National Trends in Vestibular Schwannoma Surgery: Influence of Patient Characteristics on Outcomes

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Abstract

Objective. To characterize current vestibular schwannoma (VS) surgery outcomes with a nationwide database and identify factors associated with increased complications and prolonged hospital course.

Study Design. Retrospective review utilizing the University HealthSystem Consortium national inpatient database.

Setting. US academic health centers.

Subjects and Methods. Data from patients undergoing VS surgery were analyzed over a 3-year time span (October 2012 to September 2015). Surgical outcomes, such as length of stay (LOS), complications, and mortality, were analyzed on the basis of race, sex, age, and comorbidities during the 30-day postoperative period.

Results. A total of 3697 VS surgical cases were identified. The overall mortality rate was 0.38%, and the overall complication rate was 5.3%. Advanced age significantly affected intensive care unit LOS, mortality, and complications ($P = .04$). Comorbidities, including hypertension, obesity, and depression, also significantly increased complication rates ($P = .02$). Sixty-eight patients (1.8%) had a history of irradiation, and they had a significantly increased LOS ($P = .03$).

Conclusion. Modern VS surgery has a low mortality rate and a relatively low rate of complications. Several factors contribute to high complication rates, including age and comorbidities. These data will help providers in counseling patients on which treatment course might be best suited for them.

Keywords

vestibular schwannoma, quality improvement, facial nerve, postoperative complications

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measures of medical care from its member organizations, which can be accessed online via the UHC Clinical Database/Resource Manager (CDB/RM). The data accessed via the CDB/RM are de-identified personal health information; therefore, our Institutional Review Board deemed this study not human subjects research.

The UHC CDB/RM was accessed in spring 2016 for inpatient discharges that occurred from October 2012 to September 2015 (36 months). This period included when records were first available within the database to when the discontinuation of International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) occurred. Patients undergoing excision of acoustic neuroma were identified by the corresponding ICD-9-CM procedure code V04.01. We filtered these results excluding any diagnosis of neurofibromatosis (ICD-9-CM diagnostic codes 2377, 2377.0-2377.2), as these patients typically have additional symptomatology and comorbidities that are outside the scope of this study.

Complications are defined by criteria set by reportable complication metrics developed by the Agency for Healthcare Research and Quality, UHC, or Centers for Medicare and Medicaid Services. Complication rates were determined by the number of cases with ≥1 complications. Comorbidities are assigned to patients based on ICD-9-CM diagnostic codes present on admission.°

A select number of diagnoses of particular interest to VS surgery were selected for analysis after being identified through ICD-9-CM diagnosis codes: facial nerve weakness (351-351.9, 781.94), history of irradiation (v15.3), history of coronary angioplasty (v45.82), urinary tract infection (599.0), intracerebrar hemorrhage (431), unilateral vocal cord paralysis (478.31, 478.32), CSFotorrhea and CSF rhinorrhea (388.61, 349.81), subdural hemorrhage (432.1), and dysphagia (780.20-780.22, 780.29). Other diagnostic ICD-9-CM codes of dizziness, imbalance, or headaches were thought to be common following surgery and would not be considered at complication. Also, the ICD-9-CM coding system does not provide specific procedure codes for the various approaches used in VS surgery. Other procedures codes, such lumbar drains, are not included in the ICD-9-CM coding system.

Means and standard deviations were calculated for length of stay (LOS), while means were calculated for intensive care unit (ICU) LOS. We were unable to perform standard deviations of ICU LOSs because the duration of ICU admission was not recorded in the database. Readmission rates were calculated as a percentage of patients readmitted to the hospital within 30 days after discharge as well as any complications that occurred during this same period. Long-term data and subsequent follow-up visits are not permitted with the use of this database.

**Statistical Analysis**

All analyses and graphs were performed with Sigma Plot 12.5 (Systat Software, Inc, San Jose, California) and MedCalc 16.4.3 (MedCalc Software bvba, Ostend, Belgium).

