Outcome and Cost of Craniotomy Performed to Treat Tumors in Regional Academic Referral Centers

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Received, March 5, 2002.
Accepted, January 8, 2003.

OBJECTIVE: Improved clinical and economic outcomes for high-risk surgical procedures have been previously cited in support of regionalization. The goal of this study was to examine the effects of regionalization by analyzing the cost and outcome of craniotomy for tumors and to compare the findings in academic medical centers versus community-based hospitals.

METHODS: Outcomes and charges were analyzed for all adult patients undergoing craniotomy for tumor in 33 nonfederal acute care hospitals in Maryland using the Maryland Health Service Cost Review Commission database for the years 1990 to 1996. A total of 4723 patients who underwent craniotomy for tumor were selected on the basis of Diagnostic Related Group 1 (craniotomy except for trauma, age 18 or older) and *International Classification of Diseases–9th Revision* diagnosis code for benign tumor, primary malignant neoplasm, or secondary malignant neoplasm (codes 191, 192, 194, 200, 225, 227, 228, 237, and 239). Hospitals were categorized as high-volume hospitals (>50 craniotomies/yr) or low-volume hospitals (≤50 craniotomies/yr). In-hospital mortality, length of stay, and charges were evaluated.

RESULTS: The mortality rate was 2.5% at high-volume centers and 4.9% at low-volume hospitals with an adjusted relative risk of 1.4 ($P < 0.05$), assuming equivalence of disease severity. Adjusted average length of stay in high-volume centers was 6.8, as compared with 8.8 days in low-volume hospitals ($P < 0.001$). Adjusted average total charges were $15,867 at high-volume centers and $14,045 at low-volume centers ($P < 0.001$). If all patients in the state had been treated at centers with survival rates equal to those achieved by the high-volume centers, then 46 patients would not have died of operation; that is, 48.6% fewer patients would have died, at an additional adjusted cost of $76,395 dollars per patient saved.

CONCLUSION: High-volume regional medical centers are capable of providing services with improved mortality rates and fewer hospital days, although with adjusted costs slightly higher than those at low-volume hospitals.

KEY WORDS: Craniotomy, Outcomes, Regionalization, Tumor

Neurosurgery 52:1056-1065, 2003 DOI: 10.1227/01.NEU.0000057745.48813.93 www.neurosurgery-online.com

With managed care providing the incentive to lower cost, it is important to maintain the best possible care and outcome for the patient. Studies have shown improved clinical and economic outcomes for high-risk surgical procedures including pancreaticoduodenectomy, open-heart surgery, vascular surgery, transurethral resection of the prostate, and coronary bypass in support of regionalization (3–5, 7, 12–14). Regionalization, the selective referral of patients from a geographic area to a limited number of centers, has been considered a means of providing centers-of-expertise at a limited number of high-volume referral sites in any given area (5, 12). Whereas previous studies showed the benefits of regionalization for patients sustaining neurotrauma and undergoing craniotomy for a cerebral aneurysm, no studies have evaluated regionalization with regard to the treatment of patients needing craniotomy for tumor (10, 16).

The Institute of Medicine established the National Cancer Policy Board in 1997 to review the quality and delivery of care for patients with cancer. Among their recommendations to improve care for cancer patients, the National Cancer Policy Board states "that patients undergoing procedures that are technically difficult to perform and have been associated with higher mortality in lower-volume settings, [should] receive care at facilities with extensive experience (i.e. high-volume facilities)." These technically difficult procedures include total or partial esophagectomy, pancreatectomy, removal of pelvic organs, and complex chemotherapy regimens (9). Given the technical challenges associated with craniotomy for tumor, we reviewed 4723 cases from the Maryland Health Service Cost Review Commission (HSCRC) database for the years 1990 to 1996 to evaluate the benefits of regionalization for craniotomy for tumor.

