Chapter 47
Acoustic Neuroma Surgical Cost and Outcome by Hospital Volume

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The amount of experience with challenging surgical procedures has been associated with the probability of a successful outcome (1, 2, 6, 14). In a review of the literature, Halm et al. (9) found that procedures performed at hospitals with a high volume of those surgeries resulted in better outcome than at hospitals where they are performed less often. For some more common procedures, such as cardiovascular surgeries, the health care system has responded to this information by promoting regionalization of care and has continued to evaluate the relationship between volume and outcome (2). Other challenging surgical procedures are just beginning to be examined from a experience-outcome perspective (14), primarily because of methodological issues with the definition of successful outcome and the infrequency of rare procedures.

The exploration of the hospital volume-experience relationship with patient outcome has been complicated by patient case-mix or the many and significant comorbidities of the patients in the sample (Table 47.2). Patients undergoing cardiovascular or cancer surgeries may have other comorbidities, have been hospitalized frequently, or may be older adults, all of which may adversely affect outcome independent of surgical expertise (15,19). Hospitals and case-mix are generally confounded in that a hospital may serve patients with more serious comorbidities relative to another hospital. It may be possible to tease out the affect of hospital volume statistically, but a much stronger case regarding this relationship is made by examining the affect of hospital volume on outcome within a more homogenous patient population with fewer and less significant comorbidities.

Another criticism of hospital volume-outcome studies has been directed toward the use of mortality as the patient outcome variable. Advances in medicine have led to low mortality rates for many procedures, reducing the ability to detect statistical differences, unless the sample is very large. Thus, there are few studies of the effect of volume on outcome in diseases or conditions that are less common. For the most part, the literature examines experience and outcome within common diseases across many hospitals and geographical areas. It is unknown whether the relationships between experience and outcome will be as strong in rare diseases requiring complex microsurgical procedures conducted by a team of experts. Metrics for the less common procedures, such as routine hospital discharge or length of hospital stay, avoid the statistical difficulties of infrequent occurrence and may provide a more fine-grained understanding of the impact of volume on outcome. A clearer examination of the relationship between hospital volume and complex surgical procedures in patients with few comorbidities using nonmorbidity outcomes has yet to be described.

In this study, we focus on such a patient sample and surgical procedure, i.e., craniotomy to remove an acoustic neuroma (vestibular schwannoma). An acoustic neuroma is a benign solid tumor arising from the vestibular nerve. It is rare, constituting only 6% of all intracranial tumors, with an incidence of 1 in 100,000. Patients with a unilateral acoustic neuroma are generally healthy, have not been hospitalized for other major surgeries or conditions, and are younger than patients in previous studies of volume and outcome. The average age of diagnosis of acoustic neuroma is 50 (18).

The primary treatment option for a symptomatic acoustic neuroma (or vestibular schwannoma) is microsurgical excision. Surgical resection has a number of technically involved aspects, and the selection of surgical approach (e.g., middle fossa, translabyrinthine, and suboccipital-retrosigmoidal) requires the consideration of a number of variables, including the amount of hearing in both ears, age, physical health, and size and location of the tumor. Surgical teams with extensive acoustic neuroma resection experience report mortality rates of less than 1%, normal or near-normal postoperative facial function in more than 80%, and hearing preservation rates in selected cases that may approach 70% (3, 17). An analysis of the hospital volume-outcome relationship using information from acoustic neuroma resections is attractive because of the relatively homogenous patient population and an absence of comorbidities and other confounding factors.

Medical insurance companies may refuse patient requests to have acoustic neuroma surgery at a high-volume hospital on the grounds that there is lack of evidence that patient outcome is substantially improved at the high-volume hospital or the perception that a high-volume hospital will have an increased cost with small differences in patient outcome. We report results using data from the California hospital discharge database to compare cost and outcome of 1213 acoustic neuroma surgeries among hospitals grouped by acoustic neuroma resection volume during a 3-year period. The hospitals were categorized into two groups of hospitals with a larger number of procedures performed and two groups of hospitals with fewer numbers of procedures performed. We examined the case mix at each hospital within the limits of the database. Discharge status, frequency of medical procedures indicating surgical complications, length of hospital stay, total charge of hospitalization, and average charge per day of hospitalization were the surgical outcome variables.

