Surgical and Audiologic Outcomes in Endoscopic Stapes Surgery across 4 Institutions

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Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

Abstract

Objectives. To investigate intra- and postoperative outcomes of endoscopic stapes surgery.

Study Design. Case series with chart review.

Setting. Four tertiary care otologic centers.

Subjects and Methods. Sixty-five subjects 18 years and older who underwent endoscopic stapes surgeries were analyzed. Variables analyzed included surgical techniques and intraoperative findings. Outcomes measured included postoperative hearing and complications to date.

Results. Fifty-one patients met inclusion and exclusion criteria. The average patient age was 48.1 years (range, 26-87 years), with 60.0% female patients. Patients had a median follow-up of 5.13 months (range, 0.8-57.4 months). Of the subjects, 71.7% required scutum removal. The chorda tympani nerve was manipulated in 94.0% of subjects and transsected in 12.0%. At last follow-up visit, the median air-bone gap decreased from 34.5 dB hearing level (HL) preoperatively to 9.0 dB HL postoperatively (P < .0001). Ninety percent of subjects had closure of their air-bone gap ≤ 20 dB HL. Intraoperative complications included tympanic membrane tears in 8.0% of subjects, all of which resolved at first follow-up. Postoperatively, 10.0% of subjects complained of altered taste.

Conclusions. The present multicentered study of endoscopic stapes surgery demonstrates similar audiometric and postoperative outcomes previously published in the literature, with a median postoperative air-bone gap of 9.0 dB HL. Future prospective endoscopic stapes surgery studies, addressing the need for scutum removal, postoperative taste changes, and pain scores, are merited.

Keywords

endoscopic, stapedotomy, stapedectomy

Received August 21, 2015; revised January 8, 2016; accepted January 29, 2016.

Since Valsalva first described a fixed stapes in 1704, there have been many surgical techniques to restore hearing, including removal of the tympanic membrane and ossicles, mobilization of the stapes, fenestration of the lateral semicircular canal, and removal of the stapes.1,2 Since Shea3 first reported removing the entire stapes and replacing it with a prosthesis in 1956, many variations, including stapedioplasties and small fenestra stapedotomies, have been described.

Mer is first credited with using an endoscope to evaluate middle ear anatomy in 1967.4 It took another 20 years before endoscopes were used to assess residual and recurrent cholesteatomas in the mastoid cavity and middle ear.5 As a natural extension, several studies reported endoscopic stapes surgery outcomes, with Tarabichi6 describing the procedure in 12 patients in 1999 and Poe1 describing the use of an endoscopic-assisted stapedioplasty in 5 patients in 2000. It took another 11 years when the next endoscopic stapes series was published, with Nogueira et al7 describing 14 of 15 subjects having subjective improvement in hearing at postoperative day 15. They emphasized that the endoscope allowed improved visualization of the oval window niche without needing to remove bone, thus reducing the risk of injuring the chorda tympani nerve.7 In 2013, Sarkar and

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This article was presented at the 2015 AAO-HNSF Annual Meeting and OTO EXPO; September 27-30, 2015; Dallas, Texas.

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colleagues\textsuperscript{8} reported the largest single experience of fully endoscopic stapedotomies with 30 subjects. With a mean preoperative air-bone gap of 41.5 dB, they described a 3-month mean postoperative air-bone gap of 10.1 dB, a statistically significant improvement.\textsuperscript{8} However, no information regarding complications was documented.

With the burgeoning interest in endoscopic middle ear surgery, along with minimal studies reporting endoscopic stapes surgery outcomes, we sought to describe the largest endoscopic stapes surgery experience to date, from the first multi-institutional perspective.