High-volume centers with neurosurgical services provide a regional facility for management of complex neurosurgical diseases. Generally, such regional centers are teaching hospitals, primarily affiliated with a school of medicine, and therefore with a full-time faculty medical staff. Other attributes of regional centers include a highly skilled surgical team and support staff, as well as fully equipped facilities. Surgery is supported by dedicated operating rooms with specialized neuro-nursing and a neuroanesthesia team dedicated to all neurosurgical procedures. There is a neurological intensive care unit with a full-time staff in attendance at all times. Nursing services are specialized, both in the intensive care unit and on the wards. Complete neuroradiological facilities are available on a 24-hour basis, neurosurgery resident coverage is present in the hospital at all times, chief resident coverage is available within 15 minutes, and consultation with senior neurosurgical academic staff is available at all times for problems with any patients. Utilization of hospital services is not restricted to full-time academic faculty; presumably, nonfaculty neurosurgeons enjoy part-time appointments. Most importantly, operating physicians, whether full-time or part-time, have experience in performing a high volume of operations.

Our contention was that the comprehensive spectrum of support available for diagnosis and for operative and postoperative treatment available to all neurosurgeons admitting inpatients to a regional high-volume center would improve the outcomes for patients managed in the center-of-expertise format. To assess this contention, an analysis of hospital charges and outcomes was performed for patients undergoing craniotomy for tumors in Maryland during the period 1990 to 1996.

PATIENTS AND METHODS

Hospital and Patient Characteristics

The Maryland HSCRC, a publicly available data set, was used to collect hospital discharge data from 33 nonfederal acute care hospitals in Maryland that performed craniotomy for tumors between January 1990 and December 1996. This database contains information on hospital identification, patient demographics, patient disposition at discharge, length of hospital stay, and total hospital charges. The Maryland HSCRC database is unique in that Maryland is the only state in which hospital rates are strictly regulated. Therefore, the charges approximate the actual costs. A patient was selected if the discharge record contained both Diagnostic Related Group 1 (craniotomy for tumor or hemorrhage without trauma), and an *International Classification of Diseases–9th Revision* diagnosis code for benign tumor, primary malignant neoplasm, or secondary malignant neoplasm (codes 191, 192, 194, 200, 225, 227, 228, 237, and 239). Hospital volume was the main independent variable and was modeled as a categorical variable. If a hospital performed at least one craniotomy during the study period, it was included in the analysis. Hospitals were categorized into two groups: a high-volume hospital was defined as having performed more than 50 craniotomies per year on average (i.e., 1 craniotomy/wk), and a low-volume hospital was defined as having performed 50 or fewer craniotomies per year.

Patient Characteristics

Age, race (white, African-American, other), sex, time interval (1990–1993, 1994–1996), diagnosis (benign, primary malignancy, secondary malignancy), payment source (commercial, Medicare, Medicaid, other), and place of residence (Baltimore inner city, central Maryland, southern Maryland, Maryland suburbs of Washington, DC, Eastern Shore of Maryland, western Maryland, out-of-state, or unknown) were considered as other independent variables. The Dartmouth-Manitoba adaptation of the Charlson comorbidity index was used to determine comorbidity scores, which were treated as a continuous variable (2, 15).

Patient Outcomes

The outcomes studied were in-hospital mortality, mean total length of stay, and mean total hospital charges. Results are presented in constant 1996 dollars by using the annual Health Care Financing Administration input price indices to adjust hospital charges for inflation (7) (S Heffler, personal communication, April 1997).

Statistical Analysis

Patient characteristics were compared by two methods: the χ^2 statistic for categorical variables (e.g., sex and race) and analysis of variance for continuous variables (e.g., age and comorbidity). The association of each outcome and each independent variable was assessed by bivariate analysis. From these analyses, we determined which variables to include in the multivariate models. We also examined the relationship between case volume and time period to ensure that there was no unusual temporal trend in the number of operations performed.

