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Trends in Demographics, Charges, and Outcomes of Patients Undergoing Excision of Sporadic Vestibular Schwannoma

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Abstract

Objective. To assess demographics, charges, and outcome measures by temporal and volume analysis in the treatment of vestibular schwannoma.

Design. Cross-sectional analysis.

Setting, Subjects, and Methods. The California Hospital Inpatient Discharge Databases from 1996 to 2010.

Results. A total of 6545 cases from 1996 to 2010 were identified. Of these, 86.2% occurred at high-volume centers (HVCs), and the number of annual cases decreased by 28.5% over the study period. Patients presenting for surgery were increasingly younger, non-Caucasian, and likely to have comorbidities. Total charges significantly increased over time ($P < .001$), with the median total charge in 2006-2010 being \$91,338 compared with \$38,607.92 in 1996-2000 after adjusting for inflation. Routine discharges (home or residence) were more likely at HVCs (odds ratio [OR] 5.48, $P < .001$) and less likely if patients had Medicaid (Medi-Cal; OR 0.51, $P = .002$) or Medicare (OR 0.55, $P = .022$), were 65 years or older (OR 0.56, $P = .025$), or had comorbidities (OR 0.54, $P < .001$). Shorter hospital stays were more likely at HVCs (OR 3.77, $P < .001$) and less likely if patients had Medicaid (OR 0.36, $P < .001$) or comorbidities (OR 0.61, $P < .001$). Lesser total charges were more likely at HVCs (OR 2.12, $P = .002$) and less likely if patients had comorbidities (OR 0.70, $P < .001$). Mortality was less likely at HVCs (OR 0.10, $P = .011$).

Conclusion. The profile of patients undergoing vestibular neuroma excision is changing. Surgical volume is decreasing, suggesting a trend toward more conservative management or stereotactic radiation. Patients are best served at HVCs, where routine discharges, shorter length of stay, decreased mortality, and lower total charges are more likely.

Keywords

vestibular schwannoma, acoustic neuroma, trends, outcomes, surgery, epidemiology

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Vestibular schwannoma (VS) is a slow-growing, benign nerve sheath tumor of the vestibular nerve. Its incidence is estimated to be approximately 1 in 100,000 per year in the United States.[1] Advances in diagnostic and therapeutic approaches over recent decades have changed how patients with VS are managed. The digital age has empowered patients with more information and control in the treatment decision-making process.[2] Understanding of VS tumor growth patterns has improved, with physicians more aware of the relatively stable and innocuous pattern that most tumors follow.[3,4] There is also the ever-increasing focus on the delivery of cost-effective, quality health care. These changes have undoubtedly altered the treatment landscape of VS.

The advent of computed tomography (CT) and magnetic resonance imaging (MRI) has allowed earlier detection of brain tumors and those that otherwise would have gone undiagnosed.[1] An increase in access to these imaging technologies as well as heightened physician awareness of VS have led to increased diagnostic testing.[1] MRI, in particular, has led to increased detection of smaller tumors in patients with minimal or no symptoms.[3,5] For instance, the mean tumor size at diagnosis according to Denmark's national database was 10 mm in 2008, compared with 30 mm in 1976.[6] As such, today's surgeons are seeing a greater

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number of smaller tumors, often requiring that nonsurgical options be considered in order to avoid possible surgical complications.[7]

Traditionally, the preferred treatment for VS has been surgical excision; however, within the past 2 decades, treatment options have expanded to include watchful waiting and stereotactic radiation. Observation with serial imaging has increasingly become preferred for elderly patients who do not have significant neurological symptoms or some patients with smaller tumors who are relatively asymptomatic.[3,7,8] Radiosurgery is also increasingly being used. It was demonstrated by a recent survey to be used by 42% of neurotologists, with approximately 58% of those using GammaKnife and 44% using CyberKnife.[9] Furthermore, the modern patient desires to be better informed with full disclosure of all treatment options and wishes to exercise more control over his or her treatment, largely fueled by the increasing presence of online medical websites, journals, blogs, and advocacy forums.[2,3,10]

The incidence of VS has been reported to be increasing.[1,6] While improvements in diagnostic modalities and reporting likely explain this trend, it is not completely clear why the incidence of this rare tumor is increasing.[11] This study's aim was to examine the evolution of demographics, charges, and basic outcome measures using data from the California Hospital Inpatient Discharge Database (CHIDD) over the period 1996-2010 in light of the multitude of changes in diagnostic modalities, treatment approaches, access to medical information, and treatment philosophy.

