Canal Wall Reconstruction Tympanomastoidectomy with Mastoid Obliteration

Bruce J. Gantz, MD; Eric P. Wilkinson, MD; Marlan R. Hansen, MD

Objectives: This study was designed to evaluate the authors' experience with canal wall reconstruction (CWR) tympanomastoidectomy with mastoid obliteration in the treatment of chronic otitis media with cholesteatoma. Study Design: Institutional review board approved retrospective case review. Methods: Retrospective review was performed of all patients undergoing CWR tympanomastoidectomy with mastoid obliteration from 1997 to 2004. Data included pre- and postoperative audiometry, findings at second look surgery with ossiculoplasty, and postoperative complications including wound infection and canal wall displacement. Results: One hundred thirty ears in 127 adults and children underwent the procedure. Mean time postoperative was 48 (range 2–94) months. A second look ossiculoplasty was performed in 102 (78%). Percentage of ears that remain safe without evidence of recurrence was 98.5. The postoperative infection rate decreased from an initial rate of 14.3% to 4.5% for the last 88 ears after protocol modification. Recurrence occurred in two (1.5%) patients, requiring conversion to a canal wall down mastoidectomy. Conclusions: A CWR technique can provide improved intraoperative exposure of the middle ear and mastoid without creating a mastoid bowl and reduces the incidence of recurrent disease. A single procedure is used for all patients with acquired cholesteatoma, including children. Key Words: Cholesteatoma, mastoid obliteration, otology, tympanomastoidectomy, recidivism, pediatric, adult, chronic otitis media.

INTRODUCTION

The primary goal in the surgical management of chronic otitis media with cholesteatoma is the creation of a dry, safe ear through removal of disease and alteration of anatomy to prevent recurrence. Canal wall up (CWU) techniques preserve the anatomy of the posterior canal wall, eliminating the need for periodic bowl cleaning and avoiding the risk of recurrent bowl infections. However, the recidivism rate may be as high as 36% in adults and 67% in children after CWU procedures.

The “gold standard” for management of cholesteatoma is the canal wall down (CWD) mastoidectomy. Complete posterior canal wall removal provides exposure of the entire attic, especially the region of the anterior zygomatic cell tract. Removal of the posterior canal wall enhances exposure of the entire epitympanum and middle ear, helping to ensure complete disease eradication. This approach can reduce the recidivism rate to as low as 2%.

A major disadvantage of the CWD technique is the accumulation of debris in the exteriorized mastoid cavity, requiring periodic cleaning and, on occasion, water restrictions to prevent bowl infections. Obliteration techniques can reduce the size of the cavity. A CWU or CWD technique individually is not amenable to use in all patients, and many surgeons advocate choosing a technique based on the individual clinical situation.

The CWD technique also provides for removal of the nitrogen-absorbing mucosa of the mastoid. After surgery, the new epithelial lining of the mastoid bowl is a stratified keratinizing epithelium. In the CWU procedure, the mastoid retains its native cuboidal nitrogen-absorbing epithelium. Eustachian tube dysfunction could result in reaccumulation of secretory middle ear effusion and retraction of the posterior superior quadrant of the tympanic membrane, causing recurrent cholesteatoma.

At the University of Iowa, we have been using a canal wall reconstruction (CWR) technique for the surgical management of cholesteatoma, originally described by Merckel. In this technique, the posterior canal wall is removed using a microagittal saw, facilitating the complete removal of disease. The advantages of the procedure include providing increased intraoperative exposure (similar to a CWD technique), removal and obliteration of the nitrogen absorbing mastoid epithelium with bone pâte, and reconstruction of the posterior canal wall. The procedure is designed to prevent development of postoperative retrac-
tion pockets by obliterating the mastoid cavity and isolating the tympanum from the attic and mastoid using bone chips and bone pâté. This communication describes the technique that we have been using, results, and management of complications.

MATERIALS AND METHODS

A retrospective review of patients who underwent the CWR technique between 1997 and 2004 at the University of Iowa was performed. The University of Iowa Institutional Review Board approved the study. All surgeries were performed by the two senior authors. A database was designed to record pertinent data including age, sex, side of surgery, preoperative and postoperative air-bone gap measurements, postoperative status of the canal wall and tympanic membrane, and findings at ossicular reconstruction including presence of residual disease. Occurrences of postoperative infection and cholesteatoma recurrence were recorded.