Poisson regression models were used to compare mortality outcomes across groups. Poisson models are used when event rates are low, as they are in the case of mortality in this study. Mortality rate was calculated by diagnosis group (i.e., benign tumor, primary malignancy, and secondary malignancy) and compared in the same manner. The Poisson model adjusted for age, race, comorbidity score, payment source, and diagnosis.

We calculated potential and attributable survivorship by examining the difference in mortality between high-volume centers and all low-volume hospitals as a group. We estimated lives saved as a result of procedures being performed at high-volume centers instead of low-volume hospitals by calculating the expected mortality (by multiplying the mortality rate for all other hospitals by the number of patients being operated on at high-volume centers) and then subtracting this figure from the number of deaths observed at high-volume centers. The result is survivorship attributable to having procedures performed at high-volume centers. Similarly, we calculated potential lives saved at high-volume hospitals by applying the mortality rate at the high-volume centers to the procedures performed at the other hospitals, then subtracting expected deaths from observed deaths, and thus determining potential survivorship if care had been rendered at a high-volume center. A similar analysis was performed for additional cost and saved days.

Average hospital charges and length of stay were assessed by using multiple linear regressions, which adjusted for patient age, sex, race, comorbidity score, payment source, time interval, and diagnosis. Because both average charge and length of stay of these variables were skewed to the right, a natural log transformation was performed to achieve a more normal distribution. The data were transformed back to their original scales by exponentiating the values predicted by the models to estimate the adjusted length of stay and adjusted total charges. Data management and analysis were performed by using Microsoft Access 97 (Microsoft Corp., Redmond, WA) and Stata 5.0 software (Stata Release 5; College Station, TX).

RESULTS

Patient and Hospital Characteristics

A total of 4723 patients underwent craniotomy for tumor in Maryland during the 7-year study period: 1912 with benign tumors, 1740 with primary malignant neoplasms, and 1071 with secondary malignancies. As shown in *Table 1*, 59.1% of the study population was operated on at one of the two regional centers, whereas 40.9% of the population had the procedure performed at a community hospital. Both of the hospitals in the high-volume group are academic medical centers with accredited neurosurgical training programs. One high-volume provider had 1706 cases for the given period, and the other had 1084 cases. The remaining 31 community hospitals in the low-volume group each had fewer than 200 total cases for the 7-year period (*Fig. 1*).

Table 2 displays comparative patient characteristics at the high-volume centers versus the low-volume hospitals in Maryland. Significant differences in patient characteristics were noted in age, race, comorbidity score, diagnosis, case volume distribution, payment source, and place of residence. High-volume centers treated a higher proportion of younger, Caucasian, and commercially insured patients from out-of-state and a higher percentage of patients with a comorbidity score of zero. The high-volume providers had an increased number of procedures in the second half of the study period, whereas the low-volume providers had a decrease in the number of cases.

In-hospital Mortality

In-hospital mortality rates by outcome for patients undergoing craniotomy for tumor of all types are summarized in *Table 3*, which details the observed mortality rates and the unadjusted and adjusted relative risk of mortality at high- and low-volume hospitals. At high-volume hospitals, the observed mortality was 2.5%, which is approximately 28% lower than the average state mortality and almost a 50% reduction in mortality when compared with that of low-volume hospitals, where the mortality rate was 4.9%. Patients had a 2.0 times greater unadjusted risk of dying at a low-volume hospital than at a high-volume center ($P < 0.001$). Relative risk adjusted for age, race, comorbidity score, payment source, and diagnosis was 1.4 ($P < 0.05$). When mortality rates of high-volume and low-volume providers are compared by diagnosis, only relative risk for secondary malignancies was statistically significant (adjusted relative risk, 2.1; $P < 0.05$). *Table 4* shows mortality by diagnosis for high-volume versus low-volume providers.

