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

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Abstract

Objective: Characterize current VS surgery outcomes using a nationwide database and identify factors associated with increased complications and prolonged hospital course.

Study Design: Retrospective review utilizing the University HealthSystem Consortium (UHC) national inpatient database

Setting: US Academic Health Centers

Subjects and Methods: Data from patients undergoing VS surgery were analyzed over a three year timespan (2012 – 2015). Surgical outcomes such as length of stay (LOS), complications, and mortality were analyzed on the basis of race, sex, gender, age, and comorbidities during the 30-day postoperative period.

Results: A total of 3,697 VS surgical cases were identified. The overall mortality rate was 0.38%, and the overall complication rate was 5.3%. Advanced age significantly impacted intensive care unit LOS, mortality, and complications ($p = 0.04$). Comorbidities including hypertension, obesity, and depression also significantly increased complication rates ($p = 0.02$). Sixty-eight patients (1.8%) had a history of irradiation; these patients had a significantly increased LOS ($p = 0.03$).

Conclusion: Modern VS surgery has a low mortality rate and 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 (VS); Quality Improvement; Facial Nerve; Postoperative Complications

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Introduction

Vestibular schwannomas (VS) are benign slow-growing tumors arising from the vestibular nerve. The incidence of VS is approximately 20 cases per million persons each year.¹ These tumors typically have an indolent course with patients often presenting with symptoms of asymmetric hearing loss, tinnitus, headache, and loss of balance.² Surgical treatment for VS has steadily declined over the past few decades, especially for smaller tumors.^{3,4} This trend has been countered with increasing numbers of patients being observed with serial imaging or treated with stereotactic radiation.⁵ Surgical excision of VS remains the definitive treatment option for larger tumors and for younger patients.³

As with any surgical procedure, excision of VS is not without risk. The first successful VS surgery was first performed in 1894 and initial mortality rates approached 80%.⁶ With the advent of the operating microscope, improvement in antibiotics, and refinement of surgical techniques, the current mortality rate has greatly improved to approximately 0.2%.⁷ Although the rate of serious complications has also decreased, they can still infrequently occur and include stroke, CSF leaks, wound infection, intracranial bleeding, and meningitis.^{8,9} While most studies analyze single institution's experience,¹⁰ this study made use of a multi-institutional database to capture a larger contingent of patients and institutions.

Methods

The University HealthSystem Consortium (UHC) is an organization whose membership includes over 30% of US hospitals including nearly all academic medical centers and health systems. The UHC maintains a data repository which compiles inpatient discharge summaries among other 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 time 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 v 04.01. 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 article.

Complications are defined by criteria set by reportable complication metrics developed by the Agency for Healthcare Research and Quality, UHC, or Centers for Medicare & Medicaid. Complication rates were determined by the number of cases with 1 or more complications. Comorbidities are assigned to patients based on ICD-9-CM diagnostic codes present on admission.¹¹

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), UTI (599.0), Intracerebral Hemorrhage (431), Unilateral Vocal Cord Paralysis (478.31, 478.32), CSF Otorrhea and CSF rhinorrhea (388.61, 349.81), Subdural Hemorrhage (432.1), Dysphagia (780.20–780.22, 780.29). Other diagnostic ICD 9 codes of dizziness, imbalance, or headaches were felt to be common following surgery and would not be considered at complication. Also the ICD 9 coding system doesn't provide specific procedure codes for the various approaches used in vestibular schwannoma surgery. Other procedures codes such lumbar drains are not included in the ICD 9 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 LOS because the duration of ICU admission was not recorded in the database. Readmission rates were calculated as 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, CA) and MedCalc 16.4.3 (MedCalc Software bvba, Belgium). Comorbidities and demographic variables such as age, race, and gender were evaluated by means of summary statistics. Continuous variables were summarized by mean $\pm$ standard deviation. 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 using Fisher's exact or Chi-Squared test. For continuous variables, comparisons were made using an independent t-test or a Wilcoxon Rank Sum Test. A One-Way ANOVA was also used followed by a Tukey posthoc comparison test. Finally, a Spearman rank correlation model was used to determine association among variables including LOS, ICU LOS, complication rate, and readmission rate. A p-value less than 0.05 were considered indicative of statistical significance. The correlation coefficient (R-value; range –1.0 to 1.0) is a value that determines the relationship between two 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 two variables are not related. R squared (R^2) is equal to the percent of variation between the two variables.