Comorbidities and demographic variables, such as age, race, and sex, were evaluated by means of summary statistics. Continuous variables were summarized by mean ± SD. Nominal variables were summarized by frequency and percentage. All continuous variables were tested for normal distribution, as determined by the Kolmogorov-Smirnov test. Comparisons of outcomes (nominal variables) were performed with Fisher’s exact or chi-square test. For continuous variables, comparisons were made with an independent t test or a Wilcoxon rank sum test. A 1-way analysis of variance was also used, as followed by a Tukey post hoc comparison test. Finally, a Spearman rank correlation model was used to determine associations among variables, including LOS, ICU LOS, complication rate, and readmission rate. A P value < .05 was considered indicative of statistical significance. The correlation coefficient (r value; range, −1.0 to 1.0) is a value that determines the relationship between 2 variables. Positive values that approach 1.0 signify a positive correlation, and as values approach −1.0, the variables have an inverse correlation. A value of 0 signifies that the 2 variables are not related. $R^2$ is equal to the percentage of variation between the variables.

Patients were categorized into 6 age groups (<18, 18-30, 31-50, 51-64, 65-74, >74 years). Statistical analysis for comorbidities, diagnoses, and complications was performed to determine if specific complications tended to affect a particular age group.

**Results**

We identified 3697 patients whose VSs were treated with surgical excision. The mean total hospital LOS was 4.9 ± 5.0 days. There were 2647 (71.6%) patients admitted to the ICU during their stay, who had a mean ICU LOS of 2.0 days (Table 1). The complication rate for all patients was 5.3% (n = 195), and the overall mortality rate was 0.38% (n = 14). During their initial hospital stay, 2.8% (n = 74) of patients required readmission to the ICU after previously being on the floor. Of the 195 patients who had a complication, 15.4% (n = 30) required readmission to the ICU. There were 229 patients (6.24%) readmitted within 30 days after discharge, with 73% of these (n = 167) within 14 days and 43% (n = 98) within 7 days.

**Demographics**

We found a greater number of female patients (n = 2052) than male patients (n = 1645) undergoing surgery (ratio, 1.25:1.0). Both groups had a similar LOS; however, males had a significantly increased rate of complications (6.32% vs 4.43%, P = .01) and readmission (7.13% vs 5.53%, P = .05).

The mean age was 50.5 ± 13.6 years, with 75.8% of patients aged 31 to 64 years. Increasing age was significantly and very highly correlated with ICU LOS ($r = 0.83$, $P = .04$), complication rates ($r = 1.00$, $P < .01$), mortality rates ($r = 0.83$, $P = .04$). However, age was significantly and negatively correlated with readmission rates ($r = 1.00$, $P = .04$).
Compared with Caucasians, African Americans (6.58 vs 4.64 days, \( P = .01 \)) and Asians (5.59 vs 4.64 days, \( P = .01 \)) had a significantly longer LOS. Adjusting for population with 2015 US census data, surgical case incidence among Caucasians was the highest, at 3.33:1 versus African Americans and 1.56:1 versus Asians. African Americans had the longest mean ICU stay (3.0 days), followed by Asians (2.2 days) and Caucasians (1.9 days). There were significant differences among racial groups for complication rate (\( P = .04 \)): African Americans had the highest rate of complications (8.8%), followed by Asians (4.8%) and Caucasians (4.7%). In terms of comorbidities, African Americans had a significantly higher rate of all comorbidities except depression and hypothyroidism, and Caucasians had significantly higher rates of depression (vs African Americans) and hypothyroidism (vs African Americans and Asians; Table 2). Asians had a significantly higher mortality rate (2.0%, \( n = 3, P = .04 \)) and a significantly higher rate of readmissions to the ICU (6.7%, \( P = .0040 \))—nearly 3 times that of African Americans and Caucasians. Furthermore, there was no significant difference in overall hospital readmissions (\( P = .42 \)) among Caucasians (6.4%), African Americans (6.9%), and Asians (6.0%). Eleven percent (\( n = 406 \)) of patients were excluded from the analysis on race only because the racial data were classified as “other,” they declined to identify, or data were unavailable.