TABLE 1. Hospital group classification and characteristics of patients undergoing craniotomy for tumor

Volume (cases/yr)	Hospital volume group	No. of hospitals	Total cases	Average cases/hospital/yr
≤50	Low	31	1933	8.9 (40.9%)
>50	High	2	2790	199.3 (59.1%)
Total		33	4723	20.4 (100.0%)

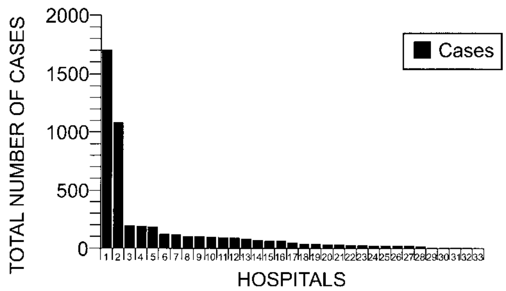

FIGURE 1. *Distribution of tumor cases at 33 Maryland hospitals from January 1990 through December 1996.*

Potential Lives Saved

The data indicate that if the best outcome had been achieved by all providers in the state during the study period, the overall mortality would have been reduced by approximately 48%; that is, 46 patients would have survived. Additionally, 5025.8 days of hospitalization would have been saved, although at an additional adjusted cost of $3,514,194, or $76,395 per patient saved. Attributable mortality was approximately 49% of expected deaths; i.e., 67 patients would have died if they had not undergone craniotomy at a high-volume hospital.

Length of Stay

Average length of stay was lower at the high-volume centers compared with low-volume hospitals. As shown in *Table 3*, the unadjusted average length of stay at low-volume hospitals was 12.5 days, compared with an average of 9.9 days at high-volume centers ($P < 0.001$). After adjustment for patient age, race, comorbidity score, payment source, diagnosis, and time interval, there remained a statistically significant difference between high-volume centers (6.8 d) and low-volume hospitals (8.8 d) ($P < 0.001$).

Hospital Charges

Hospital charges were significantly higher at high-volume centers than at low-volume hospitals (*Table 3*). Total charges at high-volume centers and low-volume hospitals were $19,356 and $16,977, respectively. The pattern remained when these values were adjusted for age, sex, time interval, payment source, diagnosis, and comorbidity score. Adjusted values were $15,867 for high-volume centers and $14,049 for low-volume hospitals. All P values were <0.001.

DISCUSSION

These data demonstrate that patients who underwent intracranial procedures for tumor performed at high-volume centers experienced better clinical outcomes and shorter average hospital stays, although costs were higher when compared with those for low-volume centers. This is consistent with previous studies showing that higher volume yields better outcome (5, 7, 11, 12, 14, 17).

These improvements may be attributable to a number of factors. The large number of operations performed relative to other hospitals in the state may result in increased expertise throughout the specialized care team. The skills of a well-trained house staff, nursing team, and all the related medical specialties available at all hours and organized by the team or center concept are important. Experienced neuroanesthesiologists and a unique neurological intensive care unit provide superior perioperative management with earlier detection and treatment of complications. Other factors include equipment that is advanced and of high quality and attending surgeon expertise. However, experience and expertise alone are not the only explanation. The availability of highly specialized centers for faculty use is a very important factor and has been investigated in other studies (7, 12). These data speak strongly for the concept that the performance of craniotomies for tumor should be concentrated in regional centers with equivalent support capabilities.

There are a few potential limitations to this study. Our principal outcome measure was in-hospital mortality. Obviously, other aspects of outcome, such as complications, functional status, quality of life, the need for further care, and postdischarge survival, should also be considered in a properly designed prospective study. However, these measures are not available in the discharge database. Another potential limitation relates to our categorization of hospitals. In our main analysis, hospitals are considered either high-volume or low-volume on the basis of a cutpoint of 50 craniotomies per year. Such aggregation may be too broad, because it assumes that the mortality rate of hospitals with very high volumes (>200 cases/yr) is similar to the mortality rate of hospitals with lesser volumes (e.g., <100 cases/yr). We conducted a sensitivity analysis, which further refined the volume groupings into four tiers: high volume (>200 cases/yr), medium volume (101–200 cases/yr), low volume (11–100 cases/yr), and minimal volume (≤10 cases/yr) (*Table 5*). The results not only support our original finding that mortality increases at low-volume centers but further substantiate this finding with a clear trend toward higher mortality as the case volume of the hospital groups decreases in the four-tier groupings from high to minimal.