Audiometric studies included pure-tone thresholds and speech reception thresholds on all patients and are reported according to guidelines published by the Committee on Hearing and Equilibrium of the American Academy of Otolaryngology-Head and Neck Surgery.

Surgical Technique

The CWR technique is similar to that of Mercke. An anteriorly based, wide musculoperiosteal Palva flap (approximately 4 × 4 cm) is created. A Sheehy bone pâté collector (Otomed, Lake Havasu City, AZ) is used to collect bone pâté from the cortex of the mastoid and squamosa of the temporal bone. Bone pâté collection stops before exposure of the mastoid air cells. Bacitracin solution is drawn through the bone pâté, and the pâté is set aside.

A complete cortical mastoidectomy is performed, including exenteration of the sinodural angle and mastoid tip air cells. The posterior canal wall is left relatively thicker than in typical CWU procedures. The facial recess is opened and extended inferiorly to the level of the floor of the external canal. The incus and head of the malleus are removed. The external canal skin is elevated off the posterior canal wall without making any incisions in the posterior canal wall skin, the annulus is elevated, and the tensor tympani tendon is transected, allowing exposure of the entire tympanum. Care is taken to raise the canal wall skin well anteriorly to protect it from the posterior canal wall cuts.

A microsagittal saw (Jed Med Bien Air, St Louis MO, or Anspach, Palm Beach Gardens, FL) is used to create superior and inferior cuts in the posterior canal wall (Fig. 1). The cuts are performed in a locking, mitered fashion to help prevent collapse of the canal into the mastoid after reconstruction. The inferior cut extends from the inferior facial recess laterally, widening and beveling as a compound miter. Superiorly, two cuts are made. The first is parallel to the temporal lobe in a posterior to anterior direction. The second cut is perpendicular to the first, made from the external canal to meet the superior cut. The posterior canal wall segment is then removed and placed aside for future reconstruction (Fig. 2). Cholesteatoma may then be completely removed from the tympanic cavity, anterior attic, and mastoid.

Reconstruction involves placing a flask-shaped tear drop piece of silastic sheeting (0.04 inch thickness) in the tympanum (Fig. 3). The taper of the silastic is placed in the eustachian tube entrance, with the remainder maintaining a middle ear space. If the shapes superstructure is present, the sheeting acts to transfer acoustic energy to the inner ear before second stage ossiculoplasty. If the superstructure is destroyed, a small wedge of silastic is placed between the footplate and the larger piece of silastic. A generous temporalis fascia graft, large enough to extend up the posterior canal wall, is used in an underlay fashion to reconstruct the tympanic membrane (Fig. 3).

The posterior canal wall segment is then replaced, and several large cortical bone chips are harvested from the outer cortex of the cranium using a nasal chisel. The bone chips are fashioned to block the attic and mastoid from the tympanum. The attic bone chip should be large enough to span the distance between the scutum and the tympanic segment of the facial nerve (Fig. 4) and extend anteriorly into the zygomatic root. The facial recess is blocked in a similar manner. Bone pâté is then carefully placed in the attic and mastoid to hold the bone chips in place. The remainder of the mastoid and attic is filled with pâté to the level of the mastoid cortex. Packing should be firm to prevent posterior displacement of the canal wall when the external canal is packed (Fig. 5).

The external auditory canal is packed by inserting a long, thin Cottle nasal speculum to compress the posterior canal wall skin back into position. This is followed by several pieces of gelfoam over the tympanoplasty as well as a half inch iodoform...
strip gauze impregnated with bacitracin ointment. The Palva flap is closed, and a quarter inch Penrose drain is placed lateral to the Palva flap. The wound is closed in two layers, and a standard mastoid dressing is applied. Patients are given perioperative antibiotics, typically piperacillin-tazobactam and levofloxacin in adults and piperacillin-tazobactam in patients under the age of 18. Penicillin-allergic patients are typically administered clindamycin with or without levofloxacin.

Intravenous antibiotics are continued for 48 hours. The Penrose drain is removed on postoperative day number 2. The mastoid dressing is changed daily until discharge, at which time the patient is instructed to remove it in 2 to 3 days. Patients are sent home with either oral levofloxacin (in adults), amoxicillin-clavulanate (in adults allergic to levofloxacin and patients under age 18), or clindamycin (in patients allergic to penicillin), to complete a 14 day course.