### Race

Compared with Caucasians, African Americans (6.58 vs 4.64 days, \( P < .01 \)) and Asians (5.59 vs 4.64 days, \( P = .01 \)) had a significantly longer LOS. Adjusting for population with 2015 US census data, surgical case incidence among Caucasians was the highest, at 3.33:1 versus African Americans and 1.56:1 versus Asians. African Americans had the longest mean ICU stay (3.0 days), followed by Asians (2.2 days) and Caucasians (1.9 days). There were significant differences among racial groups for complication rate (\( P = .04 \)): African Americans had the highest rate of complications (8.8%), followed by Asians (4.8%) and Caucasians (4.7%). In terms of comorbidities, African Americans had a significantly higher rate of all comorbidities except depression and hypothyroidism, and Caucasians had significantly higher rates of depression (vs African Americans) and hypothyroidism (vs African Americans and Asians; Table 2). Asians had a significantly higher mortality rate (2.0%, \( n = 3, P = .04 \)) and a significantly higher rate of readmissions to the ICU (6.7%, \( P = .0040 \))—nearly 3 times that of African Americans and Caucasians. Furthermore, there was no significant difference in overall hospital readmissions (\( P = .42 \)) among Caucasians (6.4%), African Americans (6.9%), and Asians (6.0%). Eleven percent (\( n = 406 \)) of patients were excluded from the analysis on race only because the racial data were classified as “other,” they declined to identify, or data were unavailable.

### Comorbidities

Nearly all comorbidities were shown to significantly increase LOS, and several were found to increase complication rates, including hypertension, obesity, depression, anemia, diabetes with chronic complications, and congestive heart failure (Table 3). Congestive heart failure had the highest association with complications (odds ratio [OR] =

### Table 1. LOS, ICU LOS, Complications, Mortality, 30-Day Readmission, and Return to ICU for Patients by Demographic.a

<table>
<thead>
<tr>
<th>Age, y</th>
<th>Cases</th>
<th>OS, d Mean</th>
<th>SD</th>
<th>P Value</th>
<th>ICU LOS, d Mean</th>
<th>P Value</th>
<th>Complications Rate</th>
<th>Mortality Rate</th>
<th>30-d Readmission Rate</th>
<th>Return to ICU Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;18</td>
<td>39</td>
<td>4.7 3.3</td>
<td></td>
<td>.07b</td>
<td>1.6 .04c</td>
<td>0.0 0.00 &lt;.01d</td>
<td>0.0 0.04e</td>
<td>7.7 1.3 .02f</td>
<td>5.1 1.9 .001</td>
<td></td>
</tr>
<tr>
<td>18-30</td>
<td>316</td>
<td>4.7 3.2</td>
<td></td>
<td></td>
<td>2.0 3.8 0.7</td>
<td>0.63 1.8</td>
<td>6.3 1.0</td>
<td>2.1 0.6</td>
<td>5.4 2.1</td>
<td></td>
</tr>
<tr>
<td>31-50</td>
<td>1339</td>
<td>4.7 4.1</td>
<td></td>
<td></td>
<td>2.0 4.4 0.8</td>
<td>0.22 0.5</td>
<td>6.9 1.2</td>
<td>2.6 0.9</td>
<td>5.5 2.3</td>
<td></td>
</tr>
<tr>
<td>51-64</td>
<td>1465</td>
<td>5.0 5.6</td>
<td></td>
<td></td>
<td>2.0 5.9 1.2</td>
<td>0.27 0.6</td>
<td>6.1 1.0</td>
<td>2.1 0.6</td>
<td>5.4 2.1</td>
<td></td>
</tr>
<tr>
<td>65-74</td>
<td>437</td>
<td>5.3 5.7</td>
<td></td>
<td></td>
<td>2.1 6.9 1.4</td>
<td>0.69 2.1</td>
<td>4.3 0.7</td>
<td>2.7 1.0</td>
<td>5.1 1.3</td>
<td></td>
</tr>
<tr>
<td>&gt;74</td>
<td>99</td>
<td>6.6 7.8</td>
<td></td>
<td></td>
<td>2.5 8.1 1.6</td>
<td>2.02 6.2</td>
<td>5.1 0.8</td>
<td>8.1 3.2</td>
<td>5.5 2.8</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: AA, African American; LOS, length of stay; ICU, intensive care unit; OR, odds ratio.

