Objective: To assess the prognostic value of different variables on the outcome of pediatric type I tympanoplasty.

Design: Retrospective review of medical records.

Setting: An otolaryngology department in a large urban tertiary care medical center.

Patients: We reviewed 72 ears in 60 patients who had undergone a type I tympanoplasty from 1987 to 2000. Patient ages ranged from 3 to 18 years.

Interventions: Type I tympanoplasty.

Main Outcome Measures: We identified the following 3 criteria for success: (1) healing of the neotympanic graft; (2) healing of the graft with a postoperative air-bone gap of no greater than 20 dB; and (3) healing of the graft with aeration of the middle ear space.

Results: Healing occurred in 59 (82%) of the 72 neotympanic grafts; 39 (83%) of the 47 healed ears for which a postoperative audiogram was available had an air-bone gap of no greater than 20 dB; and 49 (83%) of the 59 healed ears had a normally aerated middle ear space. A statistically significant difference in the rate of graft healing was identified for large perforations (76%), as well as for creation of an aerated middle ear space, when there was evidence of ongoing contralateral eustachian tube dysfunction (ie, otitis media with effusion or negative middle ear pressure, but not a perforation).

Conclusions: Pediatric type I tympanoplasty can offer reasonably good chances for postoperative graft healing, serviceable hearing, and creation of an air-containing middle ear space if performed in carefully selected patients. Caution should be exercised in performing tympanoplasty in children with evidence of ongoing eustachian tube dysfunction, as evidenced by otitis media with effusion and negative middle ear pressure, but not perforations, in the contralateral ear.

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Tympanoplasty is a relatively common procedure in children. Most tympanic membrane perforations in children result from a complication of otitis media (OM) or occur as a result of previous tympanostomy tube placement. In either case, these children may have underlying eustachian tube dysfunction, making the decision to undertake tympanic membrane (TM) grafting complicated. On the other hand, children may have the most to gain from an intact TM. Water activity is no longer restricted, hearing may improve, and the chance of middle ear contamination from the external auditory canal is decreased. Many studies have attempted to address the impact of a number of variables on the outcome of TM perforation repair in a child. Among other variables, age, status of the contralateral ear, and size and etiology of the perforation have been examined in the literature, with conflicting conclusions. Compounding the ambiguity, the criteria used to judge a tympanoplasty as successful has varied widely, contributing to the variation among reported success rates. The purpose of this study was to review our experience with pediatric tympanoplasty with an emphasis on identification of variables that adversely affect outcomes using the most stringent definitions for success.

METHODS

The patients included in the study were drawn from the University of Miami (UM) Ear Institute, Miami, Fla, and the Ear, Nose, and Throat Clinic at Jackson Memorial Hospital (JMH), Miami. Generally, patients at JMH are uninsured or funded by Medicaid, whereas the patients at the UM Ear Institute have some form of private insurance, health maintenance organization, or Medicare policy. Study patients were identified...
All patients (aged \( \leq 18 \) years at the time of surgery) undergoing tympanoplasty without mastoidectomy or ossicular chain reconstruction for TM perforation or atelectasis from January 1987 to December 2000 were included in the data collection. Only those cases attended by a fellowship-trained otologist/neurotologist with a documented follow-up period were included in the final analysis. Patients who underwent any type of mastoidectomy on the same operative date or in the same ear at a previous date, who had any type of previous or concurrent ossicular chain reconstruction, or who had no follow-up data available were excluded from further review.

A retrospective review of each patient’s medical record was undertaken, and demographic, perioperative, and postoperative information was recorded. Audiometric raw data were recorded according to previously published guidelines of the American Academy of Otolaryngology–Head and Neck Surgery (AAO-HNS). Preoperative and postoperative air-bone gaps (ABGs) were calculated by subtracting the 4-tone (500-, 1000-, 2000-, and 3000-Hz) bone conduction pure-tone average from the air conduction pure-tone average obtained at the same testing session. The resulting data were entered into a computerized spreadsheet (Excel; Microsoft Corp, Redmond, Wash) for further comparisons and analysis.