A second look tympanoplasty with ossiculoplasty is performed, typically 6 months after the initial tympanomastoidectomy.
tomy. During this second surgery, the status of the middle ear and tympanic membrane graft are assessed, the middle ear is examined for the presence of residual cholesteatoma, and ossicular reconstruction is performed. Ossiculoplasty usually involves placement of a tragal or conchal cartilage graft over a titanium ossicular prosthesis.

RESULTS

One hundred thirty ears in 127 adults and children underwent the procedure. Table I presents the patients’ demographics. Three patients had bilateral procedures performed on different occasions. Mean time postoperative was 48 (range 2–94) months. The percentage of ears that remained dry without recurrent disease was 98.5. Ten (10/130, 7.7%) patients have “safe,” shallow, self-cleaning dry retraction pockets that have not collected debris to date. Ossicular reconstruction was performed at a second stage in 102 (78.5%) cases to date. Two (2/102, 1.9%) ears had tympanic membrane perforations after second stage surgery from prosthesis extrusion, which were subsequently closed. Ten (10/102, 9.8%) ears had evidence of residual keratin pearls in the area of the oval window at second look. These were easily cleared.

Complications

Ten cases resulted in readmission for wound infections, largely in the first 2 years of our experience (1997–1999). During that period, the postoperative infection rate was 14.3% (6 of 42 ears). This has been reduced to 4.5% (4 of 88 ears) since 1999, when the protocol was modified to include the use of a subcutaneous Penrose drain and 48 hours of intravenous antibiotics with adequate coverage of Pseudomonas aeruginosa. Several different organisms were cultured from patients with infections, with Pseudomonas the predominant organism (Table II).

One patient exhibited partial canal wall resorption, and revision surgery was unnecessary. An endaural atticotomy was performed on two patients to assist in visualization of an attic retraction. These ears remain self cleaning. Two (2/130, 1.5%) individuals have required CWD revision mastoidectomies for recurrent retraction pocket cholesteatoma in the attic. These two ears remain dry but require yearly debridement. Complications divided into pediatric (<18 years) and adult (≥18 years) are shown in Table III.

Hearing Results

Best 1 year postoperative hearing results varied, with a mean improvement of 6 dB in the air-bone gap (Fig. 6) (Tables IV and V) compared with hearing before the initial procedure. Conductive hearing loss persisted in some individuals because of continued eustachian tube dysfunction. No attempt has been made to offer ventilation tubes to this population because a dry, safe ear is the primary goal.

DISCUSSION

CWR tympanomastoidectomy with bone pâte obliteration of the mastoid is a technique that provides improved control of recurrent cholesteatoma compared with CWU techniques. Preservation of near-normal anatomy and prevention of cholesteatoma recurrence is possible in almost all patients. Isolating the attic and mastoid from the tympanum with a solid bony barrier and obliteration of the mastoid with bone pâte prevents reetration of the tympanic membrane into the attic and mastoid.

In traditional CWD techniques, removal of the canal wall improves exposure and facilitates the complete removal of all cholesteatoma. However, despite the fact that most well-constructed mastoid cavities remain problem-free, they do require periodic cleaning and are prone to bowl infections. Retention of the posterior canal wall results in a higher rate of recidivism, particularly in chil-

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TABLE I.

<table>
<thead>
<tr>
<th>Patient Demographics.</th>
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<tbody>
<tr>
<td>Total Patients</td>
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<tr>
<td>Total Ears</td>
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<tr>
<td>Mean Age</td>
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<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>&lt;18 years</td>
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<tr>
<td>Previous CWU tympanomastoidectomy</td>
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<tr>
<td>Previous atticotomy</td>
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TABLE II.

<table>
<thead>
<tr>
<th>Organisms Cultured From Wound Infections (n = 10).</th>
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<tbody>
<tr>
<td>Culture negative (3)</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa (3)</td>
</tr>
<tr>
<td>Mixed flora (1)</td>
</tr>
<tr>
<td>Methicillin-resistant Staphylococcus aureus (1)</td>
</tr>
<tr>
<td>Enterobacter cloacae (1)</td>
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<tr>
<td>Staphylococcus epidermidis (1)</td>
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In our experience, recurrent disease after CWU tympanomastoidectomy results most commonly from redevelopment of retraction pockets, which might be caused by continued poor eustachian tube function.

