Variations in Stapes Surgery Cost within a Multihospital Network

Geoffrey C. Casazza, MD1, Andrew J. Thomas, MD2, Jesse Dewey3, Richard K. Gurgel, MD1, Clough Shelton, MD1, and Jeremy D. Meier, MD1,4

Abstract

Objective. To identify costs and operative times for stapedotomy and evaluate factors influencing cost variation.

Study Design. Case series with cost analysis.

Setting. Multihospital network.

Subjects and Methods. A multihospital network’s standardized activity-based accounting system was used to determine costs and operative times of all patients undergoing stapedotomy from 2013 to 2017. Subjects with additional procedures were excluded. Correlations between variable factors and cost were calculated by Spearman correlation coefficients. Audiometric and cost data were compared with a Mann-Whitney U test.

Results. The study cohort included 176 stapedotomies performed by 23 surgeons at 10 hospitals. Mean ± SD patient age was 44.3 ± 17.4 years. Mean cut-to-close time was 61.1 ± 23.55 minutes. Mean total encounter cost was $3542.14 ± $1258.78 (US dollars). Significant factors correlating with increased total encounter cost were surgical supply cost (r = 0.74, P < .0001) and cut-to-close time (r = 0.66, P < .0001). Laser utilization ($563.37 ± $407.41) was the highest-cost surgical supply, with the carbon dioxide laser being significantly more costly than the potassium titanyl phosphate (KTP; $852.60 vs $230.55, P < .001). Additionally, the carbon dioxide laser was associated with a significantly higher mean total encounter cost than the KTP laser ($4645.43 vs $2903.00, P < .001) and cases where no laser was used ($4645.43 vs $2932.47, P < .001). There was no difference in mean total encounter cost between the KTP laser and cases of no laser use ($2903.00 vs $2932.47, P = .75).

Conclusions. Significant cost variation exists in stapes surgery. Surgical supply cost, specifically laser use, may be associated with significantly increased costs. Reducing variation in costs while maintaining outcomes may improve health care value.

Keywords

otology, cost, stapedectomy, stapedotomy, otosclerosis

Variation in health care delivery occurs at all levels of the health care system—across providers and hospitals and among local and regional levels within the United States. Although certain degrees of variation are inevitable, some differences in health care delivery can be unwarranted and may occur when practice parameters differ for reasons that cannot be explained by the severity of illness, patient preferences, or the dictates of evidence-based medicine.1 This unwarranted variation may directly affect health care value, resulting in waste and potentially increased costs. Value-based health care, which better accounts for both the quality and the cost of care, is a major goal of health care reform efforts.2 Reimbursement models increasingly emphasize quality of care3—represented as a transition from a fee-for-service payment model to bundled or fixed reimbursement models.4 Bundling health care costs and fixed payment systems shift financial responsibility to facilities,5 incentivizing these institutions to minimize cost and improve (or maintain) quality, ultimately maximizing value.

Surgery for otosclerosis is one of the great successes in the history of otology. While numerous techniques have historically been described—including fenestration of the lateral canal and stapes mobilization—modern stapes surgery is defined by the stapedectomy and stapedotomy.6 Although there are some key differences in the procedure, the principle is the same: bypass the nonmobile stapes to improve the
conduction of sound to the inner ear. Surgery for otosclerosis generally results in improved and durable hearing outcomes. Understanding the cost variability in stapedotomy surgery is important to maximize value for patients.