Methods

Data Source

The CHIDD is a data set of inpatient discharge data from all licensed inpatient hospitals in California. Each record in the data set corresponds to an individual inpatient hospital discharge and contains patient-level data including information on demographics, diagnosis, procedure codes, payment source, admission source, and total charges. The data set does not contain identifiable patient information, and thus approval for this study by our institutional review board was not required.

Data for hospital discharges that occurred between 1996 and 2010 were extracted. Procedures and diagnoses were encoded using codes defined in the *International Classification of Diseases, 9th edition, Clinical Modification* (ICD-9-CM). All cases with the principal procedure code for excision of acoustic neuroma (04.01) were included in the analysis. Cases with the diagnosis code for Neurofibromatosis Type 2 (NF2) were excluded from analysis, as these cases are not reflective of the vast majority of patients undergoing VS excision.

Patient Demographics

Age was categorized into 4 groups (1-17 years, 18-34 years, 35-64 years, and 65 years and older). Patients were classified as California resident or other (out-of-state, homeless, or those cases that had an invalid or blank entry) based on reported zip codes. Ethnicity was re-encoded into 2 groups: Caucasian and ''others'' because only about 22% of cases had entries, and entries for minorities were very sparse. A case was labeled as having a comorbid condition if a diagnostic ICD-9-CM code was present for any one of the 30 common comorbidities demonstrated to have independent effects on outcomes, hospital charges, and mortality.[12]

Total Charges and Payer Data

Total charges for services rendered during hospitalization were examined. These charges were based on the hospital's full established rates (before contractual adjustments) and included daily hospital, ancillary, and any patient care services. Hospital-based physician fees were not included in these figures. Also examined in this study was payer category, defined as the type of entity or organization expected to pay the greatest share of the patient's bill. Data were re-encoded to classify the cases as having one of the following: (1) Medicare (national social insurance for elderly and people with certain diseases), (2) Medi-Cal (California's Medicaid program, national health program for families and individuals with low income and resources), (3) private coverage (includes health maintenance organizations), and (4) other (this included self-pay, worker's compensation, county indigent programs, other government and indigent programs, research or courtesy patients where no payment was required, or unreported). Payer data from 1996-1998 were not present, and therefore, these years were not included in the analysis.

Outcomes Data

Disposition was defined as the consequent arrangement or event ending a patient's stay in the hospital. Case data were re-encoded to fit one of the following disposition assignments: (1) routine discharge (patient's home or residence), (2) death, and (3) further care. Further care included any of the following: acute care within admitting hospital, other care within admitting hospital, long-term care within admitting hospital, acute care at another hospital, other care (not including long-term care) at another hospital, long-term care at another facility, residential care facility, prison/jail, left against medical advice, and home health service. Length of stay was also examined as an indicator of surgical outcome, defined as the total number of days from admission to discharge.

Analysis by Hospital Volume

Each case was assigned a hospital volume category depending on its hospital identification number and the number of cases that hospital performed. Three categories of hospital volume were determined after examination of the frequency of VS excisions performed per hospital (n = 123) over the study period 1996-2010 (**Figure 1**). Cases were labeled as being performed at a high-volume center (HVC) if the hospital performed 100 or more cases (11 hospitals), medium-volume center (MVC) if 10 to 99 cases (25 hospitals) were performed, and low-volume center (LVC) if 1 to 9 cases (87 hospitals) were performed. These cutoffs were selected to (1) incorporate and categorize the full span and skewed

