Hearing Outcomes after Revision Stapedectomy Managed with Total Ossicular Prostheses

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Abstract

Objectives. (1) To describe the use of total ossicular prostheses (TOPs) in the setting of stapedectomy requiring an incus bypass procedure. (2) To analyze the short- and long-term audiometric results of TOP utilization in the setting of stapedectomy for an incus bypass procedure.

Study Design. Case series with chart review.

Setting. Tertiary neurotologic referral center.

Subjects and Methods. Seventeen cases of TOP reconstruction after stapedectomy were performed due to advanced incus erosion. The cases were assessed for pre- and postoperative bone conduction and air conduction pure-tone averages (PTAs; 0.5, 1, 2, 3 kHz), including high-tone bone conduction (1, 2, 4 kHz), air-bone gap, and speech discrimination scores. Hearing outcomes were measured: short-term (3 weeks) and long-term (average, 22 months).

Results. Among 17 ears undergoing revision stapedectomy managed with TOP reconstruction, the average number of previous revision attempts was 1.0 (SD, 1; range, 1-5). The preoperative bone conduction PTA was 30.7 dB preoperatively, while the preoperative air conduction PTA was 64.3 dB. The mean postoperative air-bone gap significantly decreased to 18.9 dB (SD, 12.7; range, 5-46.25; \( P \leq 0.003 \)) with a mean follow-up of 22.2 months (SD, 25.0; range, 0.75-78). No significant decrement in high-tone bone conduction PTA was observed (mean, 0 dB; SD, 12.8; range, –36.7 to 20; \( P = .427 \)); however, 1 ear revealed a severe decrease in PTA and speech discrimination score postoperatively. No further revisions were noted in follow-up.

Conclusion. TOP reconstruction in the setting of previous revision stapedectomy with limited incudovestibular reconstructive options may lead to favorable hearing outcomes, but it carries an increased risk of sensorineural hearing loss.

Keywords

revision stapedectomy, reconstruction prosthesis, otosclerosis

Significant conductive hearing loss associated with otosclerosis may be treated effectively with the stapedectomy procedure. Since the early development of the procedure, in the late 1950s by Howard House and John Shea, studies have demonstrated the high success rate of primary stapedectomy for otosclerosis in closing the air-bone gap (ABG) and achieving excellent hearing results.¹⁻⁴ Despite these favorable outcomes, in a small percentage of cases, hearing may deteriorate over time, necessitating revision stapedectomy. Common findings at revision stapedectomy include necrosis of the long process of the incus, prosthesis displacement away from the oval window, prosthesis lateralization, lateral chain fixation, loosening of the prosthesis-incus connection, and bony overgrowth of the oval window.⁵ Various studies have documented the success that can be achieved with revision surgery, but hearing results in general have been poorer than those of primary stapes surgery.²⁻⁶

In the setting of limited incudovestibular reconstruction options such as severe incus necrosis, an incus bypass technique is indicated to reconstruct the sound transmission mechanism.⁷ Options for significant erosion of the long process include a malleostapedectomy or total ossicular prosthesis (TOP) reconstruction. Our study sought to explore the hypothesis that TOP reconstruction in the setting of revision stapedectomy with indication for an incus bypass procedure would improve hearing results after revision stapedectomy.

Materials and Methods

Subjects

Following local institutional review board approval (13-032; St Vincent Medical Center, Los Angeles, California), a

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Surgical Technique revised

Years between primary surgery and last revision 10.4 (1.6-33.9)
Previous revision surgeries 1.0 (0-4)
Follow-up, mo 22.2

Tympani was divided sharply. The neck of the malleus was formed (n = 9); subsequently, a total stapedectomy was performed to assess the status of the footplate or oval window. In the majority of cases, a subtotal stapedectomy had been performed to visualize. With a sharp curette, bone removal was performed if necessary to afford visualization from the round window to the horizontal facial canal and from the pyramidal eminence to the anterior oval window position. The tympanomeatal flap was then reposited and gelatin sponge packing applied.