Intermountain Healthcare (Murray, Utah) is a nonprofit integrated health care system that includes 22 hospitals across the Intermountain West. These hospitals range from tertiary care referral centers to community and small rural hospitals. Physicians who work within this system are a heterogeneous group that includes hospital-employed physicians, private physician groups who contract with Intermountain Healthcare, and academic physicians who also see patients in the network. Intermountain Healthcare maintains an Enterprise Data Warehouse (EDW), a comprehensive database containing administrative, financial, and clinical information. The financial data within the EDW are beneficial as hospital costs, not simply charges, are recorded. Charge data depend on payment agreements between hospitals and third-party payers without a correlation to the actual cost. Alternatively, cost data represent a more accurate cost assessment of the resources that were actually utilized. We previously used this database to evaluate variation in adenotonsillectomy, tympanostomy tubes placement, septoplasty, and, recently, tympanoplasty costs among hospitals and surgeons within the Intermountain Healthcare system. The purpose of this study is to identify the major expenses for stapedotomy in a multihospital network and to delineate areas of cost variation among surgeons.

Methods

This study was approved by the Institutional Review Board at Intermountain Healthcare (No. 1040488). The Intermountain Healthcare EDW was used to identify patients who underwent stapedotomy without additional procedures between January 2, 2008, and August 31, 2017. The Intermountain Healthcare EDW is a unique resource, as it contains information on the true costs of the resources used, as opposed to the charges billed to payers, and it has been successfully used in studies of procedural value.

Inclusion criteria were patients of all ages who underwent stapedotomy, as determined by the presence of Current Procedural Terminology codes and the costs for the operating room and accounted for by a per-minute basis in the operating room. However, laser operators are not specifically included in the total encounter cost.

Patients with other procedures performed, as determined by the presence of Current Procedural Terminology codes for other procedures, were excluded to limit the analysis to stapedotomy without concurrent procedures. Only procedures performed in hospital operating rooms were included in the analysis. Procedures performed at ambulatory surgical centers were excluded due to variable cost reporting within these facilities. Available pre- and postoperative audiologic data—4-frequency (500, 1000, 2000, and 3000 Hz) pure tone average (PTA) and word recognition score (WRS)—were collected from the medical record and reported per standardized reporting guidelines.

The acquired patient data were securely stored in a deidentified and password-protected file and then imported to commercially available statistical software for analysis (XLSTAT, version 21.1.1; Addinsoft Inc, Paris, France). Spearman correlation coefficients (r) were used to evaluate bivariate correlations between the total encounter cost and other variables. Total encounter costs, cut-to-close time, and audiologic data were compared on the basis of surgical supplies with a Mann-Whitney U test. All providers or hospitals with single cases were excluded for statistical comparison; P > .05 was used for a threshold of statistical significance for all comparisons.

Results

The cohort included 176 patients who underwent stapedotomy surgery (176 ears) performed by 23 surgeons at 10 hospitals. The mean ± SD patient age was 44.3 ± 17.4 years. Audiogram results were available for 66 patients (Figure 1). Pre- and postoperative audiometric data are reported in Table 1, and air-bone gap closure is reported in Figure 2.

There was a significant difference in pre- and postoperative air conduction PTA (49.9 vs 28.5 dB, respectively; P < .0001) but not between pre- and postoperative WRS (97.3% vs 96.9%, P = .2). Of the 66 patients with complete audiometric data, hearing improved in 65 patients (98.5%). One patient developed complete sensorineural hearing loss following stapedotomy. There were no other audiologic complications or facial nerve complications, and no deaths occurred in this series.

Mean total encounter cost was $3542.14 ± $1258.78 (US dollars; median, $3411.94; interquartile range [IQR], $1991.58). The mean surgical supply cost was $935.27 (median, $752.70; IQR, $559.19); mean anesthesia cost, $130.18 (median, $109.47; IQR, $66.75); mean pharmacy cost, $212.53 (median, $184.72; IQR, $146.49); and mean PACU cost, $220.52 (median, $180.34; IQR, $94.45). Operating room time was estimated by cut-to-close time. The mean cut-to-close time was 61.1 ± 23.55 minutes (median, 55; range, 21-156; IQR, 29).