Patients were categorized into six age groups (<18 years, 18–30 years, 31–50 years, 51–64 years, 65–74 years, >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 $n=3,697$ patients vestibular schwannomas that were treated with surgical excision. The mean total hospital LOS was 4.9 ± 5.0 days. There were 2,647 (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 within 14 days ($n=167$) and 43% ($n=98$) within 7 days.

Demographics

We found a greater number of female patients (2,052) compared male patients (1645) undergoing surgery (ratio 1.25:1.0). Both groups had a similar length of stay, however, males had a significantly increased rate of complications (6.32% vs. 4.43%, $p=0.01$) and readmission (7.13% vs. 5.53%, $p=0.05$).

The mean age was 50.5 ± 13.6 years with 75.8% of patients aged 31 to 64. Increasing age was found to be significantly and very highly correlated with ICU LOS ($r=0.83$, $p=0.04$), complication rates ($r=1.00$, $p < 0.01$), mortality rates ($r=0.83$, $p=0.04$). However, age was significantly and negatively correlated with readmission rates ($r=-0.89$, $p=0.02$).

Race

Compared to Caucasians, African Americans (6.58 days vs. 4.64 days, $p<0.01$) and Asians (5.59 days vs. 4.64 days, $p=0.01$) had a significantly longer LOS. Adjusting for population using 2015 US census data, surgical case incidence among Caucasians was the highest at 3.33:1 compared to African Americans and 1.56:1 compared to Asians. African Americans had the longest mean ICU stay of 3.0 days followed by Asians (2.2 days) and Caucasians (1.9 days). There were significant differences among racial groups for complication rate ($p=0.04$); African Americans had the highest rate of complications (8.8%) followed by Asians (4.8%) and Caucasians (4.7%). When analyzing comorbidities, African Americans were found to have a significantly higher rate of all comorbidities except depression and hypothyroidism. And Caucasians have significantly higher rate for depression than African Americans and hypothyroidism than both African Americans and Asians (Table 2). Asians had a significantly higher mortality rate of 2.0% ($n=3$, $p=0.04$) and significantly higher rate of readmissions to ICU (6.7%, $p=0.0040$), nearly three times that of African Americans and Caucasians. Furthermore, there was no significant difference in overall hospital readmissions ($p=0.42$) 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 was classified as "Other", declined to identify, or were unavailable data

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

Complications

The top six 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 complications analyzed significantly increased LOS with a mean LOS greater than 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 with 76 cases (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 we analyzed, nearly all significantly increased LOS and many significantly increased mortality. It should be noted that some of these diagnoses fall under certain categories of UHC complications while others did not. We found 34 patients (0.92%) developed postoperative unilateral vocal cord paralysis, and 44 patients (1.19%) had an intracerebral hemorrhage. We identified 76 patients (2.03%) with postoperative CSF rhinorrhea or otorrhea indicating 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, $p=0.26$). Patients with a history of irradiation, most likely coded for previous stereotactic radiation therapy for their acoustic neuroma, were found to have a significantly increased LOS (6.3 days, $p=0.03$), but without any significant increase in complication rate (7.35% vs. 5.52%, $p=0.41$). These patients were also more likely to present with facial nerve symptoms (OR=2.24, $p=0.01$), but were no more likely to incur facial nerve weakness from surgery (OR=0.88, $p=0.74$). Overall, 9.7% of patients presenting with facial nerve symptoms and 12.7% of patients incurring 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 their associated outcomes and LOS.

In a metaanalysis of over 32,870 patients undergoing VS surgery between 1968 and 2006, mortality rate was found to be 0.2%,⁷ while a more recent study of cases from 1994–2003 places it at 0.5%.¹⁴ This is in line with the 3,697 cases of VS excision we analyzed with a mortality rate of 0.38%. Intracranial hemorrhages and strokes accounted for the vast

majority of deaths in our study . We found a rate of intracranial hemorrhage of 1.2%, in line with recent literature reporting a rate of 0.8% to 0.9%.^{15,16}