Table 1. Patient Characteristics (N = 17).a

<table>
<thead>
<tr>
<th>Patient Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men:women</td>
<td>8:9</td>
</tr>
<tr>
<td>Ear, right:left</td>
<td>8:9</td>
</tr>
<tr>
<td>Age, y</td>
<td>50.4 ± 16.0</td>
</tr>
<tr>
<td>Follow-up, mo</td>
<td>22.2 ± 25.0</td>
</tr>
<tr>
<td>Previous revision surgeries</td>
<td>1.0 (0-4)</td>
</tr>
<tr>
<td>Years between primary surgery and last revision</td>
<td>10.4 (1.6-33.9)</td>
</tr>
<tr>
<td>Surgical technique revised</td>
<td></td>
</tr>
<tr>
<td>Stapedotomy</td>
<td>9</td>
</tr>
<tr>
<td>Partial stapedectomy</td>
<td>2</td>
</tr>
<tr>
<td>Total stapedectomy</td>
<td>6</td>
</tr>
</tbody>
</table>

*aValues presented in No., mean (range), or mean ± SD.

Hearing Assessment

Preoperative audiograms were typically performed the day of surgery. Postoperatively, the first audiogram (routinely obtained at 3 weeks) and the last available audiograms were examined. Audiometric data included air conduction (AC) and bone conduction (BC) thresholds in decibels hearing level (db HL) and speech discrimination scores (SDSs; based on standard 25-word lists). Pure-tone average (PTA) threshold was calculated from frequencies of 0.5, 1, 2, and 3 kHz. Changes in PTA and SDS were computed by subtracting the postoperative values from the preoperative values. A positive value for PTA and a negative value for SDS indicated an improvement in the respective values postoperatively, while the converse indicated a decrease in the respective parameters. ABG and ΔABG were calculated from AC and BC thresholds obtained at the same test interval. The ABG was computed by subtracting the BC PTA from the AC PTA. The ΔABG was calculated by subtracting the postoperative ABG from the preoperative ABG as described by the AAO-HNS guidelines. A high-frequency BC PTA was computed according to the AAO-HNS guidelines by averaging the BC levels for frequencies of 1, 2, and 4 kHz. The pre- to postoperative change in this parameter is a measure of sensorineural hearing loss (SNHL). Positive values reflect improved BC levels, also referred to as over-closure, whereas negative values indicate high-frequency SNHL. All patients in the present study had a complete set of audiologic data. The newly adopted AAO-HNS scattergram tool was also used to depict our data.

Data Analysis

Data from the chart review were collected on a case record form and entered into an Microsoft Excel file. With a statistical software program, a paired t test was performed to assess for significance of pre- to postoperative change in audiometric variables. Criterion for statistical significance was set at P < .05, 2-tailed.

Results

Hearing Outcomes

For the entire cohort (n = 17), the distribution of preoperative PTA and SDS is demonstrated in Figure 2. With
exception of 2 patients with severe mixed loss, all patients had good to excellent preoperative speech discrimination. The cohort had a mean follow-up of 22.2 months (range, 3 weeks to 78 months). The pre- and postoperative audiometric measurements are depicted in Table 2. The change in absolute percentage points for PTA and SDS from the preoperative condition to the long-term follow-up is depicted in Figure 3. The change in ABG distribution from pre- to postoperative assessments is shown in Figure 4. The ABG at the last audiometric follow-up was ≤20 dB in 64.7%. Additionally, 64.7% of patients demonstrated an improvement in PTA of >10 dB, with the remainder save 1 patient without significant change. There was not a significant difference in the change of high-frequency BC, a measure of sensorineural loss. The standard deviation, however, was 12.8 dB and varied from an improved BC of 20 dB to a decrease of 36.67 dB at the last postoperative audiogram, as visualized in Figure 5.

For the subset of patients with follow-up of at least 1 year (mean, 42 months; SD, 19.5; n = 8), the postoperative ABG at last follow-up was 16.9 dB (SD, 11.9). For this smaller subset of the cohort, 75% (6 of 8) demonstrated an ABG of ≤20 dB at last audiometric follow-up.

Postoperative Complications

One case of postoperative profound hearing loss was noted among the cohort. At the time of operation, the patient was noted to have a Teflon piston prosthesis that had fallen into the vestibule. A laser was used to lyse adhesions surrounding the prosthesis before lifting it out of the vestibule. No dizziness was noted by the patient during the procedure. Over the course of 1 month postoperatively, the patient had a gradual decline to no response from the ear, including 0% discrimination and 100% reduced vestibular response by videonystagmography testing despite being treated with a course of corticosteroids.

