Early Postoperative Results in Stapedectomy

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Abstract

Objective. To measure early audiometric changes after primary stapedotomy.

Study Design. Case series with chart review.

Setting. Academic inner-city hospitals.

Subjects and Methods. Consecutive patients operated on by the first author were included (only 1 ear in cases of bilateral surgery), and their audiometric results were reviewed. Data were analyzed from 45 ears. Air and bone audiometric measures were analyzed from 5 days post operation and 6 months post operation. Threshold shifts were quantified at 5 days and 6 months post operation.

Results. Overall results for the group were good, with 91% of patients achieving an air-bone gap less than or equal to 10 dB by 6 months post operation. Threshold shifts in at least 1 frequency were common at 5 days (62% of patients), but less so at 6 months (36%). Patients with shifts did not have worse overall outcomes at 6 months than those with no shifts. No difference in results was observed for the 2 prostheses used in this series.

Conclusion. Early audiometric results after stapedectomy commonly reveal worsened bone conduction (postoperative threshold shifts), which may reflect cochlear trauma, but do not lead to poorer outcomes as measured by conventional methods.

Keywords

stapedectomy, stapedotomy, threshold shifts, otosclerosis, stapes surgery

Materials and Methods

A case series with chart review of stapedotomy results was performed from available medical records from the first author’s surgical experience. Institutional Review Board approval was obtained from the University Hospital of Brooklyn at Long Island College Hospital. This series included hospital-based and private practice patients. All consecutive primary stapes surgeries with complete audiometric follow-up were included. In patients who underwent bilateral surgery, only 1 ear was included in this analysis. The first ear operated or the ear with complete audiometric data was included. Revision surgeries were not included. Data from January 1, 2008, to December 31, 2011, were reviewed; during this time, 93 primary stapedotomies in 81 subjects were reviewed.

Outcomes of stapedectomy are generally good in experienced hands. The majority of cases are successful when outcomes are evaluated by audiometry 6 or more months after surgery. Audiometry measures from an early postoperative period can be useful. Early results may reflect the surgical events with respect to incidental labyrinthine trauma. These aspects of the surgical experience may not be captured by outcome measurements made at 6 months, but may affect overall cochlear health, potentially impacting hearing years later.

Temporary threshold shifts (TTS), defined as reversible hearing loss following exposure to impulse or sound, have been reported after stapedectomy. This can be assumed to be due to limited and recoverable injury. A permanent threshold shift (PTS) is defined as a loss of bone conduction that does not recover over time. Successful outcomes of stapes surgery, as measured by accepted methods, can be achieved despite the presence of TTS and PTS as reported by several investigators. The use of the word temporary is ambiguous since some of these shifts will not recover and are actually permanent shifts. The terms early and late postoperative threshold shifts (POTS) are preferred. We seek to investigate early audiometric results after stapes surgery and characterize the threshold shifts. Early measures may prove to be valuable in assessing technical variations in the stapes operation.

Keywords

stapedectomy, stapedotomy, threshold shifts, otosclerosis, stapes surgery

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patients were performed. Patient follow-up and chart availability are difficulties present at one of our institution’s inner-city hospitals, which limited the availability of complete data on all operated patients during this time period. Complete audiometric data were available in 45 patients.

**Surgical Procedure**
All surgeries were done under general anesthesia in an academic hospital setting. A standard per-meatal laser stapedotomy using argon laser was performed with a 0.6 mm fenestration. A bucket handle prosthesis was used in most cases (24/45 cases). In cases where the lenticular process of the incus did not directly overlie the oval window, Causse fluoroplastic loop piston prosthesis was used (19/45). In 2 cases a “Big Easy” piston prosthesis was used. In all cases, a vein graft was placed in the fenestra prior to prosthesis placement. All ears were gently packed with silk strips and cotton coated with bacitracin ointment (“rosebud pack”), which was removed on postoperative day 5 before audiometry.

**Audiometry**
A certified audiologist performed all testing in a sound-treated booth; standard audiometer and immittance equipment was used. Air conduction threshold measures were obtained via insert earphones and headphones. Bone conduction thresholds measures were obtained using Radioear B71 bone oscillators. Word recognition scores were obtained using the W-22 word list via metered live voice. Calibrated immittance devices were used for tympanometry.