\( ^{a} R \) values express goodness of fit for Spearman’s rank correlation when comparing age groups and given outcome.

\( ^{b} r = 0.77. \)

\( ^{c} r = 0.83. \)

\( ^{d} r = 0.96. \)

\( ^{e} r = 0.83. \)

\( ^{f} r = -0.89. \)

\( ^{g} P < .05, \) vs Caucasian group.

### Table 2. Prevalence of Comorbidities among Patients by Race.

<table>
<thead>
<tr>
<th>Comorbidity</th>
<th>AA</th>
<th>Asian</th>
<th>Caucasian</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertension</td>
<td>52</td>
<td>30a</td>
<td>34b</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Obesity</td>
<td>21</td>
<td>3a</td>
<td>14</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Chronic pulmonary disease</td>
<td>15</td>
<td>5a</td>
<td>11</td>
<td>.05</td>
</tr>
<tr>
<td>Diabetes without chronic complications</td>
<td>15</td>
<td>7a</td>
<td>6b</td>
<td>.05</td>
</tr>
<tr>
<td>Anemia</td>
<td>8</td>
<td>7</td>
<td>3b</td>
<td>.05</td>
</tr>
<tr>
<td>Depression</td>
<td>5</td>
<td>NA</td>
<td>10b</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Hypothyroidism</td>
<td>4</td>
<td>7a</td>
<td>10b</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Renal failure</td>
<td>3</td>
<td>NA</td>
<td>1a</td>
<td>.05</td>
</tr>
</tbody>
</table>

Abbreviations: AA, African American; NA, not applicable.

\( ^{a} P < .05, \) vs AA.

\( ^{b} P < .05, \) vs AA.

\( ^{c} P < .05, \) vs Caucasian group.

### Comorbidities

Nearly all comorbidities were shown to significantly increase LOS, and several were found to increase complication rates, including hypertension, obesity, depression, anemia, diabetes with chronic complications, and congestive heart failure (Table 3). Congestive heart failure had the highest association with complications (odds ratio [OR] =
Table 3. Patient Outcomes for Given Comorbidities.\(^a\)

