Pediatric Stapes Surgery: Hearing and Surgical Outcomes in Endoscopic vs Microscopic Approaches

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Abstract

Objective. To compare endoscopic and microscopic pediatric stapes surgery.

Study Design. Case series with chart review.

Setting. Two academic otology practices.

Subjects and Methods. Surgical and hearing outcomes were compared for consecutive children (<18 years) undergoing microscopic and endoscopic stapes surgery. The main outcome measure was closure of the air-bone gap (ABG) to ≤20 dB.

Results. Twenty-two endoscopic surgeries (17 stapedectomies, 4 stapedotomies, and 1 stapes mobilization) and 52 microscopic surgeries (30 stapedectomies, 19 stapedotomies, and 3 stapes mobilizations) were performed. Patient demographics, history of ipsilateral middle ear surgery, and revision stapes surgery status were similar. The most common diagnosis for the endoscopic group and microscopic group were congenital stapes footplate fixation (45.5%) and juvenile otosclerosis (46.2%), respectively. Preoperative ABGs in the endoscopic (37.7 dB) and microscopic (32.8 dB) groups (P = .170) were similar. There were no major complications, including facial nerve injury or anacusic, in the endoscopic group. Postoperative sensorineural hearing loss (>15 dB) did not occur in any patients in the endoscopic group but was present in 2 patients in the microscopic group (P = .546). Improvement in pure-tone average (25.9 dB vs 18.5 dB, P = .382) and ABG (21.7 dB vs 14.7 dB, P = .181) was similar, and postoperatively, the median ABG was 11.3 dB and 15.0 dB for endoscopic and microscopic cases (P = .703), respectively. ABG closure to ≤20 dB (72.7% vs 65.2%, P = .591) was also similar.

Conclusion. Pediatric endoscopic stapes surgery is safe and hearing outcomes are similar to the microscopic approach when performed by experienced endoscopic ear surgeons.

Keywords

stapedectomy, stapedotomy, stapes mobilization, endoscopic ear surgery, pediatric, children, hearing loss

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Middle ear disease in the pediatric population is common and frequently presents with acquired conductive hearing loss. Whereas otitis media with effusion (OME) represents the most frequent etiology, the possibility of stapes fixation should be entertained in patients with a normal otoscopic examination.¹ The 2 most common causes of conductive hearing loss in children without a history of OME are juvenile otosclerosis (JO) and congenital stapes footplate fixation (CSFF).²³ Tympanosclerosis and congenital stapes malformations (eg, stapes bar) are other potential etiologies for stapes fixation.⁴ Roughly 15% of patients with otosclerosis are diagnosed before adulthood, and there is evidence of a congenital anomalous stapes footplate in approximately 9% of all pediatric temporal bones with ages ranging from newborn to 13 years.²⁵

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Surgical management of stapes pathology in children has been shown to be effective. More recent and robust studies have also suggested that stapes surgery results in statistically significant improvement in functional hearing for the pediatric population. Successful hearing improvement after pediatric stapes surgery occurs in most cases regardless of the etiology, although postoperative closure of air-bone gap (ABG) may be superior in JO compared to other etiologies. The potential complications of stapes surgery in children are generally comparable to those seen in adults, including hearing loss, vertigo, altered taste, and facial nerve injury, although delayed sensorineural hearing loss (SNHL) may present more commonly in the pediatric population when compared to adults. Recent meta-analyses have revealed permanently described. Laser-crimped Nitinol prostheses were used for stapedectomy cases. If the incus was not available, the average of 2 and 4 kHz was used.

The endoscope improves visualization of middle ear structures while enabling a wider field of view when compared to the traditional microscopic approach. This is perhaps even more important in the setting of narrow ear canals frequently encountered in the pediatric population. To date, reports on the use of endoscopes during middle ear surgery in children primarily focus on the treatment of cholesteatoma, with results comparable to the microscopic approach. Prior studies examining endoscopic stapes surgery in adults suggest similar outcomes with respect to hearing improvement and postoperative complications. The objective of this study was to compare surgical and audiometric outcomes in a cohort of pediatric patients treated for stapes pathology using either a microscopic or an endoscopic approach.