Pre- and postoperative audiometry were compared according to AAO-HNS guidelines, which included air and bone conduction performed at the same time. Pure-tone averages were 4 frequency averages (0.5, 1, 2, and the average of 2 and 4 kHz). Hearing outcomes were reported according to the new standard recently published in this journal.1

Air and bone conduction audiometry with word recognition testing was routinely completed on postoperative day 5. No immittance testing was done at this early postoperative session. Audiometric changes of 10 dB or greater were considered significant in individual analyses, while 5 dB changes were not considered significant.

Separate assessments were made comparing preoperative to 5-day postoperative audiometry and to 6-month postoperative audiometry. An evaluation was then made to assess changes that occurred from 5-day to 6-month postoperative results. A postoperative threshold shift was defined as a bone conduction loss of 10 dB or more.

**Statistical Analysis**
Pearson correlation coefficients (PCC) were used to establish a linear relationship between 5-day postoperative results and 6-month postoperative results at each frequency (0.5 kHz, 1 kHz, 2 kHz, 4 kHz). PCC are sensitive only to a linear relationship between 2 variables, and the positive PCC indicates the existence of a positive correlation between the 5-day and 6-month postoperative results, without specifying the magnitude of the correlation. Second, the PCC was tested against a theoretical correlation coefficient of zero to demonstrate that the correlation between our data points was not a random correlation. In addition, a two-sample t-test was conducted to compare outcome measures between the patients with early threshold shifts and those who did not have early shifts.

**Results**
Data were analyzed from 45 ears (from 45 patients). This included 27 female and 18 male patients. Twenty surgeries were on left ears and 25 on right ears. Age ranged from 17 to 84 years old with an average of 45 years and median of 43 years.

**Overall Results**
Mean pure-tone average (PTA) was 55 dB pre operation, 40 dB at 5 days post operation, and 27 dB at 6 months post operation. Average improvement of PTA was 15 dB at 5 days and 28 dB at 6 months. Mean air-bone gaps (ABG) were 30 dB pre operation, 7 dB at 5 days, and 6 dB at 6 months post operation, for an average improvement of 23 dB at 5 days and 24 dB at 6 months. At 6 months, the number of ears with average ABG less than or equal to 10 dB was 41 of 45 (91%), less than or equal to 20 dB was 45 of 45 (100%). There were no anacoustic (dead) ears, and no patients experienced a loss in PTA or bone conduction average (Figures 1 and 2).

**Air Conduction**
Air conduction thresholds at 5 days post operation were correlated with air conduction thresholds at 6 months post operation. Strong correlation exists at each of the 4 frequencies measured: 0.5 kHz, 1 kHz, 2 kHz, and 4 kHz ($P < .001$). This implies that when examining early postoperative changes in air conduction hearing thresholds, the direction of change from preoperative levels indicates the direction of long-term change. Thus, early results showing improvement in hearing thresholds predict that hearing will continue to improve in the long term; however, the magnitude of early improvement is not predictive of the magnitude of long-term improvement (Table 1).

**Bone Conduction**
Bone conduction threshold at 5 day and 6 month post operation were correlated at each frequency. Strong positive correlations exist at each of the 4 frequencies measured, with $P$ values < .05 at all thresholds. This suggests that when comparing the early postoperative results to long-term results, the observed change in early hearing thresholds predicts the direction of long-term change (Table 2).

**Postoperative Threshold Shifts**
Four frequencies were evaluated for threshold shifts: 0.5 kHz, 1 kHz, 2 kHz, and 4 kHz. On average, there was overall improvement of bone conduction when considering all
Table 1. Correlation of air conduction changes at 5 days and 6 months post operation, n = 45.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Pearson Correlation Coefficient</th>
<th>t Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 kHz</td>
<td>$r = 0.57774$</td>
<td>4.64146</td>
<td>.00003</td>
</tr>
<tr>
<td>1.0 kHz</td>
<td>$r = 0.59902$</td>
<td>4.90555</td>
<td>.00001</td>
</tr>
<tr>
<td>2.0 kHz</td>
<td>$r = 0.75509$</td>
<td>7.55242</td>
<td>.00000</td>
</tr>
<tr>
<td>4.0 kHz</td>
<td>$r = 0.83504$</td>
<td>9.95258</td>
<td>.00000</td>
</tr>
</tbody>
</table>

Figure 1. Scattergram of pretreatment hearing results.