Negative pressure in the middle ear and mastoid also likely contributes to recurrent disease. A primary determinant of middle ear pressure is the rate of gas absorption across the mastoid mucosa, and negative middle ear pressure may result from increased nitrogen absorption from diseased mucosa. Inflammatory conditions result in more negative middle ear pressures, presumably by increasing the vascularity of the epithelium, leading to more nitrogen absorption. The cuboidal epithelium of the mastoid and posterior epitympanum is theorized to play a significant role in this gas absorption. Exenteration of the mastoid epithelium, therefore, may facilitate rehabilitation of a poorly aerated ear.

If this theory is correct, mastoid obliteration, by eliminating the area where mastoid mucosa persists in a CWU procedure, may decrease the volume of air absorption from the middle ear and mastoid. This could prevent development of retraction pockets and reduce the incidence of recurrent disease compared with CWU techniques. In this series, the 1.5% recurrence rate is similar to low recidivism rates published for CWD mastoidectomy.

Mastoid obliteration has been described by many otologists. Muscle has long been used to decrease the size of the cavity. Ceramics, including hydroxyapatite granules and demineralized bone matrix, have also been used. Use of bone pâte has also been described. Black reported an infection rate of 16% in a series of 55 patients using autologous bone and reported a long-term failure rate of 52%. Interestingly, the infection rate is similar to the rate found in our series before the addition of 48 hours of perioperative antibiotics. Roberson et al. reported an infection rate of 13.8% in 62 patients and a resorption rate of 4.8% when using bone pâte washed with chloramphenicol solution.

To avoid the presence of an open mastoid cavity, CWR has been described, often with cartilage or prosthetic material. Some reports describe removing the wall and reinforcing it with fascia or other materials when it is replaced. Recently, there has been some renewed interest in this area. McElveen and Chung describe removal of the posterior canal wall with subsequent replacement and fixation with bone cement.

**Complications: Infection, Perforations, and Otorrhea**

The main complication encountered with this procedure is postoperative wound infection. All of the wound
infections in our series resolved with intravenous antibiotics, and no patients developed total loss of the posterior canal wall. Most of these infections occurred in the initial patients undergoing the procedure. To reduce the number of wound infections, we modified our protocol to include a total of 48 hours of perioperative intravenous antibiotics. In addition, bone pâte is taken only from nondiseased cortical bone that is washed in bacitracin solution. Pâte collection stops if an air cell is exposed. The wound is now drained for 48 hours to prevent hematoma formation. Levofloxacin is also now routinely used in adult patients as coverage for *Pseudomonas aeruginosa*.

The combination of these changes has reduced our rate of postoperative infection to 4.5%. It is not clear which of the measures has had the largest impact on altering postoperative infection. There have been no postoperative infections in the last 2 years with this protocol.

Postreconstruction tympanic membrane perforations occurred in two patients because of extrusion of the ossicular reconstruction prosthesis. Extrusion resulted from continued poor eustachian tube function, and both were repaired. The middle ear milieu in certain ears may be unfavorable for long-term maintenance of a prosthesis, and we have chosen as our goal a safe, dry ear. Follow-up after ossiculoplasty is crucial to monitor for prosthesis extrusion.

**Complications: Retraction Pockets, Residual, and Recurrent Cholesteatoma**

The novel technique used in this procedure to reduce the formation of recurrent retraction pockets is blockage of the attic and posterior epitympanum with bone chips. If recurrent negative pressure occurs in the tympanum, medial displacement of the tympanic membrane to the medial wall of the tympanum occurs without retraction pocket formation. Adequate bone grafts should be used to completely block the attic. Early in the study, multiple smaller chips of bone were used, which occasionally led to partial dissolution if infection occurred. Ten of the ears operated on early in the study have small, self-cleaning retractions. Continued follow-up is required in this group, although there has been no deepening of the retractions to date. Another strategy that helped eliminate retraction is the placement of a generous piece of cartilage in the posterior superior quadrant during the second look ossiculoplasty. This was not done initially, when it was thought that hydroxyapatite ossicular prostheses did not require cartilage coverage.