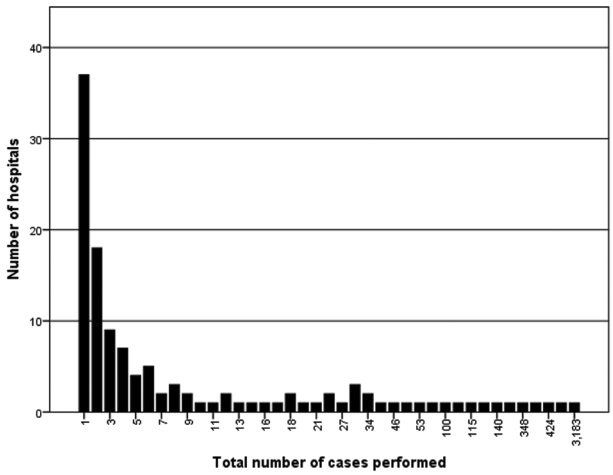

Figure 1. Distribution of total number of cases performed over study period (1996-2010) by number of hospitals.

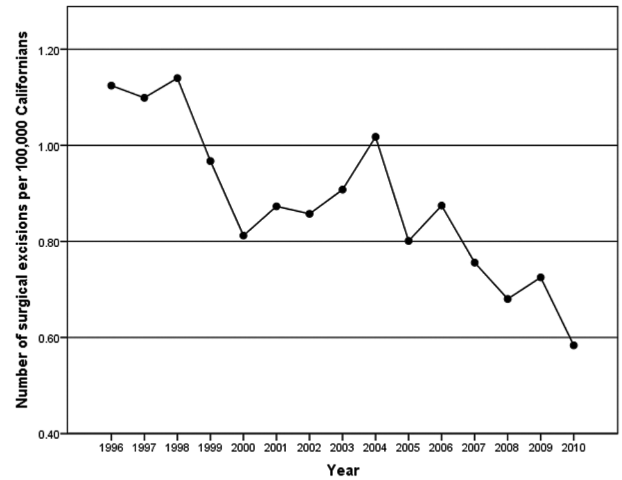

Figure 2. Number of surgical excisions per 100,000 Californians over time.

nature of the data distribution and (2) represent reasonable values for distinguishing LVCs, MVCs, and HVCs based on the experience of the authors.

Analysis by Time Period

Cases were designated as occurring in 1 of the following 5-year intervals: (1) 1996-2000, (2) 2001-2005, and (3) 2006-2010.

Statistical Analyses

Data analysis was performed using PASW Statistics, Release Version 18.0.0 (SPSS Inc, Chicago, IL). All parametric tests were employed only after confirming normality using the Kolmogorov-Smirnov test. Both total charge and length-of-stay data had significantly positively skewed distributions requiring analysis using the nonparametric Kruskal-Wallis H test. Chi-square was used to analyze age groups, gender, ethnicity, state of residence, payer type, comorbidities, and disposition. The analysis of annual rates of VS surgeries per 100,000 Californians (population estimates provided by the US Census Bureau)[13] and per 100,000 surgeries performed on Californians were evaluated by linear regression analysis and excluded out-of-state patients to capture true epidemiological trends within the state.

Binomial multivariate logistic regression was used to evaluate predictors of dependent variables. Variables that were continuous or had more than 2 levels were dichotomized. Specifically, length of stay and total charges, both continuous data sets, were dichotomized by the median length of stay and total charge values for the particular 5-year time period (1996-2000, 2001-2005, and 2006-2010) in which a case occurred. Median values rather than mean values were used due to data sets' being positively skewed. Disposition was dichotomized into routine discharges and nonroutine discharges (includes cases with the disposition of death or those requiring further care, defined previously).

Results

Surgical Volume

From 1996-2010, a total of 6545 cases were identified after excluding 457 (6.5%) NF2 patients. The annual number of surgeries decreased 28.5% from 1996-2010. The vast majority of cases (86.2%) were performed at HVCs, with only 3.6% of cases taking place at LVCs.

The number of VS excisions performed per 100,000 Californians demonstrated a downward trend (**Figure 2**) over the study period, with 1.12 cases per 100,000 Californians performed in 1996 compared with 0.58 in 2010 ($R = 0.868$, $R^2 = 0.735$, $P < .001$). This decrease occurred due to both declining numbers of cases performed (360 cases in 1996 vs 218 in 2010, after excluding patients from outside of the state) and steadily increasing state population estimates (32,018,834 in 1996 vs 37,349,363 in 2010). The number of VS excisions per 100,000 surgeries performed on Californians similarly declined over the study period, with 10.15 cases per 100,000 surgeries performed in 1996 compared with 5.60 in 2010 ($R = 0.850$, $R^2 = 0.723$, $P < .001$). A decrease in case volume was observed across all volume centers.