The database does not contain information regarding re-hospitalizations; thus, we were unable to examine hospital readmission rates. The database does not contain variables of interest for evaluation of postoperative success, such as facial nerve grade and hearing assessments; therefore, we were unable to completely determine success as defined by experts in neurotology. We hypothesized that surgeries conducted at high-volume hospitals would result in both a better surgical outcome, on average, and be less expensive relative to surgeries conducted at low-volume hospitals.

METHODS

Surgical data were extracted from the California hospital discharge database for the years 1996 to1998. Patient records were selected on the basis of principal diagnosis and principal procedure. Principal diagnosis is defined as the condition established to be the chief cause of admission of the patient to the facility of care. The principal procedure is defined as the procedure performed for definitive treatment rather than for diagnostic or exploratory purposes or that was required because of a complication. The principal procedure is that most related to the principal diagnosis, most significant in terms of risk, or was needed for Diagnosis-Related Group (DRG) assignment. The database used diagnosis and procedural codes specified in the International Classification of Diseases, 9th rev., Clinical Modification (ICD-9-CM).

Extracting records for which acoustic neuroma was the principal diagnosis and acoustic neuroma surgery was the principal procedure resulted in 1327 cases. To select the patients undergoing typical surgical resection for acoustic neuroma, the following types of patients were excluded:

• Patients admitted from a residential care facility, ambulatory surgery, long-term care, acute inpatient hospital care, other inpatient hospital care, were newborn, or were unknown

• Patients who were admitted as an infant (younger than 24 h old), had an unscheduled surgery (not scheduled at least 24 h in advance of admission), or were unknown.
• Procedures not performed on the day of admission. (Some facilities may admit the night before for early morning surgery; however, only 18 cases were excluded for this reason.)

After these exclusions, 1213 patient records remained. Records were then grouped by the number of acoustic neuroma surgeries performed at each hospital. Four categories of hospital volume were determined based on the frequency distribution of acoustic neuroma surgeries from 1996 to 1998. The lowest-volume hospital (Group 1) was defined as conducting between 1 and 5 surgeries each year (total 160 surgeries at 49 hospitals), and the second lowest-volume hospital (Group 2) was defined as conducting between 6 and 11 surgeries each year (163 surgeries at 7 hospitals). The higher-volume hospital (Group 3) was defined as conducting 15 to 50 surgeries each year (335 surgeries at 4 hospitals), and the highest-volume hospital (Group 4) conducted an average of 185 surgeries each year (555 surgeries at 1 hospital). The cutoff values for the groups were not designed to maximize group differences but followed the overall frequency distribution.

Discharge status was defined as the arrangement or event ending the hospital stay after surgery. The observed discharge outcomes were: 1) routine discharge, 2) acute care within treating hospital, 3) other care within treating hospital, 4) long-term care within treating hospital, 5) acute care at another hospital, 6) other care (not long-term care) at another hospital, 7) long-term care at another hospital, 8) died, 9) home health service, and 10) other. The following discharge outcomes were also possible in the database, but these discharge outcomes were not observed in this sample: 11) residential care facility, 12) prison/jail, and 13) left against medical advice.

Procedures performed in addition to and separate from the primary surgical procedure indicating surgical complications were: 1) craniotomy and craniectomy, 2) ventriculostomy, 3) extracranial ventricular shunt, 4) revision, removal, and irrigation of ventricular shunt, 5) other incision of cranial and peripheral nerves, and 6) anastomosis. See Table 47.1 for ICD-9-CM codes and additional descriptions for these procedures. A routine surgical outcome was defined as routine discharge status with none of the additional procedures listed above. Total charge and average charge per day of hospitalization were for services rendered during the length of stay, based on the hospital's full established rates. Charges included, but were not limited to, daily hospital services, ancillary services, and any patient care services. Hospital-based physician fees were not available in the database. Some records were excluded in the analysis of cost because of missing data (n = 188) on total charges. An additional two records were excluded: One showed an exceptionally low average charge per day (US $113), and one required numerous additional procedures that added greatly to the average charge per day, including additional repair to the cerebral meninges. The remaining 1023 records averaged US $692 per hospital day.