Two patients required atticotomies for retraction pockets. Postoperative infection with loss of bone chips blocking the attic, or insufficient blocking of the attic initially in the study, is most likely the cause of these retractions. There has been no recurrent cholesteatoma in the mastoid, and no recurrent disease has been identified in those in whom residual tympanic cholesteatoma was discovered on second look. In these individuals, the residual disease was always associated with the oval window.

The presence of residual disease found at second look ossiculoplasty reinforces the need for staging in this technique. Mercke also staged his ossiculoplasty, and in his follow-up report, he found a 7.6% incidence of residual keratin pearls at second look, which is comparable with our rate of 9.8%.15

No patients have experienced recurrent cholesteatoma in the mastoid region because of retained squamous epithelium. Attention to detail during mastoidectomy, including careful removal of all cholesteatoma and careful saucerization of all air cells and exenteration of diseased mucosa, provides a bed of mastoid bone that is prepared to incorporate the bone pâte. A possibility of long-term complications does exist if cholesteatoma is buried in the mastoid, but this has not been observed to date. Any concerning signs or symptoms in a patient that has un-

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**TABLE IV.**

<table>
<thead>
<tr>
<th>Preoperative ABG group</th>
<th>All cases (%)</th>
<th>&gt;18 yrs old (%)</th>
<th>&lt;18 yrs old (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–10 dB</td>
<td>12 (15)</td>
<td>5 (6)</td>
<td>7 (9)</td>
</tr>
<tr>
<td>11–20 dB</td>
<td>10 (13)</td>
<td>7 (9)</td>
<td>3 (4)</td>
</tr>
<tr>
<td>21–30 dB</td>
<td>19 (24)</td>
<td>15 (19)</td>
<td>4 (5)</td>
</tr>
<tr>
<td>&gt;30 dB</td>
<td>39 (49)</td>
<td>24 (30)</td>
<td>15 (19)</td>
</tr>
<tr>
<td>Sum totals</td>
<td>80 (100)</td>
<td>51 (64)</td>
<td>29 (36)</td>
</tr>
</tbody>
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**TABLE V.**

<table>
<thead>
<tr>
<th>ABG (mean ± SD)</th>
<th>Preoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>(range)</td>
<td>(0–56)</td>
<td>(3–50)</td>
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</table>
Chronic otitis media with cholesteatoma is a common condition. Treatment involves removing the cholesteatoma and reconstructing the middle ear. The decision to perform mastoid obliteration with canal wall up (CWR) depends on the patient's age and the extent of the cholesteatoma. Pediatric patients traditionally have a high risk of recurrent cholesteatoma with intact canal wall techniques. The technique has also been used in patients with prior CWU procedures and occasionally in cases with extensive posterior canal wall destruction by cholesteatoma. In these cases, larger pieces of cortical bone are required to reconstruct the posterior canal wall. The procedure has also been successful in cases of cholesteatoma complicated with lateral semicircular canal fistula, facial nerve paralysis, and encephalocele. This procedure would not be suitable for those with severe mastoid cholesteatosis. If the Cholesteatoma can not be cleared from the mastoid cell tracts, obliteration is contraindicated.

Hearing Results

The primary goal of the CWR tympanomastoidectomy is the creation of a dry, safe ear. Hearing reconstruction is a secondary, although important, consideration. Continued eustachian tube dysfunction, however, can create a milieu in which prostheses may extrude, as they did in two of our patients, and in which secretory otitis media may continue, contributing to conductive hearing loss. We did not offer these patients ventilation tube placement. We prefer to tolerate a conductive hearing loss caused by fluid in the middle ear space rather than risk creating a chronically draining ear. These ears can easily be rehabilitated with hearing aids.

CONCLUSION

CWR and bone pâte mastoid obliteration tympanomastoidectomy is a technique that facilitates exposure of the middle ear and ensures complete removal of cholesteatoma. Replacement of the posterior canal wall recreates the normal external canal anatomy and allows for elimination of the mastoid bowl. It is suitable for most patients with chronic otitis media with cholesteatoma, including adults and children. Because staging is necessary as part of the procedure, residual disease can be assessed at osseoculoplasty. Postoperative infection is a concern, and rates have been lower since the use of 48 hours of anti-pseudomonal antibiotics and adequate wound drainage. The recurrence rate in our series is similar to open cavity surgical strategies. This procedure has become our technique of choice for the treatment of cholesteatoma. All have safe, dry ears.

BIBLIOGRAPHY