\textbf{Methods}

Institutional review board approval was obtained from all institutions (12082014-1 [University of Texas, Southwestern Medical Center, Dallas, Texas], STU 082015-038 [Clinica Rivas, Bogota, Colombia], 141623 [Vanderbilt University Medical Center, Nashville, Tennessee], and UEC-E-State University of Ceara, Fortaleza, Brazil [CAAE 38628114.7.0000.5040]). A retrospective chart review of all endoscopic stapes surgeries was performed at 4 tertiary care otology centers. Inclusion criteria included patients 18 years or older, endoscopic visualization during the procedure, and intraoperative stapes footplate fixation. Exclusion criteria included patients with otitis media, retrocochlear pathology, external ear canal pathology, lack of audiometric follow-up, microscopic assistance, dehiscent facial nerve precluding placement of a prosthesis, and the presence of a tympanic membrane perforation preoperatively (\textit{Figure 1}).

Preoperative variables included sex, age, operated ear, history of ear surgery, presence of dizziness or tinnitus, unaided air- and bone-conduction thresholds, and speech discrimination scores. Surgical variables assessed included types of endoscopes used; scutum anatomy and need for removal; chorda tympani manipulation; prosthesis used; intraoperative complications, including facial nerve injury, excessive bleeding requiring use of the microscope, tympanic membrane perforation, incus fracture, or subluxation; and operative time. Postoperative variables assessed immediately and at follow-up included length of hospital stay, reason for admission, length of follow-up, unaided postoperative air- and bone-conduction thresholds, speech discrimination scores, and complications, including facial nerve weakness, sensorineural hearing loss, intractable vertigo, prosthesis extrusion, tympanic membrane retraction or perforation, and altered taste. Audiologic outcomes were analyzed based on 3 major surgical variations: endoscopic laser stapedotomy, endoscopic drill stapedotomy, and endoscopic stapedectomy. The primary outcome measured was air-bone gap, while secondary outcomes included scutum removal; chorda tympani manipulation and or transection; intraoperative complications, including tympanic membrane tears and floating footplate; and postoperative complications, including the presence of dizziness, facial nerve weakness, tympanic membrane perforation, and dysguesia.

Audiometric testing was completed preoperatively and postoperatively with the contralateral ear masked. Postoperative audiometric testing occurred at different time points, and thus reported results are from the last clinical visit. Subjects acted as their own controls. Pure-tone air conduction and bone-conduction thresholds were obtained. Pure-tone averages and air-bone gaps were calculated as outlined by the Hearing Committee of the American Academy of Otolaryngology—Head and Neck Surgery.\textsuperscript{9} Pure-tone averages were calculated averaging the air-conduction thresholds at 0.5, 1, 2, and 3 kHz, or the average of 2 and 4 kHz if 3 kHz was unavailable, and rounded to the nearest whole number. Air-bone gaps were calculated subtracting the 4-tone bone-conduction pure-tone average from the same 4-tone air-conduction pure-tone average. Postoperative sensorineural hearing loss was defined as an increase in unaided bone-conduction thresholds greater than 10 dB hearing level (HL).

While the surgical technique has been described elsewhere, all subjects at each institution underwent the same surgical technique that is unique to that institution, with slight procedural variations between institutions.\textsuperscript{7} Despite endoscopic visualization, a variable amount of scutum is removed with a curette if scutum anatomy prevented instrument access to the oval window niche. Once the stapes superstructure is adequately exposed, depending on the institution, a CO\textsubscript{2} or diode laser, or a microdrill, is used to divide the posterior stapes crus, followed by down-factoring the stapes superstructure. With the footplate in place, in institutions where a stapedotomy was performed, a fenestra is created in the footplate with either a drill or a laser, followed by placement of a variety of piston-type prostheses. In cases of partial or total stapedectomy, tragal perichondrium is harvested and placed on the promontory prior to removal of the footplate. The perichondrium is then used to cover the oval window followed by placement of a bucket handle prosthesis between the oval window and the incus lenticular process. Depending on the institution, patients were either discharged the same day of surgery or admitted overnight, regardless of the immediate postoperative course.