Demographics

Most patients during the study period were 35 to 64 years of age, female, Caucasian, from in state, privately insured, at an HVC for their surgery, and did not have a comorbid condition (**Table 1**). A smaller proportion of patients in 2006-2010 compared with 1996-2000 were aged 65 years and older (12.3% vs 17.5%, $P < .001$), were less likely to be Caucasian (75.9% vs 87.0%, $P < .001$), were less likely to report an in-state zip code (65.6% vs 76.0%, $P < .001$), and were more likely to have a comorbidity (45.9% vs 34.5%, $P < .001$).

HVCs tended to treat younger patients compared with other centers. This trend increased over time. In addition, HVCs tended to see a greater proportion of patients without comorbidities compared with other volume centers; however,

Table 1. Demographics by time period and hospital volume.[a]

	All Cases	1996-2000	2001-2005	2006-2010	*P* Value
			No. (%)		
Total No. of cases	6545	2227 (34.0)	2299 (35.1)	2019 (30.8)	
Annual average No. of cases	436.3	445.4	459.8	403.8	
Case volume proportion					<.001
HVCs	5640 (86.2)	1855 (83.3)	2067 (89.9)	1718 (85.1)	
MVCs	671 (10.3)	272 (12.2)	175 (7.6)	224 (11.1)	
LVCs	234 (3.6)	100 (4.5)	57 (2.5)	77 (3.8)	
Age, y					<.001
1-17	17 (0.5)	11 (0.9)	1 (0.1)	5 (0.6)	
18-34	292 (8.9)	91 (7.6)	114 (9.7)	87 (9.6)	
35-64	2522 (76.7)	891 (74.1)	927 (78.8)	704 (77.5)	
≥65	456 (13.9)	210 (17.5)	134 (11.4)	112 (12.3)	
Age (y) by hospital volume					
HVCs ≥65	312 (12.3)	142 (16.3)	102 (10.6)	68 (9.7)	
MVCs ≥65	97 (18.0)	46 (19.2)	26 (16.2)	25 (18.1)	
LVCs ≥65	47 (22.1)	22 (24.4)	6 (11.5)	19 (26.8)	
Between volume groups *P* value	<.001	.298	.079	<.001	
Gender					.375
Male	854 (49.2)	321 (50.5)	301 (50.1)	232 (46.6)	
Female	881 (50.8)	315 (49.5)	300 (49.9)	266 (53.4)	
Race					<.001
Caucasian	1193 (83.0)	480 (87.0)	408 (84.3)	305 (75.9)	
Other	245 (17.0)	72 (13.0)	76 (15.7)	97 (24.1)	
State of residency					<.001
In state	4586 (70.1)	1693 (76.0)	1569 (68.2)	1324 (65.6)	
Payer type					<.001
Medicare	523 (10.2)	99 (11.9)	218 (9.5)	206 (10.2)	
Medicaid	167 (3.2)	24 (2.9)	91 (4.0)	52 (2.6)	
Private coverage	3955 (76.8)	499 (60.0)	1841 (80.1)	1615 (80.0)	
Other	505 (9.8)	210 (25.2)	149 (6.5)	146 (7.2)	
Payer type by hospital volume					
HVCs, private coverage	3542 (79.0)	409 (58.3)	1715 (83.0)	1418 (82.5)	
MVCs, private coverage	334 (67.9)	69 (74.2)	107 (61.1)	158 (70.5)	
LVCs, private coverage	79 (45.9)	21 (55.3)	19 (33.3)	39 (50.6)	
Between volume groups *P* value	<.001	<.001	<.001	<.001	
Comorbidities					<.001
Yes	2645 (40.4)	768 (34.5)	951 (41.4)	926 (45.9)	
Comorbidities by hospital volume					
HVCs, yes	2213 (39.2)	624 (33.6)	825 (39.9)	764 (44.5)	
MVCs, yes	314 (46.8)	107 (39.3)	93 (53.1)	114 (50.9)	
LVCs, yes	118 (50.4)	37 (37.0)	33 (57.9)	48 (62.3)	
Between volume groups *P* value	<.001	.157	<.001	.002	