For the purposes of this study, success was defined for each patient using the following 3 criteria:

1. Healed indicated a TM that was healed without evidence of a perforation at the last clinic visit. This included patients undergoing successful paper-patch myringoplasties in the perioperative or postoperative period that did not require a second general anesthetic.

2. Healed with normal hearing indicated a TM that was healed with a postoperative ABG of no greater than 20 dB.

3. Healed with an aerated middle ear space indicated a TM that was healed in a normal anatomic position with an aerated middle ear space.

Results in patients who had a single episode of acute OM (AOM), transient OM with effusion (OME), or any other middle ear conditions that resolved and did not meet AAO-HNS criteria for tympanostomy tube insertion were classified as successes. Treatment failures included ears with postoperative chronic OME, negative middle ear pressure, AOM with perforation, or cholesteatoma. Patients identified as having negative middle ear pressure included those with focal retraction pockets, diffuse TM retraction, and/or any degree of atelectasis or adhesive otitis.

We then computed summary data. Differences were sought between a number of variables that could have a negative impact on patient outcomes such as age of the patient, size of the perforation, status of the contralateral ear, surgical technique, site of clinic care, and duration of follow-up. We performed statistical analysis using Sigma Stat Version for Windows 2.03 software (SPSS Science, Chicago, Ill.). The Mann-Whitney rank sum test, Fisher exact test, and \( \chi^2 \) analyses were applied where appropriate. Unless otherwise indicated, mean values are expressed as mean±SD.

### RESULTS

#### PATIENT CHARACTERISTICS

Seventy-two ears in 60 patients were identified that met criteria for inclusion in the study. Patient ages ranged from 3 to 18 years, with a mean age of 10.3±3.6 years. Thirteen (22%) of the patients were enrolled from the UM Ear Institute (clinic B). Fifty-seven (79%) of the surgeries were primary type I tympanoplasties, and 15 (21%), revision type I tympanoplasties.

Perforation was identified as the primary indication for surgery in 64 ears (89%), whereas 43 patients (60%) also had hearing loss as an indication for surgery. Seven ears underwent operation primarily for severe atelectasis of the TM. In these cases, the atelectatic portion of the TM was resected and grafted. Two ears with perforation also had associated severe atelectasis. Only 2 patients had complaints of significant otorrhea at or around the time of surgery. An estimate of the perforation size was available in 64 ears and ranged from 0% to 25% of the TM in 25 (39%) of the 64 ears, 26% to 50% in 29 (45%), 51% to 75% in 5 (8%), and 76% to 100% in 5 (8%).

The contralateral ear was identified as normal in 45 (63%) of 72 ears. Ten contralateral ears (14%) had documented atelectasis or some degree of high negative middle ear pressure. Thirteen contralateral ears (18%) had perforations, but only 1 (1.4%) had active otorrhea through the perforation. Among the 13 patients with contralateral perforations, 11 (85%) had undergone previous placement of bilateral tympanostomy tubes and had presumed posttympanostomy tube perforations. Two patients had tympanostomy tubes in place at the contralateral ear at the time of surgery.

The medial graft technique was performed in 55 ears (76%), and the remaining 17 ears (24%) underwent a lateral graft. Most procedures were performed through a postauricular approach (70 ears [97%]), using temporoparietal fascia as the grafting material (68 ears [94%]). Three cases required placement of cartilage underneath the neotympanic graft for prevention of retraction. Fifty-four ears (75%) had normal ossicular chains at the time of type I tympanoplasty. Seventeen exhibited some degree of ossicular or middle ear abnormality, some with simultaneous conditions present, as seen in the following tabulation:

<table>
<thead>
<tr>
<th>Ossicular Chain Pathology</th>
<th>No. of Ears</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle ear adhesions</td>
<td>5</td>
</tr>
<tr>
<td>Incus erosion</td>
<td>4</td>
</tr>
<tr>
<td>Incudostapedial joint erosion/fixation</td>
<td>4</td>
</tr>
<tr>
<td>Malleus erosion/foreshortening</td>
<td>2</td>
</tr>
<tr>
<td>Stapes fixation</td>
<td>1</td>
</tr>
<tr>
<td>Stapes disarticulation</td>
<td>1</td>
</tr>
<tr>
<td>Partial atretic plate</td>
<td>1</td>
</tr>
</tbody>
</table>

The remaining ear had no specific description of the status of the ossicular chain in the operative report.