<table>
<thead>
<tr>
<th>Comorbidity</th>
<th>Cases</th>
<th>LOS, d</th>
<th>Mean</th>
<th>SD</th>
<th>P Value</th>
<th>Complications</th>
<th>Mortality</th>
<th>Return to ICU</th>
<th>Value Rate</th>
<th>OR</th>
<th>P Value</th>
<th>Value Rate</th>
<th>OR</th>
<th>P Value</th>
<th>Value Rate</th>
<th>OR</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertension</td>
<td>1294</td>
<td>35.0</td>
<td>5.5</td>
<td>6.2</td>
<td>&lt;.01</td>
<td>2.3</td>
<td>7.6</td>
<td>1.9</td>
<td>&lt;.01</td>
<td>0.5</td>
<td>1.9</td>
<td>.37</td>
<td>3.7</td>
<td>1.6</td>
<td>.03</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Obesity</td>
<td>484</td>
<td>13.1</td>
<td>5.2</td>
<td>5.2</td>
<td>&lt;.23</td>
<td>2.3</td>
<td>8.1</td>
<td>1.7</td>
<td>&lt;.01</td>
<td>0.2</td>
<td>0.5</td>
<td>&gt;.99</td>
<td>2.3</td>
<td>0.8</td>
<td>.51</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Chronic pulmonary disease</td>
<td>377</td>
<td>10.2</td>
<td>5.5</td>
<td>5.0</td>
<td>.03</td>
<td>2.2</td>
<td>4.8</td>
<td>0.9</td>
<td>.73</td>
<td>0.0</td>
<td>0.0</td>
<td>.39</td>
<td>4.2</td>
<td>1.6</td>
<td>.13</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Depression</td>
<td>343</td>
<td>9.3</td>
<td>5.5</td>
<td>4.6</td>
<td>.03</td>
<td>2.2</td>
<td>6.7</td>
<td>1.3</td>
<td>.02</td>
<td>0.6</td>
<td>1.6</td>
<td>.38</td>
<td>5.5</td>
<td>2.2</td>
<td>&lt;.01</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Diabetes without chronic complications</td>
<td>269</td>
<td>7.3</td>
<td>5.7</td>
<td>6.2</td>
<td>.01</td>
<td>2.3</td>
<td>5.9</td>
<td>1.1</td>
<td>.71</td>
<td>0.4</td>
<td>1.0</td>
<td>&gt;.99</td>
<td>5.2</td>
<td>2.0</td>
<td>.03</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Renal failure</td>
<td>43</td>
<td>1.2</td>
<td>6.6</td>
<td>5.2</td>
<td>&lt;.03</td>
<td>3.2</td>
<td>11.6</td>
<td>2.4</td>
<td>.07</td>
<td>4.7</td>
<td>14.8</td>
<td>.01</td>
<td>9.3</td>
<td>3.6</td>
<td>.04</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Diabetes with chronic complications</td>
<td>39</td>
<td>1.1</td>
<td>7.2</td>
<td>5.8</td>
<td>&lt;.01</td>
<td>3.0</td>
<td>20.5</td>
<td>4.8</td>
<td>&lt;.01</td>
<td>2.6</td>
<td>7.4</td>
<td>.14</td>
<td>2.6</td>
<td>0.9</td>
<td>&gt;.99</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Weight loss</td>
<td>33</td>
<td>0.9</td>
<td>11.3</td>
<td>9.1</td>
<td>&lt;.01</td>
<td>4.9</td>
<td>12.1</td>
<td>2.5</td>
<td>.09</td>
<td>6.1</td>
<td>19.6</td>
<td>&lt;.01</td>
<td>12.1</td>
<td>4.9</td>
<td>.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychoses</td>
<td>28</td>
<td>0.8</td>
<td>7.6</td>
<td>6.6</td>
<td>&lt;.01</td>
<td>2.7</td>
<td>3.6</td>
<td>0.7</td>
<td>&gt;.99</td>
<td>3.6</td>
<td>10.4</td>
<td>.10</td>
<td>3.6</td>
<td>1.3</td>
<td>.56</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Coagulopathy</td>
<td>26</td>
<td>0.7</td>
<td>7.3</td>
<td>6.0</td>
<td>.01</td>
<td>4.1</td>
<td>7.7</td>
<td>1.5</td>
<td>.65</td>
<td>0.0</td>
<td>0.0</td>
<td>&gt;.99</td>
<td>15.4</td>
<td>6.4</td>
<td>.01</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>23</td>
<td>0.6</td>
<td>7.5</td>
<td>5.3</td>
<td>.01</td>
<td>2.1</td>
<td>26.1</td>
<td>6.5</td>
<td>&lt;.01</td>
<td>4.3</td>
<td>12.8</td>
<td>.08</td>
<td>0.0</td>
<td>0.0</td>
<td>&gt;.99</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>3697</td>
<td>100</td>
<td>4.9</td>
<td>5.0</td>
<td></td>
<td>2.0</td>
<td>5.3</td>
<td></td>
<td></td>
<td>0.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: ICU, intensive care unit; LOS, length of stay; OR, odds ratio.

