INTRODUCTION

Reconstructive techniques for tympanic membrane (TM) perforations have been refined over the past several decades. Two classic techniques are described: underlay (medial) tympanoplasty and overlay (lateral) tympanoplasty. Descriptions, successes, and pitfalls of these approaches are well documented. The medial approach places the graft medial to the TM and malleus, with a high success rate for small, posteriorly located perforations. Exposure of the anterior middle ear is limited, and the success rate is lower for larger perforations. In the overlay (lateral) approach, the squamous layer of the TM is removed, and the graft is placed lateral to the tympanic annulus. This technique has higher success for large and anterior perforations, but is associated with prolonged surgery and risk of blunting of the anterior angle and graft lateralization.

A variation of these techniques has been utilized for TM repair as well as for exposure to remove cholesteatoma and glomus tumors. Described by Kartush et al. in 2002 and termed over–under tympanoplasty (OUT), this approach places the graft lateral to the malleus and medial to the TM remnant. OUT has the advantage of excellent exposure while minimizing the risks of graft lateralization and anterior angle blunting.

For this study, a retrospective analysis was performed comparing the OUT technique to underlay tympanoplasty, with evaluation of perforation size, success of graft take, hearing results, and complications. The hypothesis was that the OUT technique would be comparable to medial grafting for smaller perforations and would have excellent results in larger perforations with a favorable complication profile.

MATERIALS AND METHODS

After institutional review board approval (#980814), a chart review was performed for patients undergoing tympanoplasty for dry, stable perforations between 2010 and 2015. Patients with ototrauma, middle ear disease, or previous ear surgery were excluded, as were patients with simultaneous procedures such as canalplasty, ossiculoplasty, or mastoidectomy. Primary outcome measures included graft healing after 18 months, change in air-bone gap (ABG), and change in high-frequency hearing at 8 kHz demonstrating ossicular manipulation trauma. Results were compared between OUT and medial tympanoplasty groups.
Hearing parameters included changes in ABG, speech reception threshold (SRT), and word discrimination score using the 1995 guidelines of the American Academy of Otolaryngology Committee on Hearing and Equilibrium. The pure-tone average (PTA) for bone and air conduction at 0.5, 1, 2, and 3 kHz was calculated. ABG was calculated by subtracting bone-conduction PTA from air-conduction PTA. Outcomes were analyzed according to the 2012 guidelines using scattergrams.

Data collected included age, sex, side, perforation size and location, ABG, change in hearing at 8 kHz, status of TM at 18 months, complications, and smoking status. Graft healing was considered successful if the TM was completely intact at the 18-month postoperative visit. Audiometric results were based on the audiogram performed at the 18-month follow-up compared to the preoperative audiogram.

Surgical Technique

Procedures were performed with either a postauricular or transcanal approach under general anesthesia with usage of temporalis fascia or tragal perichondrium as graft material. The edges of the perforation were rimmed in all cases. The tympanomeatal flap was elevated after an H-type flap incision was created utilizing 12- and 6-o’clock incisions connected with a horizontal incision. The size and location of the perforation determined the need for medial versus over–under technique. Smaller (<30%) or posteriorly located perforations were repaired using medial tympanoplasty, whereas larger (>30%) and anteriorly located perforations were repaired using the over–under approach (Fig. 2). Near total and total perforations were all repaired using the over–under approach. No lateral graft tympanoplasty was performed.

In OUT, the TM is elevated off of the malleus with occasional resection of the posterior malleolar ligament. The periosteal cap of the lateral process is carefully unroofed to identify the correct plane of dissection that allows elevation of the anterior TM remnant. The CO₂ laser is utilized to minimize ossicular vibration and vaporize residual epithelium near the umbo where firm attachment may remain. Some char may form on the malleus. Microscissors may also be used to detach this firm attachment at the umbo but may risk leaving epithelium. The anterior annulus is typically left in position. In total perforations, the anterior annulus may be elevated slightly to tuck the graft medial to it. Once exposure is complete, the middle ear is packed with absorbable gelatin sponge (Gelfoam; Upjohn Co., Kalamazoo, MI). The graft is placed lateral to the long process of the malleus and then medial to the remaining drum anteriorly (Fig. 3). The ear canal is then packed with absorbable gelatin sponge.

