Does Surgical Volume and Complexity Affect Cost and Mortality in Otolaryngology–Head and Neck Surgery?

Andrew J. Redmann, MD¹,², Sonia N. Yuen, MD¹, Douglas VonAllmen, MD¹, Adam Rothstein, MHA, CCRP³, Alice Tang, MD¹, Joseph Breen, MD¹, and Ryan Collar, MD, MBA¹

Abstract

Objectives. (1) To evaluate whether admission volume and case complexity are associated with mortality rates and (2) evaluate whether admission volume and case complexity are associated with cost per admission.

Study Design. Retrospective case series.

Setting. Tertiary academic hospital.

Subjects and Methods. The Vizient database was queried for inpatient admissions between July 2015 and March 2017 to an otolaryngology–head and neck surgery service. Data collected included admission volume, length of stay, intensive care unit (ICU) status, complication rates, case mix index (CMI), and cost data. Regression analysis was performed to evaluate the relationship between cost, CMI, admission volume, and mortality rate.

Results. In total, 338 hospitals provided data for analysis. Mean hospital admission volume was 182 (range, 1-1284), and mean CMI was 1.69 (range, 0.66-6.0). A 1-point increase in hospital average CMI was associated with a 40% increase in odds for high mortality. Admission volume was associated with lower mortality, with 1% lower odds for each additional case. A 1-point increase in CMI produces a $4624 higher total cost per case (95% confidence interval, $4550-$4700), and for each additional case, total cost per case increased by $6.

Conclusion. For otolaryngology inpatient services at US academic medical centers, increasing admission volume is associated with decreased mortality rates, even after controlling for CMI and complication rates. Increasing CMI levels have an anticipated correlation with higher total costs per case, but admission volume is unexpectedly associated with a significant increase in average cost per case.

Keywords

quality, cost, value, Vizient, case mix index
Methods

Institutional review board approval was obtained from the University of Cincinnati’s Institutional Review Board prior to project initiation. Data were abstracted from the Vizient Clinical Data Base/Resource Manager. Vizient (Irving, Texas) is a claims database used extensively among health system operational managers that comprises approximately 97% of academic medical centers in the United States, as well as a smaller mix of nonacademic hospitals. Vizient includes key clinical quality and cost indicators, including mortality rates, CMI, inpatient safety indicator (PSI) events as defined by the Agency for Healthcare Research and Quality (AHRQ), observed vs expected length of stay (LOS), 30-day unplanned readmission rates, and cost data, including insurance charges and total patient costs. Case volume is also available at a hospital level. Total cost was defined as the hospital’s direct costs to deliver patient care, as well as its indirect costs (ie, administrative and capital). Direct costs are those that can be completely attributed to the delivery of care, such as labor and materials. Vizient data have been validated for inpatient performance in other specialties, including neurosurgery, general surgery, and transplant surgery, and also have been used in otolaryngology, making it an appropriate database to answer our research questions.

We used the Vizient Clinical Data Base/Resource Manager to review all patients >18 years old admitted primarily to an otolaryngology–head and neck surgery service for any reason (surgical or nonsurgical) between July 2015 and March 2017. Inclusion criteria included all patients admitted to an otolaryngology service at a hospital included in the Vizient database, as defined by the primary admitting surgeon listing his or her specialty as otolaryngologist. Exclusion criteria included admission to a different service (most pertinent, patients admitted to the neurosurgery service after joint neurosurgery/otolaryngology skull base procedures and free tissue transfer patients admitted to plastic surgery [ie, general surgery] were not included in our analysis) and patients undergoing outpatient otolaryngology procedures. Patients undergoing tracheostomy alone for respiratory failure who were not primarily on an otolaryngology service were excluded. Patient files with incomplete cost or quality data in the Vizient database were also excluded. We evaluated 3 months of admission data at our own institution to determine a correlation rate between the electronic medical record (EMR) and the Vizient database to evaluate the degree of accuracy within the database.