We found weight loss, a comorbidity associated with advanced age and/or chronic illness, associated with much poorer outcomes. This included a 2.3-fold increase in both LOS and complications, 4.3-fold increase in readmission to the ICU, and a 16-fold increase in mortality. Weight loss is non-specific and may be the result of several factors including comorbidities, malnutrition or advancing age. It has been shown that weight loss is a main component of frailty, a significant risk factor for peri-operative complications.^{11,17} Moreover, malnutrition has previously been shown to lead to worse outcomes for other types of surgery.^{18–20} We also found that renal failure significantly increased mortality (12.3-fold). Renal failure has also been shown to have 3.1-fold increase in mortality rate after coronary artery bypass surgery, including a 2.1-fold increase in stroke.²¹ 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.^{22–28} in our study, we found the presence of congestive heart failure to have 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.³¹ Obesity does not confer a risk to the patient in all situations, as it has been previously been associated with improved or equal outcomes after stroke,³² and specifically otologic procedures.³³ As with any invasive procedure in patients with significant risk factors, preoperative medical optimization is advised along with proper informed consent.

As more is learned about VS growth patterns and prognosis, patients are opting more for observation and stereotactic radiation.³⁴ There is increasing evidence that many tumors are slow-growing, stable, or even regress and warrant observation.^{35–37} 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.¹ This is particularly relevant as advanced age has been well-shown to be associated with increased mortality and complication rates after surgery,^{38–40} as well as longer LOS.^{24,41,42} Not surprisingly, age is associated with a higher prevalence of comorbidities.^{43,44} Our univariate analysis revealed a very strong correlation between age and complications (r-value=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-value =0.69 and ICU LOS (r-value=0.69). These data are useful in giving meaningful advice to patients on their risks 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 in 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 lengths of stay include advancing age and complications while in the post-operative period.

African Americans were found to have a higher complication rate than other races in this study, which could follow from several factors. Studies of the Surveillance, Epidemiology, and End Results (SEER) database show 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 in African American patients found it was mostly due to an increased prevalence of comorbidities.⁴⁸ While McClellan et. al. found higher mortality amongst 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 non-specific 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%.^{50–52} While spontaneous CSF leaks have been associated with obesity,⁵³ we found no increase in postoperative CSF otorrhea or rhinorrhea in these patients.

In regards to facial nerve outcomes following VS surgery, we found 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 the facial nerve weakness pre and post surgery is inaccessible through the database. Also, long term data regarding facial nerve outcomes at regular post op interval is not available through the database. Specific information that is key to VS surgery include tumor size, individual institution case volume, surgical approach, and hearing status are unfortunately not available through this database.

Other limitations of our study is source data may be subject to inaccuracies as discharge summaries are not coded by clinicians; albeit the acting physician must sign and verify these codes on the attestation sheet, which should help to minimize errors.⁵⁴ 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.⁵⁵ 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 time 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 analysis in the future, such as allowing for analysis by type of surgical approach. Other limitations include specific information that is key to VS surgery. These include tumor size, surgical approach, preoperative and postoperative facial nerve function and team vs. individual surgeon specific data. Lastly, the study only involved 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 have identified numerous factors that are associated with increased post-operative 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.