The improvement in mortality did not come without an additional cost. Lack of efficiency, the additional cost of graduate medical education, and a commitment to research are often cited to explain this presumed increase in cost. The contributing costs have never been well defined, but house staff salaries and benefits, increased utilization of ancillary testing and of radiology facilities, and extended operating room time are all factors. Academic medical centers, often assuming the increased costs to be true without verification, cite case mix differences, and increased severity in particular, as additional causes of higher costs. A number of socioeconomic factors, such as provision of care for the indigent and nearly indigent, and the costs associated with an urban location, such as facilities maintenance and campus security, are other contributing factors.

TABLE 2. Distribution of patient characteristics and other variables by hospital volume group[a]

Characteristics	Hospital volume groups[b] Statewide (n = 4723)	High (n = 2790)	Low (n = 1933)	*P* value[c]
Mean age (yr)	54.5	52.0	58.1	<0.01
Standard deviation	15.5	15.3	15.0	
Sex (% male)	48.4	49.2	47.2	NS
Race				
% white	83.3	83.3	83.3	<0.05
% black	13.7	13.3	14.4	
Comorbidity score				
% none	71.5	77.1	63.4	<0.01
% 1	10.8	9.5	12.7	
% 2	8.5	7.7	9.6	
% ≥3	9.2	5.7	14.4	
Diagnosis				
% benign	40.5	46.5	31.8	<0.01
% primary malignant	36.8	35.6	38.6	
% secondary malignant	22.7	17.9	29.6	
Case volume distribution by time interval[d]				
% CY 1990–1993	54.2	57.2	42.8	<0.01
% CY 1994–1996	45.8	61.3	38.7	
Payment source				
% commercial	58.0	63.1	50.7	<0.01
% Medicare	29.7	24.0	38.1	
% Medicaid	7.1	7.4	6.8	
% other	5.2	5.7	4.5	
Place of residence				
% Baltimore inner city	7.3	7.2	7.5	<0.01
% Central Maryland	45.7	45.5	45.9	
% Washington DC suburbs	12.7	7.8	19.8	
% out-of-state	19.5	26.6	9.2	

[a] NS, not significant; CY, calendar year.
[b] Low volume, ≤50 cases per year; high volume, >50 cases per year.
[c] χ^2 for categorical variables, analysis of variance for continuous variable (age), for the comparison between volume groups.
[d] Row totals for hospital volume groups.

Previous studies of high-risk surgical procedures have demonstrated better outcomes at decreased costs (5, 7, 12). Cost and length of stay were not studied in previous studies of craniotomy outcomes with respect to treatment of aneurysms and neurotrauma (10, 16). One possibility for the higher cost at high-volume centers in our study may relate to the average difference in length of stay. Hospital charges are weighted to the first few days of hospitalization owing to time in the operating room and in the intensive care unit, as well as follow-up radiographic studies. These costs are higher at tertiary care centers for the reasons listed above. The additional days spent in community-based hospitals allow academic centers to make up for earlier cost inequalities. Lower complication rates and more specialized care may also contribute to high-volume centers being more cost-effective.