The Mann-Whitney test was used to test differences in total charges and average charges per day across the four hospital volume groups. Odds ratios were calculated to test for differences between the four groups in successful outcome (defined as routine discharge with no additional procedures). Odds ratios were also used to compare the four groups in frequency of routine discharge, frequency of no apparent complications, and total charges of hospitalization. Given the large disparity in number of surgeries performed at the highest-volume hospital (Group 4), separate analyses were conducted comparing Groups 1 and 2 with Group 3. These analyses resulted in nearly equal sample sizes and showed no significant differences from the analyses using all the data. These analyses were performed for the aggregated 3 years of available data and on the data from each year. A second set of analyses were conducted to determine any trends or changes over time in the relationship of volume and outcome. The results of the individual analyses by year (1996, 1997, and 1998) were not different from the aggregate 3-year analysis, and there were no changes in the results over the 3 years of data.

RESULTS

Patient Characteristics

The case-mix of each hospital group was explored for differences in patient sex, race, and age at surgery. As expected for an acoustic neuroma patient sample, there were nearly equal numbers of men and women (48 and 52%, respectively) in the total sample and across hospital groups. The sample was 86% white. Group 1 had significantly fewer white patients (79%) relative to Groups 2, 3, and 4 (÷2; $P < 0.01$). The mean age at surgery was 50.6 years for the entire sample, typical of acoustic neuroma patients. The mean age at surgery differed across the hospital groups, with Group 4, on average, conducting procedures on somewhat younger patients (47.7 years; univariate analysis of variance; $P < 0.01$). Overall, just 5% of the entire sample was older than 75 years. Groups 1, 2, and 3 tended to operate on more patients older than 75 years than Group 4 ($P < 0.01$; ÷2).

Nearly 70% of the sample presented without a comorbid condition, typical of the otherwise healthy acoustic neuroma patient. The most frequently reported comorbidity was “unspecified hypertension” (13% of entire sample), followed by “other nervous system disorders” (7% of the entire sample). All other comorbidities examined ranged from 0.8 to 3% of the entire sample. Some patients reported with multiple comorbidities. Forty percent of the patients in Groups 1 and 2 reported at least one comorbidity, whereas in Groups 3 and 4, 25% of the patients reported comorbidities.

Surgical Outcomes

Table 47.3 provides acoustic neuroma surgery hospital discharge outcome by hospital-volume group. A noticeable increase in the chance of routine discharge with increasing hospital surgical volume was observed. The data show that the risk of a nonroutine discharge is small in Group 4 (3%), but it is greater than 1 in 4 in Group 1. The odds ratios comparing the four hospital groups in terms of likelihood of routine surgical outcome are presented in Table 47.4. Surgeries at the Group 4 hospital were 14.8 times more likely to have a routine surgical outcome than surgeries at the Group 1 hospitals (95% confidence interval [CI], 8.2–26.6). Surgeries at the Group 3 hospitals were 4.6 times more likely to have a routine surgical outcome than surgeries at the Group 1 hospitals (Table 47.4).

When comparing surgeries in Groups 1 and 2 ($n = 323$) to surgeries in Group 3 ($n = 335$), Group 3 had a significantly smaller amount of nonroutine discharges (÷2 = 24.6; $P < 0.0001$). Group 3 had 4% nonroutine discharges compared to 10.5% in Groups 1 and 2. Thus, even when excluding Group 4, a significant effect of volume on routine discharge was found.

Four additional surgical procedures were identified that indicated a complication from an acoustic neuroma surgery: craniotomy-craniectomy, ventriculostomy, extracranial ventricular shunt, and anastomosis (Table 47.5). Overall, there were few additional procedures in the sample (2.8%). Craniotomy-craniectomy occurred most often of the additional procedures (56%). Groups 3 and 4 had significantly fewer additional surgical procedures relative to Groups 1 and 2 ($P < 0.05$).