Linear and logistic regression analyses were performed to evaluate the relationships between total cost, direct cost, quality metrics, admission volume, and complexity. All analysis was performed using PSPP statistical software (Boston, Massachusetts). Two-tailed t test was used to compare continuous variables between groups. The Pearson χ² test was used to compare categorical variables between groups. Univariate logistic (for mortality) and linear (for cost) regression was used to examine hospital-level data with respect to quality, cost, CMI, and admission volume. Variables significant at the α < .05 level were included in a multivariate logistic regression model to establish an odds ratio (OR) for mortality, with a cutoff of 1 standard deviation beyond the mean national mortality rate being defined as a high mortality for the sake of our analysis. A multivariate linear regression model was similarly performed to determine a coefficient for the impact of variables significant on univariate analysis on total cost. All statistics were 2-tailed and considered statistically significant if P < .05.

Results

During the 20-month study period, 338 hospitals provided data to the Vizient database and were analyzed. We determined a concordance rate of 98% between the EMR and the Vizient database for the variables evaluated in this study within our institution. Demographics are given in Table 1.

Table 1. Hospital Demographics.

<table>
<thead>
<tr>
<th>Hospital Characteristics (N = 338)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cases, mean (range)</td>
<td>182 (1-1284)</td>
</tr>
<tr>
<td>Case mix index, mean (range)</td>
<td>1.69 (0.66-6.0)</td>
</tr>
<tr>
<td>Quality factors by hospital</td>
<td></td>
</tr>
<tr>
<td>Observed length of stay, mean (range)</td>
<td>4.6 (1-14.5)</td>
</tr>
<tr>
<td>Expected length of stay, mean (range)</td>
<td>4.6 (1-9.7)</td>
</tr>
<tr>
<td>Cases going to intensive care unit, % (range)</td>
<td>21.4 (0-66)</td>
</tr>
<tr>
<td>Cases with complications, % (range)</td>
<td>3 (0-50)</td>
</tr>
<tr>
<td>Observed death rate, mean (range), %</td>
<td>1.1 (0-16.7)</td>
</tr>
<tr>
<td>Expected death rate, mean (range), %</td>
<td>1.1 (0.2-1.4)</td>
</tr>
<tr>
<td>Cost data, mean (range)</td>
<td></td>
</tr>
<tr>
<td>Observed direct costs</td>
<td>7345 (825-24538)</td>
</tr>
<tr>
<td>Observed total costs</td>
<td>13327 (1422-52582)</td>
</tr>
<tr>
<td>Expected direct costs</td>
<td>8487 (3377-17878)</td>
</tr>
<tr>
<td>Direct cost index (observed/expected direct cost)</td>
<td>0.83 (0.14-3.17)</td>
</tr>
</tbody>
</table>

The mean number of cases admitted at each hospital was 182, with a wide range seen in the study group (1-1284 cases). The complexity of each hospital as measured by CMI varied widely, from a low of 0.66 to a high of 6.0. Quality factors widely varied between hospitals in the database. In particular, the mean observed mortality rate for otolaryngology services was 1.1% (range, 0.2%-16.7%). A high mortality rate for an otolaryngology service was defined as 3%, as this was 1 standard deviation beyond the mean. The mean average total cost in the analysis was $13,321, but there was a large amount of heterogeneity seen (range, $1422-$52,582).

Logistic regression was performed to evaluate the influence of admission volume and complexity on mortality rates. These results are shown in Table 2. Increasing complexity, as illustrated by CMI, was associated with a 1.4 (95% confidence interval [CI], 1.32-1.42) odds of high mortality. Conversely, as case number increased, it was...
associated with a 1% overall decrease in odds of high mortality. These relationships persisted after controlling for complication rate. Figure 1 illustrates this in graphical form.