There were differences in total encounter cost and cut-to-close time among surgeons. Mean total encounter cost among surgeons ranged from $2466.34 to $5453.03 (Figure 3), while mean cut-to-close time among surgeons ranged from 34.7 to 85.0 minutes (Figure 4).
Surgical supply cost \((r = 0.74, P < .0001)\) and cut-to-close time \((r = 0.66, P < .0001)\) were both strongly correlated with total encounter cost \((r = 0.74, P < .0001)\), while anesthesia cost \((r = 0.499, P < .0001)\), pharmacy cost \((r = 0.60, P < .0001)\), and PACU cost \((r = 0.021, P = .016)\) were moderate and weakly correlated with increasing total encounter cost (Figure 5).

The most commonly used surgical supplies were lasers, stapes prostheses, drill burs, beaver blades, hemostatic packing material, and facial nerve monitoring electrodes (Table 2).

![Figure 2](image-url)  
**Figure 2.** Closure of air-bone gap based on surgical technique.  
CO₂, carbon dioxide laser; KTP, potassium titanyl phosphate laser.

Surgical supply cost \((r = 0.74, P < .0001)\) and cut-to-close time \((r = 0.66, P < .0001)\) were both strongly correlated with total encounter cost \((r = 0.74, P < .0001)\), while anesthesia cost \((r = 0.499, P < .0001)\), pharmacy cost \((r = 0.60, P < .0001)\), and PACU cost \((r = 0.021, P = .016)\) were moderate and weakly correlated with increasing total encounter cost (Figure 5).

The most commonly used surgical supplies were lasers, stapes prostheses, drill burs, beaver blades, hemostatic packing material, and facial nerve monitoring electrodes (Table 2).

The laser was the most expensive surgical supply at a mean $563.37 (median, $660.00; IQR, $667.90) per use and was used in 143 (81.3%) cases; the laser was not used in 33 cases (18.8%). The potassium titanyl phosphate (KTP) laser was used in 79 cases (55.2%), whereas the carbon dioxide (CO₂) laser was used in 64 cases (45.8%). The mean cost of the KTP laser was $230.55 ± 236.14 (median, $127.10; IQR, $85.00), while the mean cost of the CO₂ laser was $852.60 ± 285.53 (median, $795.00; IQR, $344.50; \(P < .001\)).

There was a significant difference in the mean total encounter cost between the CO₂ laser and the KTP laser ($4645.43 vs $2903.00, respectively; \(P < .001\)) and a significant difference in the mean total encounter cost between...
the CO₂ laser and no laser use ($4645.43 vs $2932.47, \( P < .001 \)). There was not a significant difference in total encounter cost between the KTP laser and no laser use ($2903.00 vs $2932.47, \( P = .75 \)).

There was not a significant difference in the pre– or post–air conduction PTA between cases with the and without the laser (preoperative: 50.9 vs 41.3 dB, respectively, \( P = .05 \); postoperative: 27.8 vs 34.3 dB, \( P = .95 \)) and no significant difference in mean air-bone gap change (laser, 8.0-dB change; no laser, 7.25-dB change; \( P = .78 \)). Additionally, there was not a significant difference in the pre– or post–air conduction PTA between cases with the CO₂ laser and cases with KTP (pre–air conduction PTA: 49.64 vs 51.34 dB, \( P = .99 \); post–air conduction PTA: 25.58 vs 28.43 dB, \( P = .66 \)) and no significant difference in mean air-bone gap change (CO₂: 8.9- vs 7.7-dB change, \( P = .41 \)).

By excluding the 1 patient who developed complete sensorineural hearing loss following stapedectomy, the overall rate of air-bone gap closure to ≤5 dB was 39%; ≤10 dB, 67.8%; ≤15 dB, 89.8%; and ≤20 dB, 98.3%. The detailed
division by surgical technique (KTP vs CO2 vs no laser) is presented in Figure 2.

