess for the remote chance of complications developing. A median of 11 and mean of 13.3 visits to outpatients was made over the study period of 158 months (a mean of 1 visit per year). The greatest number of visits occurred in the 24 months immediately after surgery. Only a quarter to a third of patients were ever discharged. There were no figures for CWU surgery.
for comparison. Nevertheless this study demonstrates the significant burden on resources required after CWD surgery.

**Conclusion**

The debate surrounding the pros and cons of CWU versus CWD surgery for cholesteatoma continues after more than half a century. A one stage CWD non-obliterative procedure is still advocated by some who claim that this provides maximum long term patient benefit with no difference in hearing outcomes, wet ears, extent of wax accumulation or frequency of follow up.13, 17, 20 Some believe that CWU surgery is preferable due to better audiometric outcomes and easier post-op care.3, 7

They are probably all correct in the right patient, for the right disease and by the right surgeon. No single method is suitable for every patient and cholesteatoma surgery should be individualised according to the patient’s needs and the extent of the disease.15 Successful surgery also depends to a certain extent on the availability of modern equipment including operative endoscopes and low energy laser. Finally, the surgeon’s expertise is of the utmost importance; as shown above, a CWD procedure with tympanoplasty may yield a dry ear with hearing results comparable to those following a CWU procedure in the right hands.12, 22 As Sheehy said, ‘The key to success in otologic surgery is not whose technique one uses, but how one uses it and one’s own ability and judgement’.

**Conflict of Interest**

All authors have no conflict of interest to declare. No extraneous funding was obtained.

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**References**