Linear regression was performed to evaluate the same variables’ impact on total cost and direct cost. Table 3 shows the results of this analysis. As CMI rises by 1 point, there is an additional total cost of $4,624 (95% CI, $4,550–$4,700). In addition, an increase of length of stay by 1 day increases total cost by $1,608 (95% CI, $1,587–$1,629). Finally, for each additional case a hospital admits, there is an additional total cost of $6 (95% CI, $5.8–$6.1). When identical analysis is performed for direct cost (taking out indirect costs), a 1-point increase in CMI is associated with an increased cost of $2,902 (95% CI, $2,165–$3,639), an increase in length of stay by 1 day is associated with an increased cost of $921 (95% CI, $694–$1,148), and an additional case admitted leads to an increased cost of $5 (95% CI, $3.6–$6.0). Figures 2 and 3 illustrate these data in graphical form.

**Discussion**

This report used data from a large national database to analyze institution-level otolaryngology–head and neck surgery data on mortality, patient complexity, admission volume, and total and direct costs. We found that within US academic medical centers, inpatient case volume and patient complexity have an important impact on value.

Specifically, the analysis demonstrates higher inpatient otolaryngology admission volume is associated with lower mortality while controlling for case complexity, in keeping with findings across other surgical disciplines. The analysis further suggests that higher inpatient otolaryngology case volume is actually correlated with higher total and direct costs per case, a counterintuitive finding when considering the typical impact of economies of scale.

Previous work on this topic within otolaryngology has been limited to interactions between cost and quality. In a large administrative database study, Trzeciak et al found hospitals with a higher quality ranking (as defined by hospital “star” rankings for patient experience) had a lower overall total cost. A similar position is advanced by Britt et al, who found that in total laryngectomy patients, higher quality care was associated with lower total costs.

In addition, admission volume has a high CMI, primarily due to the complexity of head and neck oncology patients and high complexity values assigned to tracheostomy patients. Intuitively, otolaryngology patients with a high CMI also have high rates of 30-day readmission rates and high rates of postoperative complications, all of which increase total costs. Patients with high CMI may also have increased costs inherent to their disease process, regardless of interventions performed. Thus, when considering the association of volume on a provider systems value proposition, one must consider the impact of complexity of CMI.

We posit that admission volume may play a role in the interaction of total cost and quality in otolaryngology (Figure 4). The nonotolaryngology literature suggests that increased case volume improves outcomes and may decrease total costs, even in complex patients. Our data agree that increased admission volume is associated with lower mortality rates but also suggest that increased admission volume is associated with increased total and direct cost per case. This is at odds with the principle of economies of scale leading to a lower cost per unit with increasing volume.

One explanation is that higher volume academic centers almost universally are teaching hospitals with residents assisting in the care of patients, which has previously been suggested to increase operative time and costs. Academic hospitals are also more likely to be tertiary referral centers, thus caring for sicker patients than community hospitals. In addition, it may be that prominent hospitals able to increase capital expenditures and accept spending on diverse and top-quality surgical materials attract surgeons, build reputation, and ultimately acquire more patients. More succinctly, investing in the surgical product may ultimately drive higher volume, particularly in a marketplace where the user (ie, patient) is not typically the buyer (ie, carrier companies and self-insured employers).

**Table 2. Factors Associated with Observed Death Rates on Logistic Regression.**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>P Value</th>
<th>Multivariate OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case mix index</td>
<td>.007</td>
<td>1.4 (1.32 to 1.42)</td>
</tr>
<tr>
<td>Admission volume</td>
<td>.003</td>
<td>–.01 (–.01 to –.01)</td>
</tr>
<tr>
<td>Complication rate</td>
<td>.06</td>
<td>NS</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; NS, not significant; OR, odds ratio.