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References

1. Stangerup SE, Caye-Thomasen P. Epidemiology and natural history of vestibular schwannomas. *Otolaryngol Clin North Am*. 2012;45(2):257–268, vii. [PubMed: 22483814]
2. Wiegand DA, Fickel V. Acoustic neuroma--the patient's perspective: subjective assessment of symptoms, diagnosis, therapy, and outcome in 541 patients. *Laryngoscope*. 1989;99(2):179–187. [PubMed: 2913427]
3. Gal TJ, Shinn J, Huang B. Current epidemiology and management trends in acoustic neuroma. *Otolaryngol Head Neck Surg*. 2010;142(5):677–681. [PubMed: 20416455]
4. Ahmed OH, Mahboubi H, Lahham S, Pham C, Djalilian HR. Trends in demographics, charges, and outcomes of patients undergoing excision of sporadic vestibular schwannoma. *Otolaryngol Head Neck Surg*. 2014;150(2):266–274. [PubMed: 24091426]
5. Theodosopoulos PV, Pensak ML. Contemporary management of acoustic neuromas. *Laryngoscope*. 2011;121(6):1133–1137. [PubMed: 21557246]
6. McRackan TR, Brackmann DE. Historical perspective on evolution in management of lateral skull base tumors. *Otolaryngol Clin North Am*. 2015;48(3):397–405. [PubMed: 25863569]
7. Sughrue ME, Yang I, Aranda D, et al. Beyond audiofacial morbidity after vestibular schwannoma surgery. *J Neurosurg*. 2011;114(2):367–374. [PubMed: 19943734]
8. Nonaka Y, Fukushima T, Watanabe K, et al. Contemporary surgical management of vestibular schwannomas: analysis of complications and lessons learned over the past decade. *Neurosurgery*. 2013;72(2 Suppl Operative):ons103–115; discussion ons115.
9. Wise SC, Carlson ML, Tveiten OV, et al. Surgical salvage of recurrent vestibular schwannoma following prior stereotactic radiosurgery. *Laryngoscope*. 2016.
10. Zanoletti E, Faccioli C, Martini A. Surgical treatment of acoustic neuroma: Outcomes and indications. *Rep Pract Oncol Radiother*. 2016;21(4):395–398. [PubMed: 27330426]
11. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care*. 1998;36(1):8–27. [PubMed: 9431328]
12. Machinis TG, Fountas KN, Dimopoulos V, Robinson JS. History of acoustic neurinoma surgery. *Neurosurg Focus*. 2005;18(4):e9.
13. House WF. Surgical exposure of the internal auditory canal and its contents through the middle, cranial fossa. *Laryngoscope*. 1961;71:1363–1385. [PubMed: 14036379]
14. McClelland S 3rd, Guo H, Okuyemi KS. Morbidity and mortality following acoustic neuroma excision in the United States: analysis of racial disparities during a decade in the radiosurgery era. *Neuro Oncol*. 2011;13(11):1252–1259. [PubMed: 21856684]
15. Slattery WH 3rd, Francis S, House KC. Perioperative morbidity of acoustic neuroma surgery. *Otol Neurotol*. 2001;22(6):895–902. [PubMed: 11698815]

16. Sluyster S, Graamans K, Tulleken CA, Van Veelen CW. Analysis of the results obtained in 120 patients with large acoustic neuromas surgically treated via the translabyrinthine-transtentorial approach. *J Neurosurg.* 2001;94(1):61–66.
17. Revenig LM, Canter DJ, Taylor MD, et al. Too frail for surgery? Initial results of a large multidisciplinary prospective study examining preoperative variables predictive of poor surgical outcomes. *J Am Coll Surg.* 2013;217(4):665–670 e661. [PubMed: 24054409]
18. Kuzu MA, Terzioglu H, Genc V, et al. Preoperative nutritional risk assessment in predicting postoperative outcome in patients undergoing major surgery. *World J Surg.* 2006;30(3):378–390. [PubMed: 16479353]
19. Sungurtekin H, Sungurtekin U, Balci C, Zencir M, Erdem E. The influence of nutritional status on complications after major intraabdominal surgery. *J Am Coll Nutr.* 2004;23(3):227–232. [PubMed: 15190047]