Continuous variables were reported as means, standard deviations, and ranges when normally distributed and medians

![Figure 1. Study design.](https://example.com/figure1.png)
when not normally distributed. Percentages were reported with denominators consisting of available patient data, as some data points were not recorded. Student \( t \) test was used to compare pre- and postoperative means with normally distributed data, while a Mann-Whitney test was applied to means with non-parametric values, with all tests 2-sided and \( P \) values \( <.05 \) considered statistically significant.

### Results

A total of 65 subjects underwent endoscopic stapes surgery between May 2010 and April 2015 (Figure 1). Fourteen cases were excluded from data analysis due to missing postoperative audiometry (\( n = 11 \)), adjunctive use of the microscope (\( n = 2 \)), or a dehiscent facial nerve precluding prosthesis placement (\( n = 1 \)). A total of 33 subjects (64.7%) did not have access to a laser intraoperatively. The mean (SD) subject age was 48.2 (12.5) years (range, 26-87 years), 60.8% were women, and 52.9% of left ears were affected. Preoperatively, no subject reported dizziness, while 55.5% (15/27) complained of tinnitus. Preoperative audiometric testing results are listed in Table 1 and Figure 2.

Intraoperatively, with the use of the endoscope, confirmation of stapes fixation was achieved in all cases prior to the removal of ear canal bone. However, despite use of the endoscope, the scutum anatomy prevented prosthesis placement in 75.5% (37/49) of cases or in 66.7% (33/50) of cases with use of a curved alligator, necessitating scutum removal. The chorda tympani was manipulated in 92.2% (47/51) of cases and transected in 11.8% (6/51) of cases. All subjects had fixed stapes, while 1 subject also exhibited malleus fixation. With regard to intraoperative complications, 7.8% (4/51) had tympanic membrane tears that were repaired with a perichondrium graft, 2.0% (1/51) had an incus subluxation, and floating footplates with

### Table 1. Pre- and Postoperative Hearing Results.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>n</th>
<th>Follow-up, mo</th>
<th>Preoperative, %</th>
<th>Postoperative, %</th>
<th>( P ) Value</th>
</tr>
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<tbody>
<tr>
<td><strong>PTA, dB HL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Endoscopic laser stapedotomy</td>
<td>9</td>
<td>5.4</td>
<td>44.6</td>
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<td>18.7</td>
<td>56.9</td>
<td>38.8</td>
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<td>3.6</td>
<td>61.9</td>
<td>32.4</td>
<td>\textbf{&lt;.0001}</td>
</tr>
<tr>
<td>Total</td>
<td>51</td>
<td>13.4</td>
<td>55.5</td>
<td>35.2</td>
<td>\textbf{&lt;.0001}</td>
</tr>
<tr>
<td><strong>BC PTA, dB HL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>9</td>
<td>5.4</td>
<td>18.6</td>
<td>21.1</td>
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<td>18.7</td>
<td>22.1</td>
<td>27.6</td>
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<td>Total</td>
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<td>22.7</td>
<td>25.7</td>
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<td></td>
<td></td>
<td></td>
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<td>Endoscopic laser stapedotomy</td>
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<td>5.4</td>
<td>26.4</td>
<td>8.1</td>
<td>\textbf{&lt;.0001}</td>
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<tr>
<td>Endoscopic drill stapedotomy</td>
<td>33</td>
<td>18.7</td>
<td>34.9</td>
<td>12.6</td>
<td>\textbf{&lt;.0001}</td>
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<tr>
<td>Endoscopic stapedectomy</td>
<td>9</td>
<td>3.6</td>
<td>32.3</td>
<td>9.2</td>
<td>\textbf{&lt;.0001}</td>
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<tr>
<td>Total</td>
<td>51</td>
<td>13.4</td>
<td>32.8</td>
<td>11.1</td>
<td>\textbf{&lt;.0001}</td>
</tr>
<tr>
<td><strong>SDS</strong></td>
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<td></td>
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<td></td>
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<tr>
<td>Endoscopic laser stapedotomy</td>
<td>9</td>
<td>5.4</td>
<td>97.8</td>
<td>95.3</td>
<td>.4570</td>
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<tr>
<td>Endoscopic drill stapedotomy</td>
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<td>18.7</td>
<td>95.4</td>
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<td>.8496</td>
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<td>Endoscopic stapedectomy</td>
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<td>3.6</td>
<td>88.9</td>
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<td>.4635</td>
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<td>51</td>
<td>13.4</td>
<td>94.7</td>
<td>95.3</td>
<td>.4735</td>
</tr>
</tbody>
</table>