Methods
This study was approved by the local institutional review boards for the University of Texas Southwestern Medical Center and Vanderbilt University Medical Center. Surgeon case logs were used to identify consecutive pediatric patients (<18 years) who underwent stapes surgery at the 2 academic otologic centers between 2008 and 2018. Although patients with active middle ear disease, tympanic membrane perforation at time of stapes surgery, or inadequate audiometric follow-up would have been excluded, no patients needed to be excluded. Patients who underwent a transcanal microscopic approach were compared to patients who underwent a transcanal endoscopic approach for the management of intraoperatively confirmed stapes fixation. The techniques for endoscopic stapedotomy and stapedectomy have been previously described. Laser-crimped Nitinol prostheses were used for stapedotomy cases and notched bucket handle prostheses were used for stapedectomy cases. If the incus was not present, a malleovestibulopexy (MVP) prosthesis was used. The decision to perform stapedotomy vs stapedectomy was determined by surgeon preference and not patient pathology.

Patient demographics and clinical characteristics, including age, sex, history of otologic surgeries (including prior stapes surgery), and operative side, were collected. Audiometric data, including unaided air conduction (AC) and bone conduction (BC) thresholds, as well as speech discrimination scores (SDSs), were recorded from the medical record. Pure-tone average (PTA) was calculated as the 4-frequency AC average at 0.5, 1, 2, and 3 kHz. ABG was calculated by averaging the difference in AC and BC thresholds at 0.5, 1, 2, and 3 kHz. If 3 kHz was not available, the average of 2 and 4 kHz was used.

Intraoperative variables that were assessed included scutum removal, chorda tympani nerve integrity, oval window fenestration method, type and size of prosthesis, operative time, and intraoperative complications such as tympanic membrane perforation, facial nerve injury, floating footplate, and fracture or subluxation of the incus. Postoperative outcome variables included immediate postoperative complications such as dizziness, facial nerve weakness, SNHL, readmission or need for revision surgery, and long-term variables included length of surgical and audiologic follow-up, prosthesis extrusion, dysgeusia, tympanic membrane retraction or perforation, and audiologic data. Audiometric data herein are presented according to the 1995 American Academy of Otolaryngology—Head and Neck Surgery consensus guidelines.

Continuous variables were reported as means or medians and ranges when not normally distributed. Categorical variables were reported as frequency counts and percentages. Mann-Whitney tests compared medians with nonparametric values. Categorical variables were compared with χ² tests. Kruskal-Wallis tests were used to compare hearing outcomes and diagnoses. All tests were 2-sided and P values <.05 were considered statistically significant. Statistical analyses were performed with SPSS 25.0 (SPSS, Inc, an IBM Company, Chicago, Illinois).

Results
There were 22 endoscopic and 52 microscopic stapes surgeries performed in pediatric patients between 2008 and 2018 at the 2 institutions. Two surgeons performed the endoscopic surgeries (B.I. and A.R.), and 3 surgeons performed the microscopic surgeries (B.I., A.R., and J.W.K.). Of note, the microscopic cohort included patients from the entire study period, whereas the endoscopic cohort included only patients since 2013 after the endoscopic technique was adopted (Figure 1). Table 1 outlines the baseline demographics of the patients for each group and causes for stapes pathology. The median age at time of surgery was 10.5 years (interquartile range [IQR], 7.3-15.5 years) for the endoscopic group and 10.5 years (IQR, 8.0-14.3 years) for the microscopic group. There were 9 right ears in the endoscopic group and 24 right ears in the microscopic group. More males had surgery for both the endoscopic (59.1%) and microscopic (59.6%) groups. There was no difference between groups when comparing history of ipsilateral middle ear surgery (31.8% vs 25.0%, P = .576), including prior stapes surgery (4.5% vs 5.8%, P = 1.000), for the endoscopic and microscopic cohorts, respectively. CSFF was the most common diagnosis for patients undergoing endoscopic stapes surgery (45.5%, P = .289). In contrast, JO was the more common diagnosis for patients undergoing microscopic stapes surgery (46.2%, P = .035).
Table 2 outlines the surgical procedure, intraoperative findings, and postoperative surgical outcomes for the patients. There were 17 stapedectomies, 4 stapedotomies, and 1 stapes mobilization performed in the endoscopic cohort and 30 stapedectomies, 19 stapedotomies, and 3 stapes mobilizations performed in the microscopic cohort. Three patients in the endoscopic group and 1 patient in the microscopic group had an additional procedure performed at the time of stapes surgery, such as lateral chain mobilization or round window drill-out. Notably, the patient who required the round window drill-out in addition to stapedectomy achieved an ABG improvement of 17.5 dB and ABG closure to 20 dB.