Additional postoperative complications included vertigo of a transient nature in 3 patients, continued tinnitus in 2 patients, and transient taste disturbance in a single patient. One patient experienced postoperative bleeding from the ear canal requiring a clinic visit that resolved with conservative measures. There were no cases of prosthesis extrusion.

Discussion

Techniques in Revision Stapedectomy in the Setting of Incus Necrosis

Revision stapedectomy in the setting of incus erosion is a challenging surgical scenario. Depending on the level of severity of incus erosion, different reconstructive options may be considered. For mild erosions of the incus long process, a typical stapes prosthesis may be placed. If necessary, the prosthesis may be bent in a manner to accommodate the shortened prosthesis. For more moderate erosions or fractures of the incus long process, prostheses such as the Lippy modified prosthesis or the Appelbaum prosthesis may be employed. These prostheses accommodate the shortened incus and span to the oval window. Hearing results in these cases have seen ABG closure to ≤10 dB in 30% to 60% of cases. Hydroxyapatite bone cement may be utilized in revision stapedectomy for the eroded incus to build up the incus long process, stabilize a fractured incus long process, or stabilize the prosthesis with good result. When the incus long process is eroded and cannot be utilized, an incus bypass procedure, such as reconstruction with TOP or the malleostapedotomy, may be employed. The malleostapedotomy involves engaging a prosthesis from the intact malleus to the oval window. A number of
specific malleostapedectomy-type techniques have been described.\textsuperscript{13,18-20} Given otologic surgeons' familiarity with ossiculoplasty techniques, we have hypothesized that TOP reconstruction in severe incus necrosis in revision stapedectomy provides acceptable hearing results for difficult revision stapedectomy cases with severe incus necrosis.

**TOP Technique**

The technique for placing a TOP in the setting of severe incus necrosis is similar to the technique of ossiculoplasty—namely, placing a prosthesis to span the gap from the tympanic membrane to the oval window. In standard fashion, cartilage is interposed between the titanium platform and the tympanic membrane through harvest of tragal cartilage with its perichondrium. In the setting of revision stapedectomy, however, the issue of a compromised or absent stapes footplate is an important consideration. In 9 of the revision cases, soft tissue of a sufficient strength, area, and resiliency was noted, and no soft tissue covering for the oval window was necessary. In the remaining cases, if a remaining stapes footplate was present, as bony regrowth is a concern, the remainder was removed. After removal of the residual footplate, a perichondrial graft was placed over the open oval window. Although some evidence suggests that the vein may provide a better interposition at the oval window, since

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**Table 2. Audiometric Results (N = 17).\textsuperscript{a}**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Preoperative</th>
<th>Short-term\textsuperscript{b}</th>
<th>Long-term\textsuperscript{c}</th>
<th>P Values</th>
<th>Short-term</th>
<th>Long-term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure-tone average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bone conduction</td>
<td>30.7 ± 16.0</td>
<td>31.0 ± 18.0</td>
<td>32.3 ± 12.7</td>
<td>.896</td>
<td>.692</td>
<td></td>
</tr>
<tr>
<td>HFBC</td>
<td>32.2 ± 17.3</td>
<td>34.7 ± 18.7</td>
<td>32.2 ± 16.7</td>
<td>.434</td>
<td>.99</td>
<td></td>
</tr>
<tr>
<td>Air conduction</td>
<td>68.4 ± 20.1</td>
<td>50.2 ± 19.1</td>
<td>48.8 ± 20.9</td>
<td>.003</td>
<td>.002</td>
<td></td>
</tr>
<tr>
<td>SDS</td>
<td>81.65 ± 31.4</td>
<td>80.5 ± 34.3</td>
<td>78.6 ± 34.2</td>
<td>.851</td>
<td>.623</td>
<td></td>
</tr>
<tr>
<td>Air-bone gap</td>
<td>35.5 ± 12.6</td>
<td>19.1 ± 11.2</td>
<td>18.5 ± 14.0</td>
<td>&lt;.001</td>
<td>&lt;.002</td>
<td></td>
</tr>
<tr>
<td>(\Delta)air-bone gap</td>
<td>—</td>
<td>14.1 ± 16.7</td>
<td>14.7 ± 15.8</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>(\Delta)HFBC</td>
<td>—</td>
<td>−2.5 ± 12.8</td>
<td>0.0 ± 12.8</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: dB HL, decibels hearing level; HFBC, high-frequency bone conduction; n/a, not applicable; SDS, speech discrimination score.