The duration of follow-up ranged from 1 to 74 months, with an overall mean follow-up of 12.5±13.5 months. Patients at the UM Ear Institute had a mean follow-up of 20.5 months, compared with only 10.0 months in patients at the JMH.

#### OUTCOMES

Among the 72 ears undergoing operation, 59 grafts (82%) healed. Thirty-nine (83%) of the 47 healed ears for which

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a postoperative audiogram was available had good postoperative hearing (≤20 dB ABG). Forty-nine (83%) of all 59 healed ears had a normally aerated middle ear space. Thirty (55%) of 55 ears with available postoperative audiograms were considered to have success in all 3 criteria (healed, ABG of ≤20 dB, and an aerated middle ear space), whereas 12 (21%) of 17 cases without postoperative audiograms were successful for healing and aerated middle ear space alone. When those cases with ossicular abnormalities were excluded, 29 (60%) of 48 ears were considered to have success in all 3 criteria.

TM HEALING

The rate of healing success was high for the entire group of patients. After surgery, perforation of the TM was noted in 17 (24%) of 72 ears. One of the perforations closed spontaneously in the perioperative period, whereas 3 of 5 cases treated with a paper-patch myringoplasty ultimately closed. Thus, 13 ears (18%) had persistent perforations after tympanoplasty, for an overall healing rate of 82% (59 of 72 ears). Four patients underwent successful revision type I tympanoplasty for reperforation.

We performed an independent analysis of healing rates in comparison with each of the individual prognostic variables (Table 1). Clinic population, choice of graft technique, age, and status of the contralateral ear showed no statistically significant value in predicting graft healing success. Despite a small number of total or near-total perforations, a significantly lower healing rate was identified in those ears with perforations involving 70% to 100% of the tympanic membrane (P = .05).

HEARING

Preoperative audiometric data were available in 70 ears and postoperative audiograms were available in 55 ears. Overall, the mean postoperative pure-tone average decreased (ie, improved) by 5.3 dB in the ear undergoing operation compared with the preoperative value (27.4 ± 11.7 vs 22.1 ± 15.1 dB; P < .001). The mean speech recognition threshold improved from 28.5 ± 12.1 dB preoperatively to 24.1 ± 16.1 dB at the last available postoperative examination (P = .006). Twenty-three (47%) of 49 ears displayed type A tympanograms at their most recent postoperative audiometric testing, compared with only 2 (3%) of 68 preoperatively. Both ears with type A tympanograms were atelectatic.

The ABG results were stratified according to AAO-HNS criteria (Figure). We found a statistically significant difference between mean preoperative and postoperative ABG (P = .004). Twenty-nine (53%) of 55 ears undergoing operation showed some improvement (reduction) in their ABG. The mean decrease in ABG postoperatively was 6.3 ± 13.7 dB. When considering only those patients with a healed TM, 39 (83%) of the 47 ears had an ABG of less than 20 dB. By contrast, of those with nonintact TMs, only 5 (63%) of 8 had an ABG of less than 20 dB. Having a normal ossicular chain at the time of surgery predicted better postoperative hearing results. When we excluded those patients with surgically confirmed ossicular abnormalities, 38 (90%) of the 42 healed ears with an available postoperative audiogram had an ABG of no greater than 20 dB.

We performed analysis of the predictive variables according to the success criteria of healing with normal hearing (Table 2). Clinic population, status of the contralateral ear, and patient age were found to have no significant impact on this outcome.