20. van Venrooij LM, de Vos R, Borgmeijer-Hoelen MM, Haaring C, de Mol BA. Preoperative unintended weight loss and low body mass index in relation to complications and length of stay after cardiac surgery. *Am J Clin Nutr.* 2008;87(6):1656–1661. [PubMed: 18541553]
21. Liu JY, Birkmeyer NJ, Sanders JH, et al. Risks of morbidity and mortality in dialysis patients undergoing coronary artery bypass surgery. Northern New England Cardiovascular Disease Study Group. *Circulation.* 2000;102(24):2973–2977. [PubMed: 11113048]
22. Patel S, Nuno M, Mukherjee D, et al. Trends in surgical use and associated patient outcomes in the treatment of acoustic neuroma. *World Neurosurg.* 2013;80(1–2):142–147. [PubMed: 22722042]
23. Thombs BD, Singh VA, Halonen J, Diallo A, Milner SM. The effects of preexisting medical comorbidities on mortality and length of hospital stay in acute burn injury: evidence from a national sample of 31,338 adult patients. *Ann Surg.* 2007;245(4):629–634. [PubMed: 17414613]
24. Grossman R, Mukherjee D, Chang DC, et al. Preoperative charlson comorbidity score predicts postoperative outcomes among older intracranial meningioma patients. *World Neurosurg.* 2011;75(2):279–285. [PubMed: 21492731]
25. Jencks SF, Williams DK, Kay TL. Assessing hospital-associated deaths from discharge data. The role of length of stay and comorbidities. *JAMA.* 1988;260(15):2240–2246. [PubMed: 3050163]
26. Fleischmann KE, Goldman L, Young B, Lee TH. Association between cardiac and noncardiac complications in patients undergoing noncardiac surgery: outcomes and effects on length of stay. *Am J Med.* 2003;115(7):515–520. [PubMed: 14599629]
27. Bucerius J, Gummert JF, Borger MA, et al. Stroke after cardiac surgery: a risk factor analysis of 16,184 consecutive adult patients. *Ann Thorac Surg.* 2003;75(2):472–478. [PubMed: 12607656]
28. Lee TH, Marcantonio ER, Mangione CM, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. *Circulation.* 1999;100(10):1043–1049. [PubMed: 10477528]
29. Lazar HL, Chipkin SR, Fitzgerald CA, Bao Y, Cabral H, Apstein CS. Tight glycemic control in diabetic coronary artery bypass graft patients improves perioperative outcomes and decreases recurrent ischemic events. *Circulation.* 2004;109(12):1497–1502. [PubMed: 15006999]
30. Kehlet H, Wilmore DW. Multimodal strategies to improve surgical outcome. *Am J Surg.* 2002;183(6):630–641. [PubMed: 12095591]
31. O'Connell BP, Rizk HG, Stevens SM, Nguyen SA, Meyer TA. The Relation between Obesity and Hospital Length of Stay after Elective Lateral Skull Base Surgery: An Analysis of the American College of Surgeons National Surgical Quality Improvement Program. *ORL; journal for oto-rhino-laryngology and its related specialties.* 2015;77(5):294–301. [PubMed: 26360829]
32. Doehner W, Schenkel J, Anker SD, Springer J, Audebert HJ. Overweight and obesity are associated with improved survival, functional outcome, and stroke recurrence after acute stroke or transient ischaemic attack: observations from the TEMPiS trial. *Eur Heart J.* 2013;34(4):268–277. [PubMed: 23076781]
33. Stevens SM, O'Connell BP, Meyer TA. Obesity related complications in surgery. *Curr Opin Otolaryngol Head Neck Surg.* 2015;23(5):341–347. [PubMed: 26339964]
34. Quesnel AM, McKenna MJ. Current strategies in management of intracanalicular vestibular schwannoma. *Curr Opin Otolaryngol Head Neck Surg.* 2011;19(5):335–340. [PubMed: 22552696]