Abbreviations: HVC, high-volume center; LVC, low-volume center; MVC, medium-volume center.
[a]Neurofibromatosis Type 2 patients were excluded. Payer type data were not available for 1996-1998, so only data from 1999 to 2000 are reflected in the 1996-2000 period. Between volume groups value refers to statistical comparison of different volume centers. All *P* value statistics are derived from χ^2 analysis.

increasing proportions of patients with comorbidities were seen across all volume centers over time.

Total Charges and Payer Data

Total charges increased over the study period; after adjusting for inflation (US Department of Labor Bureau of Labor Statistics website, Consumer Price Index [CPI] inflation calculator, 1998-2008), the median charge in 1996-2000 was $38,607.92 compared with $91,338.00 in 2006-2010, with patients at HVCs having significantly lower total charges across all periods (**Table 2**).[14] When comparing 2006-2010 to 1996-2000, charges increased fastest at LVCs. Of all

Table 2. Total hospitalization charges by time period and hospital volume.

Total Charge, dollars	1996-2000	2001-2005	2006-2010	*P* Value
Median total charge	29,229.00	47,686.00	91,338.00	<.001
HVCs median total charge	28,482.00	46,042.00	87,181.00	
25th%	24,138.00	36,600.00	68,002.00	
75th%	36,678.50	67,823.00	119,989.00	
MVCs median total charge	33,330.00	64,359.00	112,612.00	
25th %	23,765.00	48,609.50	84,822.00	
75th %	43,988.50	102,559.00	143,475.00	
LVCs median total charge	37,818.00	72,741.00	151,055.00	
25th %	29,109.25	47,139.00	103,791.00	
75th %	54,617.25	115,200.00	230,170.00	
Between volume groups *P* value	<.001	<.001	<.001	

cases, 76.8% had private insurance coverage coded as the primary payer while Medicare and Medicaid accounted for 10.2% and 3.2%, respectively (**Table 1**). HVCs had a significantly higher proportion of privately insured patients (79.0%) compared with other volume centers.

Outcomes

Overall, 91.4% of the patients were routinely discharged, 0.2% (n = 12) died, and 8.4% required further care (**Table 3**). The average length of stay was 5.2 days (standard deviation [SD] 4.4). Over time, there were no statistically significant changes in disposition (P = .129); however, significant changes in length of stay occurred ($P < .001$). The average length of stay decreased significantly over time (5.5 ± 3.3 days in 1996-2000 vs 5.0 ± 5.0 days in 2006-2010). HVCs were significantly associated with the highest rates of routine discharge, the lowest rates of mortality and proportion of patients requiring further care, and the shortest hospital stays.

Over time, patients at HVCs increasingly had shorter hospital stays (5.4 ± 2.6 days in 1996-2000 vs 4.7 ± 4.2 days in 2006-2010; $P < .001$). Over time, patients at LVCs had increasingly longer hospital stays (6.8 ± 5.6 days in 1996-2000 vs 9.2 ± 9.6 days in 2006-2010; P = .092), decreasing rates of routine discharge (72.0% in 1996-2000 vs 59.7% in 2006-2010; P = .086), and increasing rates of patients requiring further care (28.0% in 1996-2000 vs 39.0% in 2006-2010; P = .123).

Analysis of Predictors on Outcome Measures and Total Charges

Multivariate logistic regression analysis showed that higher odds of being routinely discharged were associated with surgery at an HVC (odds ratio [OR] 5.48, $P < .001$) and MVC (OR 2.05, P = .001; **Table 4**), while age 65 years and older (OR 0.56, P = .025), presence of comorbidities (OR 0.54, $P < .001$), and Medicare (OR 0.55, P = .022) and Medicaid (OR 0.51, P = .002) payer types were associated with lower odds. Lower odds of mortality were associated with surgery only at a HVC (OR 0.10, P = .011). Higher odds of having lengths of stay less than or equal to the median for the 5-year time period in which a case occurred were associated with HVCs (OR 3.77, $P < .001$) and MVCs (OR 2.18, $P < .001$), while presence of comorbidities (OR 0.61, $P < .001$) and Medicaid (OR 0.36, $P < .001$) were associated with lower odds. A higher odds of having total charges less than or equal to the median for the 5-year period in which a case occurred were associated with HVCs (OR 2.12, P = .002), while presence of comorbidities (OR 0.70, $P < .001$) and Medicaid (OR 0.52, P = .003) were associated with lower odds.