COMPlications

Forty-four percent of the ears had no complications or adverse postoperative events, whereas some complication developed (according to strict criteria) in 40 (56%) of 72 ears (See Table 3). Onset of complications occurred from 2 weeks to 60 months after the initial surgery. Most of the complications were minor and were managed conservatively with office-based procedures.

Sixteen revision surgeries were eventually required at either JMH or UM Ear Institute. A cholestea-

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**Table 1. Rates of Postoperative Graft Healing Among Different Variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Healing Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinic population</td>
<td></td>
</tr>
<tr>
<td>Clinic A</td>
<td>13/17 (77)</td>
</tr>
<tr>
<td>Clinic B</td>
<td>46/55 (84)</td>
</tr>
<tr>
<td>Graft technique</td>
<td></td>
</tr>
<tr>
<td>Medial</td>
<td>44/55 (80)</td>
</tr>
<tr>
<td>Lateral</td>
<td>15/17 (88)</td>
</tr>
<tr>
<td>Contralateral ear</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>37/45 (82)</td>
</tr>
<tr>
<td>Abnormal</td>
<td>22/27 (81)</td>
</tr>
<tr>
<td>Patient age, y</td>
<td></td>
</tr>
<tr>
<td>&lt;6</td>
<td>5/6 (83)</td>
</tr>
<tr>
<td>6-8</td>
<td>13/17 (76)</td>
</tr>
<tr>
<td>9-10</td>
<td>12/16 (75)</td>
</tr>
<tr>
<td>&gt;10</td>
<td>29/33 (88)</td>
</tr>
<tr>
<td>Perforation size, %</td>
<td></td>
</tr>
<tr>
<td>0-25</td>
<td>22/25 (88)</td>
</tr>
<tr>
<td>26-50</td>
<td>23/29 (79)</td>
</tr>
<tr>
<td>51-75</td>
<td>5/5 (100)</td>
</tr>
<tr>
<td>76-100</td>
<td>2/5 (40)†</td>
</tr>
</tbody>
</table>

*Data are expressed as number (percentage) of ears.† P = .05.
toma developed in 1 patient during the postoperative course, requiring a subsequent mastoidectomy. No anacoustic ears, life-threatening or serious complications related to general anesthesia, or comorbid medical conditions developed.

We performed analysis of the predictive variables according to the success criteria for healing with an aerated middle ear space. Forty-nine (83%) of 59 healed tympanic membranes were in a normal position, lateral to an aerated middle ear space. For healing with an aerated middle ear space, no statistically significant differences were demonstrated among the different clinic populations, grafting techniques, patient ages, and perforation sizes (Table 4). A difference was identified, however, when using the contralateral ear as a predictor of aeration of the treated ear. The status of the contralateral (nontreated) ear has often been examined as a possible prognostic indicator of tympanoplasty success. When grouping all abnormal contralateral ears (OME, perforations, tympanostomy tubes, atelectasis, negative middle ear pressures, and/or cholesteatomas) into a single category, a significant difference was identified for graft healing with an aerated middle ear space. That is, patients with abnormal contralateral ears had a significantly lower rate of middle ear aeration in the healed ear after operation ($P = .03$) (Table 4). When those patients with presumed evidence of chronic eustachian tube dysfunction (ie, contralateral OME, negative middle ear pressure, and cholesteatoma) were excluded, the significance disappeared ($P = .35$). Thus, we found no differences in healing with an aerated middle ear space among those patients with bilateral TM perforations or when a tube was in place. Conversely, children with OME or atelectasis in the contralateral ear were significantly less likely to have an aerated middle ear space when compared with children with normal contralateral ears ($P = .007$).