**Figure 1. Admission volume vs mortality rate (%).**
Strengths of this study include utilization of a validated database and the ability to use similar methodology to study both other specialties and institutions. Limitations of this study include those inherent to large administrative databases. There is a risk of incorrect coding within the Vizient database, although we attempted to assess for this by performing a dedicated chart review at our institution to ensure adequate data quality. There is also the risk of bias implicitly built into the Vizient data manager, as the program defines length of stay based on yearly national norms but does not have a standard definition of excess length of stay across years, instead relying on standard deviations within each year. In addition, while our study was designed to look at all otolaryngology inpatients instead of a specific subset, otolaryngology inpatient populations at academic medical centers are invariably weighted toward patients with head and neck cancer and patients with laryngotracheal stenosis, both of which have a higher degree of complexity than the general otolaryngology population. Also of note, our study looks at all patients admitted to an otolaryngology service, including those who did not undergo surgery, and so includes those who were readmitted after a surgical procedure. In addition, our study focused primarily (although not exclusively) on US academic medical centers, and our findings may not be generalizable to all hospitals. Finally, we chose to focus on mortality rate as a quality indicator due to its simplicity and inclusion in our database, but other factors such as patient experience and complication rates also should affect quality and must be taken into consideration when fully determining factors that influence value in health care.

Future avenues of research include exploring performance variability across service lines locally and across peer institutions nationally. Evaluation of how high-volume centers for complex procedures (microvascular free tissue transfer, laryngotracheal reconstruction, and skull base procedures in particular) perform on quality metrics compared with low-volume centers would particularly be worthy of research. The underlying cause of the relationship between

### Table 3. Factors Associated with Mean Total Cost on Linear Regression.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>P Value</th>
<th>Total Cost Multivariate OR (95% CI)</th>
<th>Direct Cost Multivariate OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case mix index</td>
<td>.001</td>
<td>4624 (4550-4700)</td>
<td>2902 (2165-3639)</td>
</tr>
<tr>
<td>Admission volume</td>
<td>.001</td>
<td>6 (5.8-6.1)</td>
<td>5 (3.6-6.0)</td>
</tr>
<tr>
<td>Complication rate</td>
<td>.135</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Mean LOS</td>
<td>.001</td>
<td>1608 (1587-1629)</td>
<td>921 (694-1148)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; LOS, length of stay; NS, not significant; OR, odds ratio.

### Figures

- **Figure 2.** Admission volume vs. mean total cost.
- **Figure 3.** Case mix index vs mean total cost.
- **Figure 4.** Value proposition of health care systems otolaryngology–head and neck surgery service lines.
volume and cost also remains unknown and is also worthy of future study. In addition, it would be beneficial to understand if factors such as local competition, density of specialty providers per capita in a region, insurance status, and quality improvement initiatives influence cost, quality, and complexity in otolaryngology.

Conclusion

Our data suggest that for patients admitted to an otolaryngology service at US academic medical centers, increasing admission volume is associated with decreased mortality rates, even after controlling for complexity (CMI) and complication rates. In addition, admission volume has a small but significant correlation with increased total costs. Finally, as complexity and length of stay rise, total costs increase, as does mortality rate.

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Author Contributions

Andrew J. Redmann, conception and design of work, acquisition, analysis and interpretation of data, drafting and critical revision of work, final approval of version, agrees to be accountable for all aspects of work; Sonia N. Yuen, analysis and interpretation of data, drafting of work, final approval of version, agrees to be accountable for all aspects of work; Douglas VonAllmen, analysis and interpretation of data, critical revision of work, final approval of version, agrees to be accountable for all aspects of work; Adam Rothstein, acquisition, analysis and interpretation of data, critical revision of work, final approval of version, agrees to be accountable for all aspects of work; Alice Tang, conception and design of work, analysis and interpretation of data, critical revision of work, final approval of version, agrees to be accountable for all aspects of work; Joseph Breen, conception and design of work, analysis and interpretation of data, critical revision of work, final approval of version, agrees to be accountable for all aspects of work; Ryan Collar, conception and design of work, analysis and interpretation of data, drafting and critical revision of work, final approval of version, agrees to be accountable for all aspects of work.

Disclosures

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References