Abbreviations: ABG, air-bone gap; BC, bone conduction; HL, hearing level; PTA, pure-tone average; SDS, speech discrimination scores.

*Bold \( P \) values represent statistical significance, \( P < .05 \).
associated postoperative vertigo occurred in 3.9% (2/51) of subjects. No facial nerve injuries were noted. The median procedural (incision to closing) time was 79.0 minutes (range, 35-170 minutes). All subjects were discharged home following institutional standards, while 2 subjects were admitted postoperatively for 3 and 7 days due to vertigo. Of note, 2 subjects, both in the first year of one institution’s experience, underwent endoscopic stapes surgery but required microscope conversion during the case and thus were excluded from analysis. One subject was converted due to excessive bleeding, precluding adequate visualization and thus requiring 2-handed surgery and suctioning of the operative field. The other subject was noted to have a deep oval window niche with poor depth perception with the endoscope. Thus, the microscope was used to drill the stapedotomy and place the prosthesis.

Postoperatively, at a median follow-up of 5.4 months (range, 0.76–57.4 months), the median air-bone gap was 9.0 dB HL (range, 0–45 dB HL), improved from 35 dB HL preoperatively (P < .001). Pre- and postoperative audiometric testing results are listed and separated by surgical technique in Table 1. Figures 2 and 3 show individual pre- and post-treatment audiometric scattergrams, respectively. All techniques demonstrated significant improvements in pure-tone averages and air-bone gaps at postoperative testing. When comparing the average postoperative air-bone gap between each surgical technique, there were no significant differences (Table 2). Assessing all subjects, 90.2% had closure of their air-bone gaps under 20 dB HL. Two subjects had >30 dB HL sensorineural hearing loss postoperatively. These 2 subjects had the stapes crurae drilled, secondary to a lack of institutional access to lasers, which could explain the cause of the loss. Removing all subjects who did not have access to lasers, no subject had sensorineural hearing loss greater than 10 dB HL, while 100.0% had closure of their air-bone gaps to under 20 dB HL, 88.9% to within 15 dB HL, and 72.2% to within 10 dB HL.

At follow-up, 9.8% (5/51) of subjects complained of altered taste, 3.9% (2/51) required a short course of systemic steroids for continued dizziness, and 1 subject each was noted to have an extruded prosthesis, a posterosuperior tympanic membrane retraction, and mild otitis externa. No subjects had a tympanic membrane perforation or profound sensorineural hearing loss. Of the 5 subjects that complained of altered taste postoperatively, the chorda tympani was transected in 1 subject.

Discussion

In this multi-institutional study of 51 patients with otosclerosis undergoing endoscopic stapes surgery, 90.2% of subjects had closure of their air-bone gap to under 20 dB HL, with a median air-bone gap of 9.0 dB HL. Although an endoscope provides improved visualization, as noted in our study with all oval windows visualized prior to any bony removal, 70% of our subjects required partial curettage of the scutum to facilitate instrument access and prosthesis placement. In addition, 92.2% of subjects required chorda tympani nerve manipulation, transected in 11.8% of cases. Reviewing the stapes microscopic literature, a much larger sample size exists. Assessing audiometric outcomes, in sample sizes ranging from 548 to 14,449 subjects, 91.3% to 95.1% of subjects had closure of their air-bone gap to at least 10 dB HL or better.10-12 When assessing chorda tympani nerve manipulation, Guder et al13 reported a manipulation and transection rate of 94.4% and 5.6%, respectively, while Yung et al14 described a transection rate of 10.2% from a multisurgeon experience. We believe these rates do not significantly differ from our results because the visualization advantage of the endoscopic approach is negated when instrument design prevents prosthesis placement. Reviewing microscopic complications, complete sensorineural hearing loss occurs in 0.5% to 0.97%, tympanic