35. Smouha EE, Yoo M, Mohr K, Davis RP. Conservative management of acoustic neuroma: a meta-analysis and proposed treatment algorithm. *Laryngoscope*. 2005;115(3):450–454. [PubMed: 15744156]
36. Selesnick SH, Johnson G. Radiologic surveillance of acoustic neuromas. *Am J Otol*. 1998;19(6):846–849. [PubMed: 9831166]
37. Yamakami I, Uchino Y, Kobayashi E, Yamaura A. Conservative management, gamma-knife radiosurgery, and microsurgery for acoustic neurinomas: a systematic review of outcome and risk of three therapeutic options. *Neurol Res*. 2003;25(7):682–690. [PubMed: 14579782]
38. Hamel MB, Henderson WG, Khuri SF, Daley J. Surgical outcomes for patients aged 80 and older: morbidity and mortality from major noncardiac surgery. *J Am Geriatr Soc*. 2005;53(3):424–429. [PubMed: 15743284]
39. Marusch F, Koch A, Schmidt U, et al. The impact of the risk factor “age” on the early postoperative results of surgery for colorectal carcinoma and its significance for perioperative management. *World J Surg*. 2005;29(8):1013–1021; discussion 1021–1012. [PubMed: 15981044]
40. Chuang SK, Perrott DH, Susarla SM, Dodson TB. Age as a risk factor for third molar surgery complications. *J Oral Maxillofac Surg*. 2007;65(9):1685–1692. [PubMed: 17719384]
41. Hein OV, Birnbaum J, Wernecke K, England M, Konertz W, Spies C. Prolonged intensive care unit stay in cardiac surgery: risk factors and long-term-survival. *Ann Thorac Surg*. 2006;81(3):880–885. [PubMed: 16488688]
42. Polanczyk CA, Marcantonio E, Goldman L, et al. Impact of age on perioperative complications and length of stay in patients undergoing noncardiac surgery. *Ann Intern Med*. 2001;134(8):637–643. [PubMed: 11304103]
43. Incalzi RA, Capparella O, Gemma A, et al. The interaction between age and comorbidity contributes to predicting the mortality of geriatric patients in the acute-care hospital. *J Intern Med*. 1997;242(4):291–298. [PubMed: 9366807]
44. Faurey A, Chetner M, Metcalfe J, et al. Associations among age, comorbidity and clinical outcomes after radical cystectomy: results from the Alberta Urology Institute radical cystectomy database. *J Urol*. 2008;180(1):128–134; discussion 134. [PubMed: 18485375]
45. Carlson ML, Marston AP, Glasgow AE, et al. Racial differences in vestibular schwannoma. *Laryngoscope*. 2016.
46. Babu R, Sharma R, Bagley JH, Hatef J, Friedman AH, Adamson C. Vestibular schwannomas in the modern era: epidemiology, treatment trends, and disparities in management. *J Neurosurg*. 2013;119(1):121–130. [PubMed: 23432451]
47. Sanna M, Taibah A, Russo A, Falcioni M, Agarwal M. Perioperative complications in acoustic neuroma (vestibular schwannoma) surgery. *Otol Neurotol*. 2004;25(3):379–386. [PubMed: 15129121]
48. Fiscella K, Franks P, Meldrum S, Barnett S. Racial disparity in surgical complications in New York State. *Ann Surg*. 2005;242(2):151–155. [PubMed: 16041203]
49. Slaterry WH 3rd, Brackmann DE. Results of surgery following stereotactic irradiation for acoustic neuromas. *Am J Otol*. 1995;16(3):315–319; discussion 319–321. [PubMed: 8588625]
50. Merkus P, Taibah A, Sequino G, Sanna M. Less than 1% cerebrospinal fluid leakage in 1,803 translabyrinthine vestibular schwannoma surgery cases. *Otol Neurotol*. 2010;31(2):276–283. [PubMed: 20042905]
51. Mangus BD, Rivas A, Yoo MJ, et al. Management of CSF Leaks Following Vestibular Schwannoma Surgery. *Otology & neurotology: official publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology*. 2011;32(9):1525.
52. Selesnick SH, Liu JC, Jen A, Newman J. The incidence of cerebrospinal fluid leak after vestibular schwannoma surgery. *Otol Neurotol*. 2004;25(3):387–393. [PubMed: 15129122]
53. Goddard JC, Meyer T, Nguyen S, Lambert PR. New considerations in the cause of spontaneous cerebrospinal fluid otorrhea. *Otol Neurotol*. 2010;31(6):940–945. [PubMed: 20684056]
54. O'Malley KJ, Cook KF, Price MD, Wildes KR, Hurdle JF, Ashton CM. Measuring diagnoses: ICD code accuracy. *Health Serv Res*. 2005;40(5 Pt 2):1620–1639. [PubMed: 16178999]