For the patients with at least one reported comorbidity (n = 357), discharge status was analyzed by hospital group. More than one third of the patients with a comorbidity had a nonroutine discharge in Group 1 (36.5% of 63 patients with comorbidities). This percentage decreases to 4.2% in Group 4. Patients with comorbidities in Groups 2 and 3 also had fewer nonroutine discharges (15.9% in Group 2 and 9.5% in Group 3). These differences were significant (÷2 = 38.7; $P < 0.0001$). If the patients from Group 4 are removed, comorbid patients at the Group 3 hospitals had a significantly better chance of a routine discharge when compared with Groups 1 and 2 (÷2 = 10.2; $P < 0.001$).

The average total length of stay by hospital volume group is shown in Table 47.6. The average length of stay ranged from 4.4 to 6.0 days. There were no significant differences between the hospital groups in average length of hospital stay (Mann-Whitney; not significant). The average hospital stay for Groups 1 and 2 was 5.7 days (SD, 4.0) compared with 4.4 days (SD, 2.1) for Group 3. This difference was significant (t test; $P < 0.0001$).

Cost

Total hospitalization cost by hospital volume group is shown in Table 47.7. Total cost is reported in quartiles based on total dollar charges for all surgeries with cost data. The median total charge was US $26,862. Table 47.8 shows average hospitalization cost per day (total cost divided by days in hospital). Average cost per hospitalization day was broken into quartiles based on all surgeries with cost data. Median average cost per day was US $5,032. Both Tables 47.7 and 47.8 suggest that the higher-volume hospitals are, on average, less expensive than the lower-volume hospitals, despite the nearly equal length of hospital stay. The difference in cost is particularly apparent for the Group 4 hospital. The highest-volume hospital had lowest total charges and cost per day than any of the other three groups ($P < 0.001$). Group 3 alone also had lower total charges and average charges per day than the Groups 1 and 3 combined ($P < 0.001$).

DISCUSSION

Our results provide evidence that acoustic neuroma surgeries, a technically challenging and rare surgery, conducted at high-volume hospitals have a better outcome and cost less on average than surgeries at low-volume hospitals. Even if the patient experienced a comorbid condition at the time of the acoustic neuroma surgery, the chances of a routine discharge were significantly better at the higher-volume hospitals compared with the lower-volume hospitals. The results are consistent with literature supporting the existence of a “higher procedural volume, better outcome” relationship for a variety of high-risk surgical procedures. For example, treatments for cardiovascular disease and pancreatic, lung, or liver cancer have been reported to have substantially lower mortality rates at high-volume hospitals than at low-volume hospitals (4, 5, 8–13, 16).

The strength of the association between volume and outcome has varied by the procedure studied. For example, pancreatic cancer surgery had one of the largest differences in mortality rate across high- and low-volume hospitals, whereas total knee replacements had one of the lowest. Findings regarding the benefits of a high volume in improving perioperative and long-term mortality are particularly striking for high-risk procedures, such as esophagectomy and pancreatic resection. For less risky and more common procedures, including other types of cancer and cardiovascular disease, volume differences regarding mortality persist but are more modest (9).

These studies have used mortality as the main outcome variable. In the past, acoustic neuroma resection has been associated with higher levels of mortality. However, advances in microsurgical techniques, intraoperative monitoring, and neuroanesthesia have significantly reduced the mortality rate from approximately 40% in the 1950s (8) to 2 to 5% in 1979 (20) and an additional decrease in mortality rate to 0.08% in the present sample. Because mortality rates are infrequent and acoustic neuroma is a rare condition, use of mortality as the outcome variable would have presented statistical difficulties. Here, we have used data from the California hospital discharge database regarding complication rates instead of mortality. Patients treated in higher-volume centers were significantly less likely to undergo procedures in the postoperative period indicative of complications such as brain hemorrhage, hydrocephalus, and cerebrospinal fluid leak. Also, patients at higher-volume centers were more likely to be discharged to their home without need for rehabilitative services. Patients treated at lower-volume centers were more likely to be discharged from the hospital to other inpatient facilities or to need continuing rehabilitative services.