*Comorbidities are assigned to patients per International Classification of Disease, Ninth Revision, Clinical Modification diagnostic codes by Elixhauser Comorbidity software. Complications, mortality, and return to ICU were analyzed for statistical significance by comparing each group with patients negative for the respective comorbidity.

6.4), followed by diabetes with chronic complications (OR = 4.9). Only weight loss and renal failure were found to significantly increase mortality, with a 18.5- and 14.2-fold increase, respectively.

Complications. The top 6 complications, as defined according to UHC standards, are shown in Table 4. Complications are assigned to patients based on diagnostic codes, as stated in the Methods section. All analyzed complications significantly increased LOS, with a mean LOS >15 days. Except for postoperative infection, all were also associated with a significantly increased mortality rate of at least 35-fold. Stroke was the most common complication (n = 76, 2.06%) and was associated with a significantly increased LOS (15.3 ± 16.0 days) as well as the greatest increase in mortality rate among complications (13.2%, OR = 137.0).

Other Outcomes. Of the specific postoperative diagnoses of interest that are nearly all significantly increased LOS, and many significantly increased mortality. Note that some of these diagnoses fell under certain categories of UHC complications while others did not. We found that 34 patients (0.92%) developed postoperative unilateral vocal cord paralysis and 44 (1.19%) had a cerebrospinal fluid (CSF) leak during hospitalization. We identified 76 patients (2.03%) with postoperative CSF rhinorrhea or otorrhea indicative of a CSF leak during their initial hospitalization. There was no detectable difference in the occurrence of CSF rhinorrhea or otorrhea in obese patients (OR = 0.67, P = .26). Patients with a history of irradiation, most likely coded for previous stereotactic radiation therapy for their acoustic neuroma, had a significantly increased LOS (6.3 days, P = .03) but without any significant increase in complication rate (7.35% vs 5.52%, P = .41). These patients were also more likely to present with facial nerve symptoms (OR = 2.24, P = .01) but were no more likely to incur facial nerve weakness from surgery (OR = 0.88, P = .74). Overall, 9.7% of patients presented with facial nerve symptoms, and 12.7% incurred facial nerve weakness after surgery.

Discussion
This study is the first to utilize UHC data for outcomes related to VS surgery to decrease the potential for bias inherent to single-institution data. The UHC CDB/RM affords us the opportunity to analyze outcomes on a national level by incorporating data across most US academic medical centers. This enables us to eliminate differences by institution and region to gain a better understanding of modern morbidity and mortality rates as well as which patient factors affect outcomes. We are conducting additional UHC database studies to address the influence of institutional case volume and the associated outcomes and LOS.

In a meta-analysis of >32,870 patients undergoing VS surgery between 1968 and 2006, the mortality rate was 0.2%,\(^7\) while a more recent study of cases from 1994 to 2003 placed it at 0.5%.\(^12\) This is in line with the 3697 cases of VS excision that we analyzed, with a mortality rate of 0.38%. Intracranial hemorrhages and strokes accounted for the majority of deaths in our study. We found a 1.2% rate of intracranial hemorrhage, in line with recent literature reporting 0.8% to 0.9%.\(^13-16\)
We found weight loss, a comorbidity associated with advanced age and/or chronic illness, to be significantly associated with much poorer outcomes. This included a 2.3-fold increase in length of stay (LOS) and complications, a 4.3-fold increase in readmission to the ICU, and a 16-fold increase in mortality. Weight loss is nonspecific and may be the result of several factors, including comorbidities, malnutrition, and advancing age. Studies showed that weight loss is a main component of frailty, a significant risk factor for perioperative complications. Moreover, malnutrition was shown to lead to worse outcomes for other types of surgery. We also found that renal failure significantly increased mortality (12.3-fold). Renal failure had a 3.1-fold increase in mortality rate after coronary artery bypass surgery, including a 2.1-fold increase in stroke. The presence of other comorbidities, such as hypertension, diabetes, and congestive heart failure, are known to increase hospital complications, mortality, and LOS for various surgical procedures. In our study, we found that the presence of congestive heart failure had a 26.1% increased risk of having a complication. Interestingly, we found no significant difference in LOS among obese patients, whereas obesity has been associated with an increased LOS for lateral skull base surgery on analysis of the American College of Surgeons National Surgical Quality Improvement Program database. Obesity does not confer a risk to the patient in all situations, as it has been associated with improved or equal outcomes after stroke and, specifically, otologic procedures. As with any invasive procedure among patients with significant risk factors, preoperative medical optimization is advised with proper informed consent.