Discussion

This study evaluates the mean cost for stapedotomy across a multihospital network. This network represents a range of health care systems, including a major tertiary care center, an academic pediatric hospital, and urban, community, and rural hospitals across the Intermountain West. The critical advantage of this data analysis is the use of a standardized cost-based accounting system that does not rely on hospital charges. Charge data reflect variable payment agreements between hospitals and insurers and may not represent true costs accrued by the hospital. Although hospital charges are indirectly associated with resource utilization, these charges are often several magnitudes higher than the true hospital costs and may not accurately reflect cost from the hospital’s perspective. The database used in this study allows us to more accurately assess the actual resources used and avoid overestimating the costs.

Results of our analysis identified variation in stapedotomy cost among surgeons. Only procedures performed in hospital operating rooms or hospital outpatient surgery departments were included in our analysis. Due to the variable cost reporting at ambulatory surgical centers, we were unable to include these costs within our analysis. We would expect the lower costs at these outpatient centers, due to the emphasis on streamlined cost models and the generally uncomplicated cases, especially when compared with the hospitals that we examined. Future research is needed to substantiate this assumption.

In our analysis, stapedotomy was performed on 176 patients (176 ears) by 23 surgeons at 10 hospitals. This large number of included patients, surgeons, and hospitals created a heterogeneous population—including surgeons with academic affiliations, private-practice surgeons, fellowship-trained neurotologists, fellowship-trained otologists, and hospitals within urban, suburban, and rural designations. All of

<table>
<thead>
<tr>
<th>Table 2. Cost of Commonly Used Surgical Supplies.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost, US$ (Mean ± SD)</strong></td>
</tr>
<tr>
<td><strong>Laser</strong></td>
</tr>
<tr>
<td>CO2</td>
</tr>
<tr>
<td>KTP</td>
</tr>
<tr>
<td>Stapes prosthesis</td>
</tr>
<tr>
<td>Beaver blades</td>
</tr>
<tr>
<td>Hemostatic packing material</td>
</tr>
<tr>
<td>Skeeter and hand drill burs</td>
</tr>
<tr>
<td>Electrodes for facial nerve monitoring</td>
</tr>
</tbody>
</table>

Abbreviation: CO2, carbon dioxide; KTP, potassium titanyl phosphate.
this heterogeneity makes our findings applicable to a large range of practice environments. Although some regional and national differences are inevitable, we expect the cost variations identified to be applicable to other similar health systems.

Our analysis demonstrated that both surgical supply cost and cut-to-close time were the most correlated with increasing total encounter cost. It is important to note that surgeon and anesthesia professional fees are not included in our total encounter cost and were not included in our analysis—due to contract negotiations between Intermountain Healthcare and the employed and contracted physicians, we are not permitted to disclose the specific physician professional fees.

Surgical supply cost was most strongly correlated with an increasing total encounter cost—most likely a result of laser utilization. A laser was used in 143 of the 176 cases (81.3%) at a mean cost of $563.37 per use. Utilization of the CO2 laser was significantly more costly than the KTP laser or in those cases of no laser. Interestingly, there was no difference in the mean total encounter cost between those cases in which the KTP laser was utilized and those where no laser was used, suggesting that the CO2 laser is a major contributor to increasing cost in stapedotomy. This increased cost may be due to higher costs of the associated accessories for the CO2 laser—including the handpiece and fiber. Additionally, differences between the costs of the various lasers may be explained by contract negotiations by the various surgical suppliers contracted with our institution. Due to these contract negotiations, we are not permitted to disclose specific costs; however, these findings are likely generalizable to multiple institutions across the country.

Results of our audiometric data demonstrated no difference in hearing outcomes between cases utilizing the CO2 laser and the KTP laser or in those cases where no laser was utilized. Lasers have been commonplace in stapes surgery for decades18 and are a helpful adjunct to create the footplate fenestra and crimp the prostheses. Numerous studies have compared hearing outcomes of laser-assisted stapes surgery and traditional nonlaser fenestration techniques. While improved hearing outcomes have been associated with laser use, these results are limited by the small number of included patients and studies and likely variation in surgical technique.19-23 Subgroup analysis of the different laser types—CO2, KTP, erbium-YAG, and so on—has been limited due to a small number of studies. Results may suggest some benefit from the CO2 laser over the other commonly use lasers24,25 although similar results were not seen in our study. Given our findings and those within the literature, if the laser is to be used, consideration of KTP laser over the CO2 may offer a better value for patients. However, this may depend on surgeon preference and experience.