\textsuperscript{a}Values presented in mean ± SD dB HL, except for SDS (in mean ± SD percentages).

\textsuperscript{b}First postoperative visit: 3 weeks.

\textsuperscript{c}Last available follow-up: average, 22.2 months.
cartilage is used to interface between the prosthesis and the tympanic membrane, perichondrium is used in our cases.21

**Hearing Results after Revision Stapedectomy for Severe Incus Necrosis with TOP Reconstruction and Comparison with Other Reports**

To our knowledge, this is the largest series reporting outcomes of TOP reconstruction in revision stapedectomy. No reports in the literature were found specifically addressing hearing results after TOP in revision stapedectomy. Sheehy, in 1982,7 reported results of 203 patients requiring an incus bypass procedure during stapedectomy with a malleostapectomy technique (90%) or TOP reconstruction (10%) in a heterogenous grouping of primary and revision stapedectomies and fenestrations. For those revision stapes procedures requiring an incus bypass where TOP reconstruction was performed, the ABG was closed to <20 dB in 73%. The results of the current study are congruent with this finding. The current study revealed ABG closure to <20 dB in 65%. SDS were well preserved among the cohort.

If we compared the current cohort results with those of published malleostapedectomy techniques, our results are comparable as well. Results of malleostapedectomy have been reported somewhat more variably. One-year postoperative results achieving ABG closure to <10 dB has ranged from 18% to 60% with malleostapedectomy techniques.12-14,20,22

**Risk of Sensorineural Loss**

Revision stapedectomy has been shown to carry a more significant risk of SNHL (3%-8%).4,7,23 The current study supports this finding with 1 of the 17 (5.9%) in the cohort acquiring a profound loss. With increased exposure of the vestibule and manipulation of the prosthesis in the vestibule, the risk for SNHL increases. A subset analysis was conducted between those patients requiring complete footplate removal with placement of perichondrium as a proxy for increased inner ear manipulation and those patients where perichondrium was not used, and it did not reveal a significant change in high-frequency BC between the 2 groups ($P = .83$). The single dead ear in the series, however, resulted in a case that required lifting a prosthesis that had fallen into the vestibule. Although there were no symptoms to indicate injury in the perioperative period and despite careful removal of the prosthesis, the patient lost PTA, SDS, and caloric responses over the course of 2 months despite steroid treatment. In light of the significant risk of SNHL with this technique as well as revision stapedectomy, it is important to emphasize alternative hearing rehabilitation options, including hearing aids and osseointegrated devices. Additionally, 2 patients with >91 dB PTA and SDS <10% underwent the procedure without significant benefit, thereby emphasizing the need to carefully counsel patients on outcomes, risks, and careful consideration of alternative rehabilitative options.

**Limitations**

Limitations of the current study include those inherent to observational case series review, including selection bias and its retrospective nature; however, clear inclusion and exclusion criteria were selected. The lack of a true comparison cohort further limits the strength of the conclusions drawn from the analysis of the study data. A nearly 2-year follow up supports the durability of TOP reconstruction; however, a larger cohort with additional long-term results would help strengthen this observation.

**Conclusion**

The familiar ossiculoplasty technique of TOP reconstruction may be employed in revision stapedectomy with limited incudovestibular reconstructive options. Total ossicular reconstruction in this challenging scenario may lead to favorable hearing outcomes, but it carries an increased risk of SNHL.

**Author Contributions**

J. Eric Lupo, concept and design, acquisition and analysis of data, draft, final approval; Brian M. Strickland, acquisition of data, critical revision, final approval; John W. House, concept, critical revision, final approval.

**Disclosures**

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Sponsorships: None.

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**References**


**Figure 5.** Individual patient change in preoperative high-frequency bone conduction pure-tone average (HFBC PTA) at the latest available follow-up.