Medical tympanoplasty is performed similarly. The tympanic membrane is left attached to the malleus. The graft is placed medial to the TM remnant as well as the malleus. The tympanomeatal flap is placed back into position, and the ear canal is packed with absorbable gelatin sponge.

Statistical Analysis

All statistical analyses were performed using SPSS version 19 (IBM, Armonk, NY). Two-tailed statistical significance was set at .05. Continuous variables were described using mean and standard deviation. Categorical variables were described using frequency distributions. Continuous variables were compared using the Student t test or the nonparametric Mann-Whitney test when normality could not be assumed. The χ² test was used to compare proportions. Univariate logistic regression analysis was used to test significance of individual variables in predicting surgical success.

RESULTS

Of 149 patients, 38 were excluded because they did not have at least an 18-month follow-up visit with an audiogram. These patients were of similar demographics and TM perforation size as included patients. Of the 111 patients included in the analyses, 84 underwent OUT and 27 patients underwent medial tympanoplasty. In the OUT group, mean age was 22.7 years (range, 3–80 years). Smoking was noted in 10 patients, and secondhand smoke exposure in five patients. The mean follow-up was 25.6 months (range, 18–70 months). In the medial tympanoplasty group, the mean age was 27.8 years (range, 5–72 years). Smoking was noted in two adults, and secondhand smoke exposure was noted in five patients. The mean...
follow-up in this group was 26.1 months (range, 18–48 months). These characteristics did not vary significantly between groups (P > .05). Perforation size and location are shown in Table I. The average size of perforation in the OUT group was 50%, and in the medial tympanoplasty group it was 25% (P < .001).

All 27 patients undergoing medial tympanoplasty and 84% (71/84) of the OUT group had complete take of the graft at the 18-month visit (Table II). Thirteen OUT patients (15%) developed a recurrent perforation, 10 of which were very small without hearing loss or impact on quality of life. Three patients, all of whom had total perforations initially, developed larger perforations and are being considered for revision surgery. Patients with anterior perforations and total perforations had closure rates of 81% and 75%, respectively. None of the patients in either group suffered from graft lateralization or blunting. Successful healing in both groups was found to be independent of age, graft material used, size and location of perforation, smoking, or secondhand smoke exposure.

In the medial group, mean ABG improved by 11.6 ± 12.3 dB. SRT improved from 20 ± 13.2 dB to 13.9 ± 12.3 dB. Neither was found to be statistically significant (P > .05). Word recognition scores remained stable and are shown in comparison to PTA in Figure 4. Specific evaluation at 4 kHz and 8 kHz showed improved hearing by 7.7 dB (P = .41). In the OUT group, the hearing results showed improvement in all frequencies, especially in low frequencies. ABG improved by 11.9 ± 7.2 dB (P = .07). SRT scores improved from 21.9 ± 12.6 dB to 15.0 ± 11.8 dB (P < .001). Word discrimination scores remained stable from 98.6% to 98.5%. Preoperative and postoperative PTA and word recognition scores are shown in Figure 5. Specific evaluation at 4 kHz and 8 kHz showed improved hearing by 9.3 dB (P = .06).

Due to the unequal distribution of patients in each group, an analysis was performed to directly compare patients with similar-sized perforations. A cohort of 27 patients from the OUT group matched for perforation size to the medial tympanoplasty group was selected. Closure rates were found to be similar in this analysis. A statistically significant difference in postoperative ABG improvement (5.2 dB in the OUT group vs. 2.1 dB in the medial group, P < .001) was seen. No other variables showed a significant difference between the two groups.

Four of the 84 (5%) OUT patients developed small cholesteatomas at the umbo due to trapped epithelium or incomplete removal of epithelium. These four patients underwent microdissection of the umbo using scissors as opposed to the CO2 laser for the elevation of the tympanic membrane from the malleus. These small pearls were treated in the office with excision or exteriorization. No middle ear cholesteatoma developed.