As more is learned about VS growth patterns and prognosis, patients are opting more for observation and stereotactic radiation. There is increasing evidence that many tumors are slow growing and stable or even regress and warrant observation. However, as our results and other studies demonstrate, the potential benefits of watching and waiting in the older population must be balanced against the increasing risks of having surgery at advanced age. Mean age at VS diagnosis has also increased significantly over the past several decades, from 49 years old in 1976 to 58 years old in 2008, but the size of the tumor at the time of diagnosis has decreased. Age was also correlated with mortality and ICU LOS. Age was associated with a higher prevalence of comorbidities. Our univariate analysis revealed a very strong correlation between age and complications (r = 0.96). However, this correlation does not eliminate confounding factors associated with advancing age that surely have an effect on risk of complications, such as most comorbidities. Age was also correlated with mortality (r = 0.69) and ICU LOS (r = 0.69). These data are useful in giving meaningful advice to patients on their risks.

### Table 4. Pre- and Postoperative Diagnoses and Complications.

<table>
<thead>
<tr>
<th>Cases</th>
<th>LOS, d</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>Mean</td>
</tr>
<tr>
<td>History of irradiation</td>
<td>68</td>
<td>1.84</td>
</tr>
<tr>
<td>History of coronary angioplasty</td>
<td>47</td>
<td>1.27</td>
</tr>
<tr>
<td>Dysphagia</td>
<td>113</td>
<td>3.06</td>
</tr>
<tr>
<td>CSF rhinorrhea</td>
<td>68</td>
<td>1.84</td>
</tr>
<tr>
<td>UTI</td>
<td>51</td>
<td>1.38</td>
</tr>
<tr>
<td>Intracerebral hemorrhage</td>
<td>44</td>
<td>1.19</td>
</tr>
<tr>
<td>Unilateral vocal cord paralysis</td>
<td>27</td>
<td>0.73</td>
</tr>
<tr>
<td>CSF otorrhea</td>
<td>18</td>
<td>0.49</td>
</tr>
<tr>
<td>Subdural hemorrhage</td>
<td>16</td>
<td>0.43</td>
</tr>
<tr>
<td>Stroke</td>
<td>76</td>
<td>2.06</td>
</tr>
<tr>
<td>Postoperative respiratory failure</td>
<td>50</td>
<td>1.35</td>
</tr>
<tr>
<td>Aspiration pneumonia</td>
<td>31</td>
<td>0.84</td>
</tr>
<tr>
<td>PE or DVT</td>
<td>29</td>
<td>0.78</td>
</tr>
<tr>
<td>Postoperative infection</td>
<td>9</td>
<td>0.24</td>
</tr>
<tr>
<td>Postoperative sepsis</td>
<td>7</td>
<td>0.19</td>
</tr>
<tr>
<td>Total</td>
<td>3697</td>
<td>100</td>
</tr>
</tbody>
</table>

Abbreviations: CSF, cerebrospinal fluid; DVT, deep vein thrombosis; ICU, intensive care unit; LOS, length of stay; OR, odds ratio; PE, pulmonary embolism; UTI, urinary tract infection.