Discussion

Our study demonstrated that significant changes in the treatment landscape of patients who have undergone VS excision in California from 1996 to 2010 have occurred. Although the state population has been increasing since 1996,[13] the number of VS excisions for the population has decreased significantly. This is interesting given that the incidence of vestibular schwannoma has been reported to be increasing.[1,6,15] Declining surgical volume is likely attributable to a trend toward conservative management such as observation with serial imaging or stereotactic radiation, improvements in imaging resolution for tracking growth, better understanding of tumor growth patterns, and decreasing tumor sizes at initial presentation.[3,4,16]

Median total charges have increased nearly 2.5 times from 1996-2000 to 2006-2010 after adjusting for inflation, with rates increasing fastest at LVCs. A significant cost-saving benefit is apparent at HVCs, corroborating previous findings that hospital volume has a strong inverse association with hospitalization charges.[17-20] Our analysis also showed that the proportion of privately insured patients differed widely among different volume centers, with 79.0% of patients privately insured at HVCs, followed by 67.9% at MVCs, compared with only 45.9% at LVCs.

Patients in 2006-2010 compared with 1996-2000 were less likely to be 65 years and older and more likely to be 35 to 64 years of age, have comorbidities, and reside out of

Table 3. Outcomes by time period and hospital volume.[a]

	Disposition		Length of Stay		
P value between time periods	.129		<.001		
	No. (%)				
	All Cases	High Volume	Medium Volume	Low Volume	*P* Value
1996-2010					
Disposition					<.001
Routine (home)	5985 (91.4)	5304 (94.0)	533 (79.4)	148 (63.2)	
Died	12 (0.2)	5 (0.1)	4 (0.6)	3 (1.3)	
Further care	548 (8.4)	331 (5.9)	134 (20.0)	83 (35.5)	
Length of stay					<.001
Mean ± SD days	5.2 ± 4.4	5.0 ± 3.9	6.0 ± 6.1	8.1 ± 8.4	
2006-2010					
Disposition					<.001
Routine (home)	1842 (91.2)	1623 (94.5)	173 (77.2)	46 (59.7)	
Died	1 (0.0)	0 (0.0)	(0.0)	1 (1.3)	
Further care	176 (8.7)	95 (5.5)	51 (22.8)	30 (39.0)	
Length of stay					<.001
Mean ± SD days	5.0 ± 5.0	4.7 ± 4.2	5.8 ± 7.0	9.2 ± 9.6	
2001-2005					
Disposition					<.001
Routine (home)	2119 (92.2)	1952 (94.4)	137 (78.3)	30 (52.6)	
Died	7 (0.3)	4 (0.2)	1 (0.6)	2 (3.5)	
Further care	173 (7.5)	111 (5.4)	37 (21.1)	25 (43.9)	
Length of stay					<.001
Mean ± SD days	5.0 ± 4.8	4.8 ± 4.5	6.7 ± 5.7	9.0 ± 10.3	
1996-2000					
Disposition					<.001
Routine (home)	2024 (90.9)	1729 (93.2)	223 (82.0)	72 (72.0)	
Died	4 (0.2)	1 (0.1)	3 (1.1)		
Further care	199 (8.9)	125 (6.7)	46 (16.9)	28 (28.0)	
Length of stay					<.001
Mean ± SD days	5.5 ± 3.3	5.4 ± 2.6	5.7 ± 5.6	6.8 ± 5.6	

[a]*P* values for disposition calculated from χ^2 analysis. *P* values for length of stay calculated from the Kruskal-Wallis H test.

state. Interestingly, HVCs treated increasing proportions of younger patients, privately insured patients, and patients without comorbidities compared with LVCs. Higher proportions of patients with comorbidities at LVCs has also been seen in other epidemiological studies on VS.[17,19] The reason for decreasing age at presentation of surgery is likely multifactorial. A regression analysis by Tan et al[3] demonstrated that decreasing tumor size (OR −8.04, $P < .001$), age (OR 8.26, $P < .001$), and year of presentation (OR 2.58, $P = .010$) were significantly associated with patient preference to choose observation rather than surgery. Thus, younger patients presenting for surgery are likely a product of an increasing trend toward observation of smaller tumors in older adults.