Table 2. Postoperative Air-Bone Gap Surgical Technique Comparison. *

<table>
<thead>
<tr>
<th>Laser Stapedotomy</th>
<th>Drill Stapedotomy</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.1 dB HL (n = 9)</td>
<td>12.6 dB HL</td>
<td>.1926</td>
</tr>
<tr>
<td>12.6 dB HL (n = 33)</td>
<td>Stapedectomy</td>
<td>.5396</td>
</tr>
<tr>
<td>9.2 dB HL (n = 9)</td>
<td>Laser Stapedotomy</td>
<td>.6290</td>
</tr>
</tbody>
</table>

Abbreviation: HL, hearing level.

*Comparison of postoperative air-bone gaps between surgical techniques using the Mann-Whitney test.
membrane perforation in 0.18% to 0.72%, and temporary facial nerve paralysis in 0% to 0.07% of subjects.\textsuperscript{10-12} Szymanski et al\textsuperscript{15} reviewed 4 stapedotomy techniques between 420 patients, reporting floating footplate, incus luxation or subluxation, and tympanic membrane perforation rates of 1.2%, 3.6%, and 2.1%, respectively. Our reported rates of floating footplates, incus subluxation, and tympanic membrane perforation rates were 4.0%, 2.0%, and 8.0%, respectively. Our nascent experience may account for the differences. An evolution in results should be expected, which is reinforced with Shea’s experience\textsuperscript{12,16} with stapedectomies, since he reported that 91% of subjects closed their air-bone gap to within 10 dB HL in 1961, but by 1998, this rate improved to 95.1%.

With regard to our audiologic outcomes, institutional differences dictate discussion. Two institutions do not have lasers, thus requiring drilling of the stapes superstructure to fracture the posterior crus and the footplate to create a fenestra, possibly accounting for the higher incidence of hearing loss, as noted in 2 subjects (>30 dB HL sensorineural hearing loss postoperatively). Moreover, losing depth perception with the endoscope may pose a risk to the inner ear when drilling to create the fenestra, making the laser the ideal instrument for endoscopic stapedotomy. In addition, increased resident autonomy at South American centers may also account for different outcomes. Although we recognize the reported results are significantly underpowered to make any comparisons between techniques and demonstrate no significant differences (Table 2), future studies regarding implementation of the laser compared with the drill in both microscopic and endoscopic stapes procedures is warranted.

Endoscopic limitations and advantages are better illustrated in several subjects who were excluded from analysis. Both subjects who required microscopic conversion highlighted 2 commonly reported limitations of endoscopic ear surgery: lack of 2-handed surgery and loss of binocular vision. In contrast, a revision stapedectomy highlighted significant visualization advantages the endoscope offers. With the subject having undergone a stapedectomy 8 years prior and maintaining a persistent maximal conductive hearing loss, during the revision case, the endoscope allowed precise appreciation of a soft footplate and a wire loop that was barely touching a presumed vein graft. This prosthesis was easily removed without concerns of traumatizing the vestibule.