Scutum removal with a curette was required in fewer endoscopic cases than microscopic cases (59.1% vs 84.6%, respectively, \( P = .032 \)). There was no difference in the rate of chorda tympani transection between the endoscopic and microscopic groups (9.1% vs 11.5%, respectively, \( P = 1.000 \)). Persistent altered taste lasting longer than 3 months occurred in 2 patients in each group (\( P = .579 \)). There were no cases of facial nerve injury. Uncontrolled dizziness was not present in any patients in the endoscopic group but occurred in 1 patient in the microscopic group, requiring an overnight hospital admission. This patient’s symptoms resolved the following day without recurrence. All other patients were discharged on the same day as surgery. Median surgical length was longer for the endoscopic group by approximately 20 minutes (97.5 vs 78.0 minutes, \( P = .013 \)). Operative length was no different for the first 10 as compared to the last 10 endoscopic stapes surgeries performed (95.20 vs 107.00 minutes, \( P = .301 \)).

Table 3 outlines the preoperative and postoperative audiometric data for the patients. BC thresholds for 6 of the microscopic cases were missing, but these patients had AC thresholds in the normal range. Complete audiometric data were available for all endoscopic cases. Preoperatively, patients in the endoscopic and microscopic cohorts had similar levels of hearing impairment, as measured by PTA, ABG, and SDS. Endoscopic patients had a 37.7-dB ABG preoperatively compared to a 32.8-dB ABG for microscopic patients (\( P = .170 \)). Postoperatively, the median ABG improved to 11.3 dB and 15.0 dB for endoscopic and microscopic cases (\( P = .703 \)), respectively. Similarly, PTA improved by 25.9 dB and 18.5 dB for each cohort (\( P = .382 \)). Figure 2 and Figure 3 are scattergrams outlining postoperative audiometric changes for the endoscopic and microscopic cases, respectively.

Table 1. Baseline Demographics and Cause for Stapes Pathology.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Endoscopic (n = 22)</th>
<th>Microscopic (n = 52)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, median (IQR), y</td>
<td>10.5 (7.3-15.5)</td>
<td>10.5 (8-14.3)</td>
<td>.673</td>
</tr>
<tr>
<td>Male, No. (%)</td>
<td>13 (59.1)</td>
<td>31 (59.6)</td>
<td>1.000</td>
</tr>
<tr>
<td>White race, No. (%)</td>
<td>14 (63.6)</td>
<td>45 (86.5)</td>
<td>.054</td>
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<tr>
<td>Right ear, No. (%)</td>
<td>9 (40.9)</td>
<td>24 (48.1)</td>
<td>.800</td>
</tr>
<tr>
<td>Prior ipsilateral ME surgery, No. (%)</td>
<td>7 (31.8)</td>
<td>13 (25.0)</td>
<td>.576</td>
</tr>
<tr>
<td>Revision stapes surgery, No. (%)</td>
<td>1 (4.5)</td>
<td>3 (5.8)</td>
<td>1.000</td>
</tr>
<tr>
<td>Diagnosis, No. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSFF</td>
<td>10 (45.5)</td>
<td>16 (30.8)</td>
<td>.289</td>
</tr>
<tr>
<td>JO</td>
<td>4 (18.2)</td>
<td>24 (46.2)</td>
<td>.035</td>
</tr>
<tr>
<td>Tympanosclerosis</td>
<td>1 (4.5)</td>
<td>8 (15.4)</td>
<td>.265</td>
</tr>
<tr>
<td>Stapes bar</td>
<td>3 (13.6)</td>
<td>2 (3.8)</td>
<td>.152</td>
</tr>
<tr>
<td>Other</td>
<td>4 (18.2)</td>
<td>2 (3.8)</td>
<td>.060</td>
</tr>
<tr>
<td>Atresia</td>
<td>1 (4.5)</td>
<td>0 (0.0)</td>
<td>.297</td>
</tr>
<tr>
<td>Displaced prosthesis</td>
<td>0 (0.0)</td>
<td>1 (1.9)</td>
<td>1.000</td>
</tr>
<tr>
<td>Trauma</td>
<td>1 (4.5)</td>
<td>1 (1.9)</td>
<td>.509</td>
</tr>
<tr>
<td>Unknown</td>
<td>2 (9.1)</td>
<td>0 (0.0)</td>
<td>.086</td>
</tr>
</tbody>
</table>