Many academic medical centers perform a high volume of high-risk procedures and serve as tertiary referral centers on a state, regional, national, or international basis. These data suggest that there are great gains to be made, both in terms of saving human lives and in conservation of resources, by maintaining and expanding the concept of centers of expertise on a regional basis. No patient should be deprived of the opportunity for an improved outcome. Academic medical centers and other tertiary referral hospitals need to assess the costs and

TABLE 3. Unadjusted and adjusted outcomes by hospital volume group[a]

Outcome	Statewide	Hospital volume group	
		High	Low
Mortality			
Unadjusted (%)	3.5%	2.5%	4.9%
Unadjusted relative risk	NA	1.0	2.0[b]
Adjusted relative risk[c]	NA	1.0	1.4[d]
Average length of stay (d)			
Unadjusted	11.0	9.9	12.5[b]
Adjusted[c]	NA	6.8	8.8[b]
Average total charges ($)			
Unadjusted	18,383	19,356	16,977[b]
Adjusted[c]	NA	15,867	14,049[b]

[a] NA, not applicable.
[b] $P < 0.001$ when compared with the high-volume providers.
[c] Poisson regression model adjusts for age, race, comorbidity score, payment source, and diagnosis. Multivariate linear regression models for length of stay and total hospital charges adjust for age, sex, race, comorbidity score, payment source, time interval, and diagnosis.
[d] $P < 0.05$ when compared with the high-volume providers.

TABLE 4. Unadjusted and adjusted mortality by hospital volume group[a]

Mortality	Statewide	Hospital volume group	
		High	Low
Benign			
Unadjusted (%)	2.1%	1.3%	3.7%
Unadjusted relative risk	NA	1.0	2.9[b]
Adjusted relative risk[c]	NA	1.0	1.9[d]
Primary malignant			
Unadjusted	4.1%	3.7%	4.7%
Unadjusted relative risk	NA	1.0	1.3[d]
Adjusted relative risk[c]	NA	1.0	1.0[d]
Secondary malignant			
Unadjusted	4.9%	3.0%	6.5%
Unadjusted relative risk	NA	1.0	2.2[e]
Adjusted relative risk[c]	NA	1.0	2.1[e]

[a] NA, not applicable.
[b] $P = 0.001$ when compared with the high-volume providers.
[c] Poisson regression model adjusts for age, race, comorbidity score, and payment source.
[d] Not significant.
[e] $P < 0.05$ when compared with the high-volume providers.

outcome of care to determine which services are improved by aggregation in tertiary centers and which can be performed equally well in less specialized facilities.

The center-of-expertise concept is characterized by regional centers with the organization of all necessary and ancillary services within the department. These centers are disease oriented and incorporate all specialists, surgical and nonsurgical, who may play a role in the management of a particular disease. Thus, all neurosurgery faculty have subspecialized interests, and the teams include several faculty members who specialize in neuro-oncology tumor surgery. Within the specialized nursing, anesthesia, and radiology teams are individuals who are further subspecialized, as an integral part of the center concept. All patients of full-time academic faculty are included in these centers, and the facilities are available for the patients of all private practitioners who use the hospital. For example, the neuro-oncology programs often include neurosurgeons, neurologists, neurological oncologists, radiation oncologists, neuropathologists, neuroradiologists, and dedicated nurses. Weekly teaching conferences are held to discuss un-

TABLE 5. Unadjusted and adjusted outcomes by four-tier hospital volume groups[a]

Mortality	Statewide	Hospital volume groups			
		High	Medium	Low	Minimal
Benign					
Unadjusted	2.1%	1.2%	1.5%	3.0%	6.0%
Unadjusted relative risk	NA	1.0	1.2[b]	2.5[c]	4.9[d]
Adjusted relative risk[e]	NA	1.0	1.0[b]	1.6[b]	2.6[c]
Primary malignant					
Unadjusted	4.1%	3.8%	3.6%	4.0%	6.2%
Unadjusted relative risk	NA	1.0	1.0[b]	1.1[b]	1.6[b]
Adjusted relative risk[e]	NA	1.0	1.0[b]	0.8[b]	1.2[b]
Secondary malignant					
Unadjusted	4.9%	2.4%	3.3%	4.6%	10.4%
Unadjusted relative risk	NA	1.0	1.4[b]	2.0[b]	4.4[c]
Adjusted relative risk[e]	NA	1.0	1.4[b]	1.9[b]	3.9[c]