Laser safety has been demonstrated in numerous studies.18 Both the CO2 laser and the KTP laser are safe for use in the middle ear. The KTP laser has a short wavelength (532 nm) and is well absorbed by hemoglobin. The shorter wavelength of the KTP laser, however, is poorly absorbed by bone, leading to a higher penetration and theoretical risk of thermal damage to the inner ear structures26; this has not been seen clinically.25 In contrast, the CO2 laser utilizes a longer wavelength (10,600 nm; within the infrared spectrum), which is strongly absorbed by bone with minimal penetration into surrounding tissues. A major disadvantage of the CO2 laser is the invisible beam, which necessitates an aiming beam18; the duel beams could be theoretically misaligned, resulting in inadvertent damage to surrounding structures. Furthermore, because the CO2 laser utilizes a helium stream, there is a small risk of inner ear insufflation when the stapedotomy is performed. Although this is exceedingly rare, the resultant sensorineural hearing loss could be devastating.

Many surgeons are likely unaware of the costs associated with the care that they are providing. Very little formal training during medical school or residency is focused toward health care expenses. Findings of this analysis are not intended to propose that patient care and management decisions should be relegated to cost analysis equations; however, as health care practitioners, we must examine the costs associated with the care that we deliver, and we must understand why the cost variability exists. If a more expensive option is not achieving a better outcome to justify the more costly care, then finding an alternative that reduces the cost while maintaining equivalent outcomes is critical. Through an individual improvement process, overall resource utilization within the health care system can be reduced.

A primary strength of our study was the large number of patients included in the cohort. Additionally, a diverse population of private and hospital-employed physicians and hospitals providing care in urban and rural environments were included in our analysis, and we were not limited exclusively to academic physicians providing care at a tertiary care institution. Although data were entered prospectively into the institutional EDW, they were reviewed and analyzed retrospectively. This limited our analysis, as we must rely on accurate coding and presume that the accounting system was accurate in recording costs. Specific details regarding the procedure, including primary versus revision stapedotomy, were not available for analysis. Additionally, the complexity and numerous variables associated with stapedotomy, including surgeon background and experience, make a detailed analysis of the cost of stapedotomy challenging. However, significant factors effecting cost were identified in this study.

**Conclusions**

Variation exists in stapedotomy surgery. Use of lasers, especially the CO2 laser, was significantly associated with increased cost. While some costs are inevitable and associated with a set hospital fee or case complexity, some variables, including surgical supplies, do offer an opportunity for cost reduction and improved value for patients. Future research is needed to identify surgeon- and hospital-specific influencers of increased cost in otologic surgery and to understand how these variables affect patient outcomes.
Author Contributions

Geoffrey C. Casazza, study design and conceptualization, data collection, synthesis, and analysis, data interpretation, drafted and edited manuscript; Andrew J. Thomas, study design, data synthesis and analysis, drafted and edited manuscript; Jesse Dewey, data collection and synthesis, manuscript editing and revisions; Richard K. Gurgel, study design, data synthesis and analysis, manuscript editing and revision; Clough Shelton, study design, data synthesis and analysis, manuscript editing and revision; and Jeremy D. Meier, study design, data synthesis and analysis, data interpretation drafted, edited, and revised manuscript.

Disclosures

Competing interests: Richard K. Gurgel, Med-El—surgical advisory board; Advanced Bionics, Cochlear LLC—research support (institution); Clough Shelton, US Department of Defense—clinical trial; Jeremy D. Meier, Agency for Healthcare Research and Quality—R03 grant recipient; Ambu—consultant.

Sponsorships: None.

Funding source: None.

References