Most studies reporting outcomes following endoscopic stapes surgery have demonstrated the safety and comparable outcomes of endoscopic stapes surgery with traditional microscopic stapes surgery. Reported added advantages with endoscopic visualization include cost-effectiveness,\textsuperscript{14} enhanced ability to teach,\textsuperscript{17} improved access to unfavorable external or middle ear anatomy,\textsuperscript{18} ability to operate on those patients with short necks or cervical osteoarthritis precluding neck movement,\textsuperscript{19} and in those patients in whom the taste of food significantly contributes to their quality of life.\textsuperscript{18} Nonetheless, in addition to the known disadvantages of endoscopic middle ear surgery, including 1-handed surgical technique, loss of binocular vision and depth perception, and need for additional training, the current work, along with Migirov et al,\textsuperscript{18} noted greater difficulty and thus increased need for scutum removal with right-handed surgeons in left-sided ears, and vice versa, due to scutum anatomy preventing prosthesis placement despite adequate visualization with an endoscope. It was also noted that the chorda tympani nerve can quickly dry out from the close proximity of the light source, even despite setting the light intensity to 60%.

Patient-derived outcomes were not assessed in the current study, but Kojima et al\textsuperscript{17} previously compared the outcomes of 15 subjects who underwent full endoscopic stapes surgery for either otosclerosis or congenital stapedial fixation with a control group of 35 subjects who underwent traditional microscopic stapes surgery. Noting that Japanese patients tend to have narrow and curved external auditory canals, requiring either posterior or anterior auricular incisions to perform stapes surgery, they also assessed the severity of postoperative pain.\textsuperscript{17} They reported that 14 subjects who underwent endoscopic surgery rated the severity as “almost no pain.” In 4 subjects who underwent bilateral surgeries, one ear with endoscopes and the other with a microscope, all reported no pain following endoscopic surgery, while all microscopic patients had irritating pain 2 to 3 days following surgery.\textsuperscript{17}

The present work represents the largest collection of endoscopic stapes surgeries, the first from a multi-institutional perspective, which significantly expands the literature of endoscopic stapes surgery experience and outcomes. It also provides the first comparison in audiologic outcomes using 3 different endoscopic stapes surgery techniques, favoring endoscopic laser stapedotomies and stapedectomies over drilled stapedotomies. However, limitations of the study include the retrospective analysis, the heterogeneity of multiple institutions, and lack of patient-centered outcomes.

**Conclusion**

This report from 4 tertiary care otologic referral centers is the largest reported experience of endoscopic stapes surgery to date. The results reinforce that endoscopic stapes surgery is an effective technique for managing otosclerosis with a median postoperative air-bone gap of 9.0 dB HL. Future studies prospectively assessing postoperative taste alterations, pain scores, and need for scutum removal are warranted.

**Acknowledgments**

The authors thank Luz Adrian Rincon, AuD, and Carla Valenzuela, MD, for help with the data collection.

**Author Contributions**

Jacob B. Hunter, data collection, data analysis, data interpretation, drafting of manuscript, revising manuscript, final approval of manuscript; M. Geraldine Zuniga, data collection, data analysis, drafting of manuscript, revising manuscript, final approval of manuscript; Janaina Leite, data collection, revising manuscript, final approval of manuscript; Daniel Killeen, data collection,
revising manuscript, final approval of manuscript; Cameron Wick, data collection, revising manuscript, final approval of manuscript; Julian Ramirez, data collection, revising manuscript, final approval of manuscript; Jose A. Rivas, data interpretation, revising manuscript, final approval of manuscript; Joao F. Nogueira, data interpretation, revising manuscript, final approval of manuscript; Brandon Isaacson, data interpretation, revising manuscript, final approval of manuscript; Alejandro Rivas, data interpretation, revising manuscript, final approval of manuscript.

Disclosures

Competing interests: Brandon Isaacson is a consultant for Advanced Bionics, Medtronic Midas Rex, Olympus, and Stryker and is on the Advanced Bionics Medical Advisory Board. Alejandro Rivas is a consultant for Med-El, Advanced Bionics, Cochlear, Grace Medical, Olympus, and Stryker.

Sponsorships: None.

Funding source: Grant support from NCATS/NIH UL1 TR000445 due to utilization of REDCap database for collection of patient data.

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