Abbreviations: CSFF, congenital stapes footplate fixation; IQR, interquartile range; JO, juvenile otosclerosis; ME, middle ear.
There were no patients in the endoscopic group who had postoperative SNHL, defined as a decrease in BC thresholds ≥15 dB, but there were 2 patients in the microscopic group (17.5-dB and 53.8-dB decrease, respectively). Closure of the ABG to ≤10 dB was achieved in 45.5% of endoscopic cases compared to 34.8% of microscopic cases (P = .433).
whereas closure of the ABG to ≤20 dB was achieved in 72.7% of endoscopic cases and 65.2% of microscopic cases ($P = .591$). There was no change in median SDS in either group. Audiometric follow-up was longer in the microscopic group when compared to the endoscopic group (27.0 vs 7.1 months, respectively, $P < .001$).

Discussion
The current study summarizes the largest experience to date of endoscopic stapes surgery in pediatric patients. Prior to this, the largest endoscopic series in children included only 5 patients with stapes fixation.\(^4\) We demonstrated ABG closure to ≤10 dB in 45.5% and to ≤20 dB in 72.7% of patients treated with the endoscopic approach. This compares favorably to the internal microscopic control group, in which closure to ≤10 dB was achieved in 34.8% and to ≤20 dB in 65.2%. This also compares favorably to external microscopic controls in the published literature. Specifically, in a cohort of 25 adult and pediatric patients who underwent microscopic stapes surgery for presumed CSFF, Massey and colleagues\(^24\) achieved ABG closure to ≤10 dB in 48% and to ≤20 dB in 80% of cases. Notably, this analysis excluded revision stapes surgery, and it was unclear how many of these patients were children since individual patient data were not included. In a separate study evaluating 33 pediatric patients with complete audiometric follow-up who underwent primary microscopic stapes surgery, Denoyelle and colleagues\(^10\) reported ABG closure to ≤10 dB in 67% of patients and ABG closure to ≤20 dB in 94% of patients. Finally, in a meta-analysis summarizing 445 pediatric ears, Asik and colleagues\(^13\) revealed ABG closure to ≤10 dB in 69.9%, while noting an important difference in closure rates between JO (80.2%) and CSFF (54%).

Whereas some studies have identified CSFF as more common than JO,\(^10,11\) others have demonstrated the reverse.\(^12\) In the present study, 26 patients had CSFF and 28 patients had JO; however, CSFF represented a plurality of the diagnoses for the endoscopic cohort (45.5%), whereas JO represented a plurality of the diagnoses for the microscopic cohort (46.2%). Attention to the cause of stapes fixation is important as prior work has suggested there may be worse audiometric outcomes in patients with CSFF compared to JO.\(^11,12\) This study, however, failed to identify a relationship between cause for stapes fixation and hearing outcomes.

Importantly, we have demonstrated that pediatric endoscopic stapes surgery is safe when performed by experienced endoscopic ear surgeons. There were no cases of facial nerve paralysis or anacusis. In fact, no patient in the endoscopic cohort experienced significant postoperative SNHL (≥15 dB) or significant dizziness, and all endoscopic patients were discharged the same day as surgery. Moreover, rates of chorda tympani nerve transection, intraoperative tympanic membrane perforation, and postoperative dysgeusia were similar to the microscopic cohort. Two patients in the endoscopic group experienced an intraoperative tympanic membrane perforation that required placement of an underlay graft. Despite this, each of these cases was able to be completed. In addition, there was 1 patient for whom the distal long process and lenticular process came out with the stapes superstructure and required a malleovestibulopexy prosthesis. This patient improved from an SDS
of 0% preoperatively to 100% postoperatively and was noted to have a 32.5-dB improvement in ABG; however, a persistent 32.5-dB ABG was present following surgery.