Figure 2. Scattergram of 6-month posttreatment hearing results.
45 patients (Table 3, Figure 3). An improvement of bone conduction is likely a result of the Carhart effect, which disappears postoperatively. Twenty-eight of 45 (62%) patients experienced an early POTS, and a total of 16 of 45 (36%) patients experienced late POTS, defined as worsened bone conduction of 10 dB or more at 1 or more frequency (Table 4, Figure 4). In the 28 patients with early shifts, the mean shifts for 0.5 kHz, 1.0 kHz, 2.0 kHz, and 4.0 kHz were: 12.0 dB, 14.0 dB, 11.4 dB, and 19.1 dB, respectively (Table 5). In the 16 patients with late shifts, the mean shifts were: 17.5 dB, 10 dB, 10 dB, and 14.4 dB, respectively (Table 6).

Sixteen of 28 patients (57%) with early POTS had shifts at only 1 frequency. Six patients (21%) had early shifts at 2 frequencies, and 4 patients (14%) had early shifts at 3 frequencies. Two patients (7%) experienced shifts at all 4 frequencies tested. The incidence of early POTS was most frequent at 4 kHz and nearly equal at the other 3 frequencies. This is likely influenced by the presence of a preoperative Carhart notch.

Sixteen patients experienced late POTS, of which 10 (22% of the entire group) had shifts persisting from the 5-day measures and 6 patients (13%) who experienced a late shift with no prior shift at 5 days. In all 6 patients with exclusive late shifts, the shift was observed at only 1 frequency. This included 1 patient with a shift at 0.5 kHz only, 2 patients with shifts at 1.0 kHz only, 1 patient at 2 kHz only, and 2 patients at 4 kHz only.

The largest shifts were observed at 4 kHz. The single largest was a 55 db worsening of bone conduction at 4 kHz measured at 5 days. This recovered to the preoperative bone conduction level at 6 months. The maximum late POTS was also observed at 4 kHz. In this patient, a shift of 30 dB was observed at 4 kHz at 5 days and 25 dB at 6 months.

The 28 patients with early POTS did not have statistically worse long-term outcomes than those with no early shifts. The mean pure-tone average for the 28 patients with early POTS was 53 dB pre operation, 41 dB at 5 days post operation, and 25 dB at 6 months post operation; compared to 58 dB pre operation, 37 dB at 5 days post operation, and 30 dB at 6 months for the 17 patients with no early POTS. A 2-sample t-test was used to compare the mean PTA of the early shifters to mean PTA of non-early shifters. Although the patients with early POTS displayed slightly better results at the 6-month mark, no statistical significance was established at 5 days or 6 months. Average improvement of PTA for the 28 patients with early POTS was 12 dB at 5 days...
post operation and 28 dB at 6 months versus improvements of 21 dB at 5 days post operation and 28 dB at 6 months for the patients without early shifts.

For the 28 patients with early POTS, mean air-bone gaps were 30 dB pre operation, 7 dB at 5 days post operation, and 6 dB at 6 months post operation. The 17 patients with no early shifts had mean air-bone gaps of 30 dB pre operation, 7 dB at 5 days post operation, and 6 dB at 6 months post operation. At 6 months, the number of ears for early shifters with average ABG less than or equal to 10 dB was 26 of 28 (93%) versus 14 of 17 patients (82%) with no early shifts. This difference was not statistically significant.

We compared the outcomes by prosthesis type. Outcomes were nearly identical. Mean preoperative pure-tone average for the 19 patients receiving a loop piston and the 24 receiving bucket handles was the same: 55 dB. At 5 days the PTA was 37 dB for bucket handles and 42 for the loops. At 6 months the PTA was 27 for the bucket handles and 28 dB for the loops. Mean air-bone gaps pre operation were 31 dB for the bucket handles and 28 dB for the loops. At 5 days the ABG was 6 dB for the bucket handles and 8 dB for the loops. At 6 months post operation, the bucket handle group had an average ABG of 7 dB, and the loop group had an average ABG of 6 dB.