**DISCUSSION**

In this study, medial tympanoplasty and OUT both demonstrated excellent comparable success for small and posterior perforations. The OUT technique had a high rate of TM closure with anterior, near total, and total perforations. No patient suffered significant complications, hearing loss, infection, graft lateralization, or atelectasis. Four patients did develop small epithelial pearls near the umbo after the over–under approach; these were easily excised in the office setting. OUT provides excellent exposure with minimal risk and little additional surgical time. By exposing the entire middle ear space, disease anterior to the malleus can be addressed, and placement of graft material is more directly visualized. Additionally, placing the graft lateral to the malleus limits the reduction in middle ear space that may occur if the malleus is retracted. This approach blends the advantages and minimizes the disadvantages of the classic medial graft and lateral graft techniques.

Myringoplasty was originally described by Berthold in 1878 using full thickness skin grafts for TM repair, and techniques have been developed since then to improve success.9 Many variations have been developed over the years, including various approaches to the perforation, materials used, and stabilization techniques.10–13 The medial technique is commonly utilized and is technically straightforward, as the graft is placed medial to the...
remaining TM and malleus. The lateral graft technique requires longer operative time and may be more technically challenging. Success rates with these techniques range from 77% to 96.14–18 Higher success rates are found using the lateral graft approach for large and anterior perforations, which have a reduced rate of closure overall.4,17

<table>
<thead>
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<th>Size Location</th>
<th>&lt;20%</th>
<th>20%–40%</th>
<th>50%–99%</th>
<th>Anterior</th>
<th>Posterior</th>
<th>Inferior</th>
<th>Central</th>
<th>Total Perforations</th>
</tr>
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<td>OUT group</td>
<td>3/3 (100%)</td>
<td>41/47 (87%)</td>
<td>15/18 (83%)</td>
<td>25/31 (81%)</td>
<td>15/15 (100%)</td>
<td>17/20 (85%)</td>
<td>2/2 (100%)</td>
<td>12/16 (75%)</td>
</tr>
<tr>
<td>Medial group</td>
<td>9/9 (100%)</td>
<td>18/18 (100%)</td>
<td>0</td>
<td>7/7 (100%)</td>
<td>10/10 (100%)</td>
<td>10/10 (100%)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

OUT = over–under tympanoplasty.

Fig. 4. Hearing outcomes for the medial tympanoplasty group. (A) Postoperative word recognition scores and pure-tone averages. (B) Changes in word recognition scores and pure-tone averages, calculated as postoperative values minus preoperative values.

Fig. 5. Hearing outcomes for the over–under tympanoplasty group. (A) Postoperative word recognition scores and pure-tone averages. (B) Changes in word recognition scores and pure-tone averages, calculated as postoperative values minus preoperative values.
A 90% success rate and 5.3 dB improvement in ABG was previously reported on 120 patients who underwent OUT in association with mastoidectomy and ossiculoplasty.\(^5\) However, many patients suffered from cholesteatoma in the middle ear space and mastoid, and other reports revealed high initial success but worsened results over time and occasional blunting.\(^19,20\) The current study excluded these types of patients to determine long-term benefit of OUT in patients with dry, stable perforations. OUT was found to be successful in perforation closure in 84% (71/84) of cases including many large and total perforations. Thirteen patients developed recurrent perforations located in the anterior–inferior region, most of which were noted in cases when the size of the perforation was greater than 50%, especially in the anterior location. Ten of these 13 (77%) perforations were small and dry, with minimal effect on hearing, and none of these underwent revision surgery. In three out of 84 patients (4%), all of whom initially had total perforations, larger perforations occurred that are being monitored.

A potential disadvantage of the over–under technique is risk of sensorineural hearing loss (SNHL) from the manipulation of the ossicular chain during dissection of the TM. Kazikdas et al. reported SNHL in selected patients.\(^2\) The current study excluded these types of patients to determine long-term benefit of OUT in patients with dry, stable perforations. OUT was found to be successful in perforation closure in 84% (71/84) of cases including many large and total perforations.

CONCLUSION
OUT has a high success rate with TM perforations, including anterior, near total, and total perforations. ABG and SRT improved in these patients without evidence of high-frequency hearing loss from dissection on the malleus. Minimal complications were found with the over–under approach. No anterior blunting or lateralization of the graft occurred. OUT enhances the advantages and minimizes the disadvantages of the classic medial and lateral graft techniques and is well suited for all types of TM perforations.

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