55. Sutton JM, Hayes AJ, Wilson GC, et al. Validation of the University HealthSystem Consortium administrative dataset: concordance and discordance with patient-level institutional data. *J Surg Res.* 2014;190(2):484–490. [PubMed: 24909867]

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Table 1:

Length of Stay (LOS), Intensive Care Unit (ICU) LOS, Complications, Mortality, 30 day Readmission, and Return to ICU for patients by demographic. R values express goodness of fit for Spearman's rank correlation when comparing age groups versus given outcome.

Age Group	Cases		LOS		p	ICU LOS		p	Complications		p	Mortality		p	30 Day Readmission		p	Return to ICU		p
	N	(%)	Mean ±	SD		Mean			Rate	(OR)		Rate	(OR)		Rate	(OR)		Rate	(OR)	
<18	39	(1%)	4.7 ±	3.3	$r = 0.77$ $p = 0.07$	1.6	$r = 0.83$ $p = 0.04$	$r = 0.96$ $p < 0.01$	0.00%	(0.0)	$r = 0.83$ $p = 0.04$	0.00%	(0.0)	$r = 0.83$ $p = 0.04$	7.7%	(1.3)	$r = -0.89$ $p = 0.02$	5.1%	(1.9)	$p = <0.001$
18 – 30	316	(9%)	4.7 ±	3.2		2.0			3.8%	(0.7)		0.63%	(1.8)		9.2%	(1.6)		5.4%	(2.1)	
31 – 50	1339	(36%)	4.7 ±	4.1		2.0			4.4%	(0.8)		0.22%	(0.5)		6.3%	(1.0)		2.1%	(0.6)	
51 – 64	1465	(40%)	5.0 ±	5.6		2.0			5.9%	(1.2)		0.27%	(0.6)		6.1%	(1.0)		2.6%	(0.9)	
65 – 74	437	(12%)	5.3 ±	5.7		2.1			6.9%	(1.4)		0.69%	(2.1)		4.3%	(0.7)		2.7%	(1.0)	
>74	99	(3%)	6.6 ±	7.8		2.5			8.1%	(1.6)		2.02%	(6.2)		5.1%	(0.8)		8.1%	(3.2)	
Race																				
Asian	150	(4%)	5.6 ±	4.5	$p = 0.01$ [†]	2.2			4.7%	(0.9)		2.00%	(6.6)		6.0%	(1.0)		6.7%	(2.6)	
AA	160	(4%)	6.6 ±	9.0	$p < 0.00$ [†]	3.0			8.8%	(1.8)		0.00%	(0.0)		6.9%	(1.1)		1.9%	(0.6)	$p = <0.001$
Caucasian	2971	(80%)	4.6 ±	3.6		1.9			4.8%	(0.7)		0.27%	(0.3)		6.4%	(1.1)		2.4%	(0.5)	
Sex																				
Female	2052	(56%)	4.9 ±	4.6	$p = 0.76$	2.0			4.4%	(0.7)		0.44%	(1.4)		5.5%	(0.8)		2.6%	(0.8)	$p = 0.45$
Male	1645	(44%)	5.0 ±	5.4		2.1			6.3%	(1.5)		0.30%	(0.7)		7.1%	(1.3)		3.1%	(1.2)	
Total	3697	(100%)	4.9 ±	5.0		2.0			5.3%			0.38%			6.2%			2.8%		

OR: Odds Ratio, AA: African American.

[†] p-values when compared to Caucasian group

Table 2:
Prevalence of comorbidities among African American (AA), Asian, and Caucasian patients.

Comorbidity	AA	Asian	Caucasian	p
Hypertension	52%	*30%	+34%	<0.05
Obesity	21%	*3%	14%	<0.05
Chronic pulmonary disease	15%	*5%	11%	0.05
Diabetes without chronic complications	15%	*7%	+6%	0.05
Anemias	8%	7%	+3%	0.05
Depression	5%	N/A	+10%	<0.05
Hypothyroidism	4%	*7%	+10%	<0.05
Renal failure	3%	N/A	+1%	0.05

* The test of the difference between AA and Asian in the same row is significant at $p < 0.05$.

+ The test of the difference between AA and Caucasian in the same row is significant at $p < 0.05$.

Table 3:

Patient outcomes for given comorbidities. Comorbidities are assigned to patients based on ICD-9-CM diagnostic codes by Elixhauser Comorbidity software. Length of Stay (LOS), Intensive Care Unit (ICU) LOS, Complications, Mortality, and Return to ICU were analyzed for statistical significance by comparing each group to patients negative for the respective comorbidity. OR: Odds Ratio, SD: Standard Deviation.

Comorbidity	Cases	LOS		p	ICU LOS		Complications		Mortality		p	Return to ICU		p
		Mean ± SD	SD		Days	Rate	(OR)	p	Rate	(OR)		Rate	(OR)	
Hypertension	1294 (35.0%)	5.5 ± 6.2	6.2	< 0.01	2.3	7.6%	(1.9)	< 0.01	0.5%	(1.9)	0.37	3.7%	(1.6)	0.03
Obesity	484 (13.1%)	5.2 ± 5.2	5.2	0.23	2.3	8.1%	(1.7)	< 0.01	0.2%	(0.5)	1.00	2.3%	(0.8)	0.51
Chronic pulmonary disease	377 (10.2%)	5.5 ± 5.0	5.0	0.03	2.2	4.8%	(0.9)	0.73	0.0%	(0.0)	0.39	4.2%	(1.6)	0.13
Depression	343 (9.3%)	5.5 ± 4.6	4.6	0.03	2.2	6.7%	(1.3)	0.02	0.6%	(1.6)	0.38	5.5%	(2.2)	< 0.01
Diabetes w/o chronic complications	269 (7.3%)	5.7 ± 6.2	6.2	0.01	2.3	5.9%	(1.1)	0.71	0.4%	(1.0)	1.00	5.2%	(2.0)	0.03
Renal failure	43 (1.2%)	6.6 ± 5.2	5.2	0.03	3.2	11.6%	(2.4)	0.07	4.7%	(14.8)	0.01	9.3%	(3.6)	0.04
Diabetes w/ chronic complications	39 (1.1%)	7.2 ± 5.8	5.8	< 0.01	3.0	20.5%	(4.8)	< 0.01	2.6%	(7.4)	0.14	2.6%	(0.9)	1.00
Weight loss	33 (0.9%)	11.3 ± 9.1	9.1	< 0.01	4.9	12.1%	(2.5)	0.09	6.1%	(19.6)	< 0.01	12.1%	(4.9)	0.02
Psychoses	28 (0.8%)	7.6 ± 6.6	6.6	< 0.01	2.7	3.6%	(0.7)	1.00	3.6%	(10.4)	0.10	3.6%	(1.3)	0.56
Coagulopathy	26 (0.7%)	7.3 ± 6.0	6.0	0.01	4.1	7.7%	(1.5)	0.65	0.0%	(0.0)	1.00	15.4%	(6.4)	0.01
Congestive heart failure	23 (0.6%)	7.5 ± 5.3	5.3	0.01	2.1	26.1%	(6.5)	< 0.01	4.3%	(12.8)	0.08	0.0%	(0.0)	1.00
Total	3697 (100%)	4.9 ± 5.0	5.0		2.0	5.3%			0.4%			2.8%		