Much of the variability among reported success rates for pediatric tympanoplasty can be attributed to differing criteria for success. In general, investigators who use the strictest criteria usually report lower success rates. For instance, Bluestone et al published a success rate of only 35%, but defined success only in those ears in which the graft took and was maintained, with no evidence of negative middle ear pressure, OME, or cholesteatoma. Similarly, Manning et al reported a 78% graft healing rate,
but only 52% of their treated ears displayed evidence of good eustachian tube function. Many authors, however, quote much higher success rates (89%-95%) after pediatric type I tympanoplasty. A closer examination of these studies, however, reveals that the criteria for success often includes only healing of the graft, with or without hearing outcomes.

The goals for most pediatric tympanoplasty operations are 3-fold. First, the goal is to create an intact TM to prevent middle ear contamination and allow unrestricted water activities. Second, the intact TM should allow good, serviceable hearing. Finally, an aerated, sound-conducting middle ear space should be achieved. With this in mind, the present study followed the lead of Bluestone et al3 and Manning et al4 to define success. Although a healed TM was the primary goal of the surgery, it was not the only measure of success.

The overall success rates in the present study compare quite favorably with those previously reported by others. Specifically, 82% of ears had healed grafts at the last clinic visit. Eighty-three percent of the healed TMs had a postoperative ABG of no greater than 20 dB, whereas 83% of the healed ears had an aerated middle space. In children with normal ossicular chains, the hearing success increased to 90%. By taking all 3 success categories together, 55% of the ears with available postoperative audiograms were considered to have successful treatment. This finding included those ears with documented ossicular or middle ear abnormalities. Excluding those cases with ossicular or middle ear abnormalities, results in 29 (60%) of 48 ears were classified as successes according to all 3 criteria. When compared with the success rates of Bluestone et al3 (35%) and Manning et al4 (52%), that of the present study increased to 90%. This finding included those ears with documented ossicular or middle ear abnormalities. Excluding those cases with ossicular or middle ear abnormalities, results in 29 (60%) of 48 ears were classified as successes according to all 3 criteria. When compared with the success rates of Bluestone et al3 (35%) and Manning et al4 (52%), that of the present study increased to 90%.

The current study’s result of 83% is comparable and confirms a reasonably good benefit to children undergoing this procedure.

Numerous potential prognostic factors have been cited for the successful outcome of pediatric tympanoplasty. Surgical technique and the ability of the patient to heal are clearly important for closing the perforated TM. Techniques for performing tympanoplasty can vary widely by author and institution, and largely reflect the primary surgeon’s training and experience. Medial and lateral graft techniques were performed in the present study and have been described by others10 as safe and effective in children. Te et al8 noted particularly good healing rates and low complication rates with the lateral technique, despite its being considered a more technically difficult procedure. The results of the present study agree with those of Te et al8 and Rizer.10 Specifically, healing, hearing, and middle ear aeration rates were comparable between the 2 techniques. The decision to perform a medial vs a lateral graft tympanoplasty lies in the personal choice and experience of the primary surgeon and the size of the perforation, not the patient’s age.

To achieve a normally functioning middle ear after tympanoplasty clearly requires more than an intact graft. In this regard, some level of preoperative decision making is required in an attempt to predict whether normal middle ear function will return after TM perforation closure. Presumably, the single most important factor in predicting this level of success would be the ability of the closed middle ear space to maintain a normal gas composition. In this regard, normal mucosal gas transfer and eustachian tube function are critical. To date, no test has been able to predict with certainty that eustachian tube–middle ear function in a patient with a perforated TM is adequate for tympanoplasty success. Thus, factors that might be associated with normal or abnormal eustachian tube–middle ear function have been used as prognostic variables. These variables include age, contralateral ear status, presence of mucosal disease, and craniofacial anomalies, to name a few.

Age is often cited as a key prognostic factor in evaluation for tympanoplasty in children because eustachian tube function is known to normalize with advancing age. Some authors recommended a minimum age to consider tympanoplasty, ranging from 6 to 8 years. In a meta-analysis of 19 articles by Vrabec et al,12 only increasing age was associated with a statistically higher chance of surgical success. Nevertheless, some have described successful tympanoplasties in patients as young as 2 years,13 leading some authors to dispute the existence of a minimum or “magical” age.14,15 In the present study, age was not a negative prognostic variable, although few patients underwent operation at younger than 6 years. The youngest patient in the present series was aged 3 years at the time of surgery, with success in all 3 categories.