Benefits of endoscopic ear surgery are well established and include improved visualization with the ability to “see around” corners, improved trainee experience, and the possibility of decreased need for removal of the scutum in stapes surgery.25-27 The present study recapitulated this finding of decreased need for scutum removal when using the endoscope. Because endoscopic stapes surgery provides significantly improved visualization, we believe this enhances our ability to treat patients with difficult or abnormal anatomy with a higher degree of confidence. Furthermore, we suspect this improves diagnostic accuracy for identifying causes of failure when performing revision stapes surgery.28 To become facile at this approach, we have tended to perform it for all cases, rather than just the more difficult cases. Prospective studies with larger cohorts will be needed to confirm these hypotheses.

There are, of course, limitations to the endoscope, the most important of which is relegating the surgeon to one-handed surgery. As such, endoscopic stapes surgery, especially in children, is not advisable for novice surgeons. The lack of depth perception and one-handed surgery using the endoscope present significant challenges when managing the footplate, whether a small fenestra or a stapedectomy is performed. For these reasons, we recommend that surgeons learning endoscopic ear surgery first gain significant experience with more straightforward otologic surgeries, such as tympanoplasty, prior to embarking on endoscopic stapes surgery. In addition, we found that endoscopic stapes surgery took, on average, nearly 20 minutes longer than microscopic stapes surgery. The operative length of the first 10 and last 10 endoscopic stapes surgeries was similar, suggesting this is not simply due to a “learning curve,” although larger numbers and a prospective study would better answer this question.

Several limitations to this study deserve mention. These include the inherent limitations of a retrospectively performed study in a relatively small study population. Endoscopic cases had shorter follow-up than microscopic cases since this technique was adopted later. Each surgeon in this study had significant experience with microscopic stapes surgery prior to performing endoscopic stapes surgery. This almost certainly contributed to improved outcomes for endoscopic stapes surgery than otherwise would have been obtained for novice surgeons. Nevertheless, since most otologic surgeons have learned the microscopic approach first (with the exception of perhaps the current residents training at high-volume endoscopic ear centers), we feel this improves external validity of this comparison. Moreover, the steps of endoscopic and microscopic stapes surgery are essentially equivalent. The skill set unique to the endoscope can largely be learned performing other endoscopic ear surgeries. The ideal comparison between endoscopic and microscopic stapes surgery, however, would be to simultaneously and prospectively evaluate outcomes. Of course, the present findings were aimed at essentially proving noninferiority, rather than improved outcomes, for the endoscopic approach. Finally, it is important to note that this study was performed by surgeons with significant experience in endoscopic ear surgery, a fact that may limit the generalizability of this study for novice endoscopic ear surgeons.

Conclusion

Pediatric endoscopic stapes surgery is a safe and effective procedure when performed by highly experienced endoscopic ear surgeons. Complication rates and hearing results are similar when compared to the traditional microscopic approach. ABG closure rates to within 10 and 20 dB were less robust than in adult populations but were similar to the published literature for pediatric patients.

Author Contributions

Anthony M. Tolisano, substantial contributions to the conception and design of the work; acquisition, analysis, and interpretation of data for the work; drafting the work; final approval; agreement to be accountable; Miles R. Fontenot, acquisition of data for the work; drafting the work; final approval; agreement to be accountable; Ashley M. Nassiri, acquisition of data for the work; drafting the work; final approval; agreement to be accountable; Jacob B. Hunter, analysis and interpretation of data for the work; critical revisions; final approval; agreement to be accountable; Joe Walter Kutz Jr., substantial contributions to conception of work; critical revisions; final approval; agreement to be accountable; Alejandro Rivas, substantial contributions to conception of work; critical revisions; final approval; agreement to be accountable; Brandon Isaacson, substantial contributions to conception of work; critical revisions; final approval; agreement to be accountable.

Disclosures

Competing interests: Joe Walter Kutz, consultant for Eloxx, Achaogen, and Medtronic; Alejandro Rivas, consultant for MED-EL, Advanced Bionics, Cochlear, Grace Medical, Stryker, Cook Medical, and Olympus; Brandon Isaacson, advisory board for MED-EL and Advanced Bionics and consultant for Stryker, Medtronic, Advanced Bionics, Olympus, and Storz.

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