Table 4:

‡Complications as defined by Agency for Healthcare Research and Quality (AHRQ), University Health Consortium, and Centers for Medicare and Medicaid (top six complications shown). CSF: Cerebrospinal Fluid, UTI: Urinary Tract Infection, PE: Pulmonary Embolism, DVT: Deep Vein Thrombosis. . See Appendix 1 for International Classification of Disease, 9th edition diagnosis codes that were used in compiling diagnoses and complications.

Diagnoses Present on Admission	Cases		LOS		p	ICU LOS		Mortality	
	n	(%)	Mean ± SD	SD		Mean (days)	Rate	(OR)	p
History of Irradiation	68	(1.84%)	6.3 ± 6.3	6.3	0.03	3.2	0.0%	(0.0)	1.00
History of Coronary Angioplasty	47	(1.27%)	7.9 ± 12.6	12.6	< 0.01	4.8	0.0%	(0.0)	1.00
Postoperative Diagnoses									
Dysphagia	113	(3.06%)	12.8 ± 16.1	16.1	< 0.01	5.3	1.8%	(5.4)	0.07
CSF Rhinorrhea	68	(1.84%)	9.3 ± 5.0	5.0	< 0.01	2.6	0.0%	(0.0)	1.00
UTI	51	(1.38%)	20.6 ± 23.5	23.5	< 0.01	11.6	3.9%	(12.4)	0.02
Intracerebral Hemorrhage	44	(1.19%)	17.0 ± 15.9	15.9	< 0.01	9.4	11.4%	(51.9)	< 0.01
Unilateral Vocal Cord Paralysis	27	(0.73%)	13.7 ± 13.6	13.6	< 0.01	5.2	0.0%	(0.0)	1.00
CSF Otorrhea	18	(0.49%)	7.1 ± 5.3	5.3	0.07	2.5	0.0%	(0.0)	1.00
Subdural Hemorrhage	16	(0.43%)	20.3 ± 23.2	23.2	< 0.01	14.3	21.7%	(113.8)	< 0.01
Complications[‡]									
Stroke	76	(2.06%)	15.3 ± 16.0	16.0	< 0.01	9.9	13.2%	(137.0)	< 0.01
Postoperative Respiratory Failure	50	(1.35%)	19.4 ± 16.6	16.6	< 0.01	14.5	16.0%	(115.6)	< 0.01
Aspiration Pneumonia	31	(0.84%)	22.5 ± 16.6	16.6	< 0.01	14.2	9.7%	(35.6)	< 0.01
PE or DVT	29	(0.78%)	16.5 ± 15.1	15.1	< 0.01	9.7	10.3%	(38.4)	< 0.01
Postoperative Infection	9	(0.24%)	21.0 ± 14.5	14.5	< 0.01	11.3	0.0%	(0.0)	1.00
Postoperative Sepsis	7	(0.19%)	23.0 ± 7.0	7.0	< 0.01	13.2	28.6%	(122.6)	< 0.01
Total	3,697	(100%)	4.9 ± 5.0	5.0		2.0	0.38%		