Establishing a relationship between hospital volume and successful surgical outcome in a relatively healthy patient population undergoing a rare microsurgical procedure using outcome measures other than mortality represents an important methodological step forward for the volume/outcome literature. The results show that much experience with a relatively rare disease results in better patient outcome and reduced costs, thereby reducing the burden on the health care system. The robust relationship between experience and outcome suggests that complex cases or persons with comorbidities are best served at high-volume centers, which are also the most cost-effective.

Whereas our data strongly suggest a relationship between hospital volume and outcome in the surgical treatment of acoustic neuroma, there are several limitations. As with other studies in this area, we made use of a centralized database and were restricted to the information recorded in this database. However, there are factors that are important predictors of successful treatment outcome for acoustic neuroma surgery for neurootologist, which were not available from the database. One important predictor of treatment outcome is tumor size. Acoustic neuromas may be detected or become symptomatic at various sizes, typically, at presentation, acoustic neuromas range from several millimeters to larger than 4 cm. The potential for postoperative complications (such as facial nerve paresis) is greater for large tumors than for small tumors (18). However, we have no reason to believe that the low-volume hospitals resect larger tumors compared with the high-volume hospitals. It is often the case that the larger tumors are resected at the higher-volume centers.

Because the California hospital discharge database does not register information by individual surgeon, our analysis centered only on hospital volume. Various studies comparing the effects of hospital volume and surgeon volume have shown each to be independently significant. This has not, however, been a universal finding. Because acoustic neuroma surgery is typically performed by a two-surgeon team, analysis of individual surgeon volume becomes a particularly complicated issue. In addition, hospital volume could interact with surgeon volume. For example, high hospital volume may be associated with improved outcome for medium-volume surgeons relative to outcome for medium-volume surgeons operating in lower volume centers.

The California hospital discharge database data also show demographic or case-mix differences among hospital groups. Compared with previous hospital volume-outcome studies, these patients had fewer comorbidities, fewer serious comorbidities, and were younger. Those at low-volume centers tended to be older and have more comorbidities. This disparity may reflect actual differences among the hospital groups in the patients from their service areas.

Alternatively, the difference could be related to treatment philosophy. The high-volume centers may pursue a more conservative approach to patients with these slow growing tumors. “Watch and wait” is a treatment option for many older patients, as well as for those with severe illnesses suggestive of shorter expected actuarial survival. Because data for all patients, including those seen in consultation but not treated with surgery, were not available from the California hospital discharge database, the reasons for the age and comorbidity differences cannot be definitively determined. Future studies should provide for case-mix adjustments to eliminate possible differences in the complexity of cases seen at low- versus high-volume hospitals. Preoperative tumor size, number of previous acoustic neuroma surgeries, preoperative facial nerve grade, preoperative hearing ability, and presence or absence of Neurofibromatosis Type II are examples of key variables indicating the complexity of the case.

The more difficult cases are often referred to high-volume hospitals, and, as a result, a benefit in outcome at the high-volume hospitals may be even greater than our results suggest. Our results suggest that acoustic neuroma resection is less expensive at high-volume hospitals than low-volume hospitals in terms of both average total hospitalization charge and average cost per hospitalization day. This was the case for the Group 3 hospitals relative to Groups 1 and 2 in addition to the lower average cost at the Group 4 hospital. Our data do not take into consideration costs after discharge, which are obviously larger for patients who do not have routine outcomes. Thus, overall costs are even larger for patients undergoing surgery in low-volume hospitals. Our findings are consistent with other studies that found high-volume hospitals to be less expensive for radical prostatectomy and abdominal aortic aneurysm repair (5, 7).

Further investigation with more direct measures of patient outcome, such as facial nerve grade and other patient-specific morbidity factors, are required to fully clarify the difference in outcome between hospitals with differing levels of expertise for acoustic neuroma resection. However, these data show that the rate of complications are significantly less frequent and the overall costs are lower at high-volume hospitals, indicating that high-volume hospitals are cost-effective for the patient and for third-party payers.

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