While HVCs were demonstrated to have a higher proportion of younger patients and patients without comorbidities, multivariate logistic regression analysis demonstrated that independent of age and comorbidity status, having a VS excision at an HVC led to significantly better outcomes across all outcome measures examined. A true difference in practice settings may exist, or perhaps a difference in selection criterion for surgery between HVCs and LVCs exists. Studies have found that high-volume surgeons were less likely to perform excision of VSs in patients with advanced morality risk scores or in patients with urgent or emergent cases.[19,20]

Older age was significantly associated with only decreased likelihood of routine discharge. Surgery at HVCs had significant associations with all dependent variables, while presence of comorbidities also had significant associations with nearly all dependent variables with the exception of mortality. Medicaid and Medicare patients were less likely to be routinely discharged. Medicaid patients were also less likely to have shorter length of stays and lower total charges.

Better outcomes at higher volume centers have been well established for many different surgical procedures including

Table 4. Multivariate logistic regression of predictor variables on clinical endpoints.[a]

	Routine Discharge				Mortality			
Predictors	Coefficient (SE)	Wald χ^2	OR (95% CI)	*P* Value	Coefficient (SE)	Wald χ^2	OR (95% CI)	*P* Value
Age (reference: <65 y)								
Age ≥65	–0.58 (0.26)	5.03	0.56 (0.34-0.93)	.025	0.56 (1.20)	0.22	1.74 (0.17-18.20)	.642
Comorbidity status (reference: none)								
≥1 comorbidities	–0.62 (0.14)	20.52	0.54 (0.41-0.71)	<.001	1.06 (0.84)	1.58	2.89 (0.55-15.07)	.208
Hospital volume (reference: low-volume centers)								
High-volume centers	1.70 (0.21)	67.55	5.48 (3.65-8.23)	<.001	–2.28 (0.90)	6.42	0.10 (0.02-0.60)	.011
Medium-volume centers	0.72 (0.23)	10.09	2.05 (1.32-3.20)	.001	–0.84 (0.87)	0.95	0.43 (0.08-2.34)	.329
Time period (reference: 1996-2000)								
2006-2010	–0.08 (0.19)	0.16	0.93 (0.64-1.35)	.685	–1.70 (1.25)	1.86	0.18 (0.02-2.11)	.173
2001-2005	0.02 (0.19)	0.02	1.02 (0.71-1.48)	.901	0.14 (0.86)	0.03	1.15 (0.21-6.26)	.869
Primary payer (reference: private insurance)								
Medicare	–0.60 (0.26)	5.25	0.55 (0.33-0.92)	.022	1.10 (1.28)	0.75	3.02 (0.25-36.71)	.386
Medicaid	–0.68 (0.22)	9.37	0.51 (0.33-0.78)	.002	1.06 (1.01)	1.10	2.87 (0.40-20.71)	.295
	Length of Stay ≤ Median for Case-Respective Time Period				**Total Charge ≤ Median for Case-Respective Time Period**			
Predictors	Coefficient (SE)	Wald χ^2	OR (95% CI)	*P* Value	Coefficient (SE)	Wald χ^2	OR (95% CI)	P Value
Age (reference: <65 y)								
Age ≥65 y	–0.36 (0.22)	2.80	0.70 (0.46-1.06)	.094	0.09 (0.24)	0.14	1.09 (0.68-1.76)	.710
Comorbidity status (reference: none)								
Comorbidity	–0.49 (0.09)	28.42	0.61 (0.51-0.73)	<.001	–0.36 (0.10)	13.14	0.70 (0.57-0.85)	<.001
Hospital volume (reference: low-volume centers)								
High-volume centers	1.33 (0.20)	44.27	3.77 (2.55-5.57)	<.001	0.75 (0.24)	9.91	2.12 (1.33-3.39)	.002
Medium-volume centers	0.78 (0.22)	12.48	2.18 (1.41-3.35)	<.001	0.39 (0.26)	2.16	1.47 (0.88-2.47)	.141
Primary payer (reference: private insurance)								
Medicare	–0.24 (0.22)	1.20	0.79 (0.52-1.21)	.273	–0.36 (0.25)	2.06	0.70 (0.43-1.14)	.151
Medicaid	–1.02 (0.19)	29.32	0.36 (0.25-0.52)	<.001	–0.65 (0.22)	8.95	0.52 (0.34-0.80)	.003