*Complications as defined by the Agency for Healthcare Research and Quality, University Health Consortium, and Centers for Medicare and Medicaid Services (top 6 complications shown).
of surgery and how delaying surgery can lead to a potentially riskier surgery at a more advanced age. Unfortunately, due to the nature of the database, a multivariate analysis was unable to be performed to identify confounders. Interestingly, we found a correlation with younger age and readmission. We hypothesize that this could be due to a false reassurance of clinical appearance among younger patients during discharge and follow-up. We did find that the overall LOS was 4.9 days, but the standard deviation was 5 days. This means that there was considerable variability in the LOS across institutions. Factors associated with longer LOSs include advancing age and complications in the postoperative period.

African Americans had a higher complication rate than did other races in this study, which could follow from several factors. Studies of the SEER database (Surveillance, Epidemiology, and End Results) showed that African Americans and Asians typically have larger VS tumors at time of surgery,45,46 which are associated with a higher complication rate.47 However, a statewide study of general surgical complications among African American patients found that they were mostly due to an increased prevalence of comorbidities.48 While McClellan et al found higher mortality among African American patients undergoing VS surgery,14 we failed to find a significant difference with our study’s African American population, as none died.

During the hospitalization for VS surgery, we found a CSF leak rate of 2.6%; however, there are likely additional cases of CSF leaks in this study population that we were unable to identify due to the nonspecific nature of some ICD-9-CM diagnostic codes. Additionally, this database did not include CSF leaks that occurred after the initial hospitalization. Recent reported rates of CSF leak range from 0.8% to 10.6%.49-51 While spontaneous CSF leaks have been associated with obesity,52 we found no increase in postoperative CSF otorrhea or rhinorrhea in these patients.

In regard to facial nerve outcomes following VS surgery, we found that 12.7% of patients have facial nerve weakness following surgery but 9.7% of patients presented with facial nerve symptoms. Detailed information regarding the severity of facial nerve weakness prior to and after surgery is not available through the database. Unfortunately, specific information that is key to VS surgery, including tumor size, institution case volume, surgical approach, and hearing status, are not available through this database.

Another limitation of our study is that source data may be subject to inaccuracies, as discharge summaries are not coded by clinicians, although the acting physician must sign and verify these codes on the attestation sheet, which should help to minimize errors.53 We believe the data to be accurate, as there is evidence that information gathered from the UHC CDB/RM database is highly concordant with institutions’ medical records.54 We were also unable to perform multivariate regression analysis, as we were limited by the CDB/RM to summary data from searches of patient characteristics. However, univariate analyses remain helpful for identifying which factors may portend a worse outcome, which is invaluable for the surgeon consulting a patient. We were also unable to identify some complications specific to VS surgery, such as CSF leak and long-term facial nerve outcomes. Our study period ended with the implementation of ICD-10-CM, a more comprehensive and thorough release of diagnostic codes that may provide more detailed data for future analysis (eg, by type of surgical approach). Other limitations include specific information that is key to VS surgery, such as tumor size, surgical approach, pre- and postoperative facial nerve function, and team- versus individual surgeon-specific data. Last, the study involved only the 30-day postoperative period, including all complications and readmissions, which precludes long-term data.

Conclusion
The UHC database is a valuable tool to investigate outcomes in relatively rare diseases such as VS. In doing so, we found an extremely low mortality rate for modern VS surgery. We identified numerous factors that are associated with increased postoperative morbidity and mortality that are valuable in determining which treatment course might be best suited for a patient. This decision may be influenced by information pertaining to the risks for the patient’s given demographic and health status.

Author Contributions
Jonathan L. Hatch, manuscript preparation, data analysis; Michael J. Bauschard, manuscript preparation, data analysis, study design; Shaun A. Nguyen, manuscript preparation, data analysis; Paul R. Lambert, manuscript preparation, data interpretation, study design; Ted A. Meyer, manuscript preparation, data interpretation, study design; Theodore R. McRackan, manuscript preparation, data collection and analysis.

Disclosures
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