A total of 15 of the 24 patients (63%) with bucket handle prosthesis demonstrated early POTS compared to 12 of 19 (63%) with loop pistons. In the patients with early shifts, the mean shifts at the 4 frequencies for bucket handles was: 11.7 dB, 11.7 dB, 12.1 dB, and 13.9 dB, respectively. The mean shifts for the loop prosthesis group was: 12.1 dB, 17.5 dB, 10.0 dB, and 24.4 dB.

**Discussion**

This study was undertaken to quantify the bone conduction changes measured by audiometry following stapes surgery. Our data demonstrate and quantify the bone conduction changes at 4 frequencies. Others have reported such changes but did not quantify the degree of change at individual frequencies. Sergi et al reported on audiometric changes occurring at 2 days post operation but did not detail the patient incidence nor the range of changes observed. St. Martin’s group detailed the occurrence of bone conduction changes at 4 kHz but not at other frequencies.

Our results identify the frequent occurrence of threshold shifts early after surgery with a significant number of shifts persisting or occurring 6 months after surgery. Shifts occurred at all 4 frequencies measured, with a predilection at 4 kHz for more frequent and larger shifts. This report also compared the incidence of threshold shifts associated with 2 commonly used prostheses with no difference found.

Although not supported by this study, early measures after stapes surgery may be an indicator of surgical events. Minor labyrinthine trauma may occur but may be hard to measure, such as from operative noise, pressure, or manipulation or from chemical labyrinthitis secondary to bleeding, surgical liquids or contaminants (injected anesthetics, topical hemostatic agents, or sterilizing solutions). Since the vast majority of cases are successful when measured by audiometry at 6 or more months, these technical factors may not be captured in outcome measures and yet may have a long-term impact (measured in years) on cochlear health.

Choice of laser, fenestra size, prosthetics, and many other technical factors have been debated with regard to optimizing outcomes in stapes surgery. Early measures may inform this debate, especially since late outcomes appear to be blind to these cochlear effects.

Temporary threshold shifts have been reported after stapledectomy and have usually been attributed to limited and recoverable cochlear injury. Antoli-Candela et al had offered an explanation for high frequency loss after stapes surgery, proposing that stapes fixation actually favors transmission of high frequencies and that surgery may attenuate the transmission of these high frequencies.

Recovery of threshold shifts has been variably reported. Whereas some authors have reported recovery of early

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**Table 4. Threshold shifts at 4 frequencies.**

<table>
<thead>
<tr>
<th>Bone Conduction Shifts</th>
<th>0.5 kHz</th>
<th>1.0 kHz</th>
<th>2.0 kHz</th>
<th>4.0 kHz</th>
<th>Number of Individuals with Shifts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early shift</td>
<td>10</td>
<td>10</td>
<td>11</td>
<td>17</td>
<td>28</td>
</tr>
<tr>
<td>Persisting shift</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Late shift only</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Total late postoperative threshold shifts</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>8</td>
<td>16</td>
</tr>
</tbody>
</table>

*Number of individuals is not additive since 2 patients with persisting shifts also had new-onset shifts at other frequencies.

**Figure 4. Postoperative bone conduction results.**
threshold losses, other series document the existence of permanent threshold shifts.\textsuperscript{3,6} St. Martin et al observed a decline in pure tone thresholds at 4 kHz and 8 kHz shortly after stapes surgery that did not universally recover. Conversely, Antonelli et al reported improvement at 4 kHz after an initial TTS.\textsuperscript{6}

It has been reported that air and bone hearing thresholds deteriorate faster in patients following otosclerosis surgery than in normal controls when measured over many years.\textsuperscript{7} The etiology of progressive hearing loss in patients after stapes surgery may be attributed to the cochlear effects of otospongiosis or may, in part, be a result of surgical factors that are not recognized until years after surgery.

This study documents the variations in hearing measurements after stapes surgery. Further study may help establish whether these early measures directly reflect surgical technique.

**Author Contributions**

Neil M. Sperling, concept and design, drafting of manuscript, final approval; Krishna Sury, acquisition of data, revising content, final approval; Jessica Gordon, acquisition of data, revising content, final approval; Shaun Cox, analysis of data, revising content, final approval.

**Disclosures**

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**References**