Because eustachian tube function is thought to be symmetrical, it would then follow that contralateral ear status predicts success when localized mucosal disease is not present. In a study of 318 pediatric tympanoplasties in which nearly 60% of patients had abnormal contralateral ears, Chandrasekhar et al15 found no effect on healing rates. Similarly, Koch et al13 could find no correlation between an abnormal contralateral ear and surgical success, although only 29% of their 64 tympanoplasties had abnormal contralateral findings. With an even smaller sample size of 9 abnormal contralateral ears, Gi anoli et al16 could not identify any statistical significance between the 2 groups. A more recent meta-analysis of those articles and others confirmed these findings.12

Other investigators have reported the abnormal contralateral ear as a negative prognostic factor in pediatric tympanoplasty. Adkins and White17 identified a higher failure rate in patients with bilateral perforations. Among their small sample size of 8 children, 3 of 4 failures came from the group displaying bilateral perforations. Kessler et al identified more reperforations 6 months or later after surgery in patients with contralateral evidence of OM. Finally, Ophir et al17 reported that contralateral perforation was not a negative prognostic factor, whereas OME or atelectasis was associated with poorer outcomes.

The findings of the present study were similar to those previously reported by Ophir et al.17 That is, classifying the contralateral ear as only normal or abnormal did not reveal the effect of underlying eustachian tube or middle ear dysfunction on success rates. Although healing and hearing rates were not adversely affected by the presence of an abnormal contralateral ear, the ability to maintain an aerated middle ear space was affected. Spe-
cifically, when examining the rates of those ears that healed with an aerated middle ear space, a significant difference was identified between those patients with nor-


d and normal contralateral ears (92% vs 68%; P =.03). When those factors that would presumably be associated with abnormal eustachian tube–middle ear condition (ie, high negative middle ear pressure, atelecta-
sis, and OME) were removed, the significance of this variable disappeared. That is, patients with only a TM perforation or tube in place in the contralateral ear fared as well as those with normal contralateral ears for the outcome of healing with an aerated middle ear space (92% vs 83%; P =.35). This implies a poorer prognosis in those patients with evidence of contralateral eustachian tube dysfunction (ie, high negative middle ear pressure, OME, and atelectasis).

On the basis of the findings of the present study, we believe that most patients being considered for tympanoplasty who have a contralateral dry perforation, es-


cially after prior tympanostomy tube insertion, are probably displaying iatrogenic TM findings, and not evidence of ongoing eustachian tube dysfunction. Their excellent prognosis for tympanoplasty success in all 3 categories is similar to that of patients with a normal contralateral ear. On the contrary, contralateral evidence of negative middle ear pressure or OME portends a poorer prognosis. Although the chances of healing the neotympanic graft with good hearing remain relatively high, there is a greater chance of development of OME, atelectasis, or choleste
toma in the treated ear, presumably due to the symmetrical nature of pediatric eustachian tube dysfunction. We therefore believe that children with evidence of contralateral high negative pressure or OME should be strongly counseled to forgo elective tympanoplasty until contralateral eustachian tube function had resolved.

CONCLUSIONS

Pediatric type I tympanoplasty, when performed by experienced surgeons on carefully selected patients, is a safe procedure irrespective of the surgical approach. Healing of the TM graft with reasonably good hearing can be achieved in a very high proportion of patients. The ability to obtain an aerated middle ear space free of high negative pressure, retraction, and OME is somewhat more difficult and likely depends on underlying eustachian tube–middle ear dysfunction. In the present study, the presence of high negative pressure, atelectasis, and OME in the contralateral ear was associated with a less successful outcome for obtaining adequate middle ear aeration. Caution should be exercised in performing tympanoplasty in children with ongoing eustachian tube–middle ear dysfunction in the contralateral ear.

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