Abbreviations: CI, confidence interval; OR, odds ratio.
[a]Reference for age: less than age 65 years. References for comorbidity: no comorbidities. Reference for hospital volume: low-volume hospitals. Reference for time period: 1996-2000. Reference for payer type: private insurance. Median length of stay and total charge for a case were determined by the median value for the 5-year time period in which a case occurred. For analysis of mortality, there were only 9 cases that had data for all predictor variables of interest despite there being a total of 12 deaths that occurred in the data set, so only these cases were used for analysis. Data and calculations reflected in tables are in reference only to cases that contained reported information. Time was excluded from the regression analysis for length of stay and charge because the median values used to dichotomize cases were relative to time.

pancreatic cancer resections, abdominal aortic aneurysm repairs, radical prostatectomies, coronary artery bypass grafts, and head and neck cancer resections.[21-26] In a study of 10 diverse procedures representing several surgical subspecialties with mortality rates greater than 1% previously demonstrated to have volume-outcome benefit, Birkmeyer et al[21] estimated that a 5% to 25% reduction in mortality could be realized if these procedures were regionalized to higher volume centers.

Discussion of MVCs relative to their volume counterparts is also warranted. Because of the significantly positively skewed distribution of cases performed per hospital over the study period, discerning case load cutoffs for defining MVCs was admittedly challenging. Thus, while the conclusions for the differences found between HVCs and LVCs in this study are well substantiated, those for MVCs may be less clear. Of note, MVCs as defined by our study were found to demonstrate results largely intermediary relative to HVCs and LVCs, with respect to proportions of patients with comorbidities, hospitalization charges, length of stay, and disposition. Multivariate logistic regression demonstrated that while HVCs had a significant impact on all 4 clinical endpoints examined, surgery at an MVC affected only routine discharge and length of stay. These data largely suggest that while a significant difference exists between HVCs and LVCs, the difference between HVCs and MVCs is less pronounced.

This study has several limitations. The CHIDD does not provide information about the servicing surgeon or case complexity, such as tumor size, preoperative radiation, surgical approach, or extent of resection. These are all factors that have been demonstrated to affect surgical outcome for VS excisions, thus limiting our ability to more adequately examine the provided care.[8,17,27-29] Because data on the servicing surgeon were not available and considering that one of the major tenets of this study is the volume-outcome relationship, it is important to note that it is unclear to what extent the volume-outcome benefit observed here is attributable to surgeon experience and quality differences between hospitals. Our study also may have been limited by the definitions used for comorbidity, which may vary greatly between studies.

Conclusions

The profile of patients undergoing VS resection is changing. Decreasing surgical volume reflects a trend toward conservative management. Hospital charges are increasing across all volume centers, with rates highest at LVCs. Patients experience better outcomes and lower total charges at HVCs. Mortality rate, while decreasing, is still not insignificant.

Author Contributions

Omar H. Ahmed, manuscript composition, study design, data analysis, data acquisition, final approval to submit for publication; **Hossein Mahboubi**, study design, data analysis, data acquisition, manuscript revision, final approval to submit for publication; **Sari Lahham**, data analysis, manuscript revision, final approval to submit for publication; **Cory Pham**, data analysis, manuscript revision, final approval to submit for publication; **Hamid R. Djalilian**, study design, data analysis, manuscript revision, final approval to submit for publication.

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