[a] NA, not applicable.
[b] Not significant.
[c] $P < 0.05$ when compared with high-volume providers.
[d] $P = 0.001$ when compared with high-volume providers.
[e] Poisson regression model adjusts for age, race, comorbidity score, and payment source.

usual or problem patients. Uniform treatment protocols are used that are available to patients of all who practice at the hospital. Many investigational protocols are included as well. Thus, all patients have the expertise of the group available, and treatment decisions are not dependent on any single physician. Furthermore, there is formal and informal networking among the centers of excellence. For example, Johns Hopkins is the center of a national consortium of 11 brain tumor centers that work together to improve brain tumor care (6).

Previous studies show selective referral of patients to centers with better outcomes (7, 8, 12, 14). Our data suggest that tertiary care centers, complete with all necessary support facilities, provide the best outcome for the largest number of patients at competitive prices. The number of centers needed to provide satisfactory care for all neurosurgery patients can be determined. Unnecessary duplication of these specialized facilities will undoubtedly lead to increased cost through underutilization. The positive relationship between numbers of surgical cases and outcome of care for both hospitals and individual surgeons (1) has been reported for other operations (10, 16). Some third-party payers have already developed the concept of contracting with centers of excellence to match patients with centers that provide superior outcome. Organ and bone marrow transplantation and coronary artery bypass are examples of procedures already aggregated in this way. Patients requiring these services are directed by their insurers to previously selected providers.

For regionalization to be effective, several critical events need to occur. The nature of the disease must be determined quickly. Rapid and safe transfer to the tertiary center should occur as necessary. The physicians involved need to agree on standardized care plans, and these plans must be expanded to include nursing services as well. The center has to maintain an overall commitment to cost control while providing the most up-to-date technological and human support available. Surgeons must be prepared to monitor outcomes to ensure the best results for all patients. It is likely that costs can be reduced further by standardization of discharge planning, early implementation of rehabilitation measures, and consolidation of the additional consultation and therapies needed for many of the patients. All of these factors are fundamental to the center-of-expertise concept.

It is clear that regionalization will bring another set of cost analysis problems. Transferring all tertiary neurosurgical care to a few centers will increase costs at those centers and decrease costs at smaller hospitals that no longer render such highly specialized care. This must be recognized in advance and documented so that appropriate comparisons are made between referral centers and other hospitals. These changes have substantial implications for neurosurgical training. Provision must be made for resident experience with patients who have neurosurgical diseases not requiring tertiary care. It may not be feasible to care for patients with less serious diseases in these tertiary centers. This means that the staff of the academic medical center may have to have lower-cost facilities for portions of their practices. Improved patient characterization, severity indices, and outcome measures are all necessary for appropriate comparisons to be made among centers. Currently, there are no mechanisms that clearly measure value added, compare patients, or completely define costs and outcomes. The neurosurgical community must provide leadership in the derivation of all of these measures to assess quality of care appropriately and inform the public and insurers about the quality of that care.

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Acknowledgments

We thank Colleen Lee and Ginny Hsieh for help with data management, Dr. Pamela Talalay for review of the manuscript, and Shinji Ohara and Lance Rowland for assistance with the production of the figure and tables.

COMMENTS

It has been shown that aneurysm clipping and treatment of specialized tumors, such as vestibular schwannomas, are better accomplished in large-volume centers than in smaller hospitals. In this article, Long et al. demonstrate that high-volume hospitals have lower mortality rates and shorter length of stay for patients who undergo brain tumor surgery, as well.

One interesting feature of this analysis is that its conclusions agree with intuition. It is reasonable that hospitals that treat more patients would provide better, more efficient treatment. This result may be attributable to the use of critical pathways, more effective use of residents and hospital beds, or greater sophistication of other services that assist in cardiac and other problems. Increasingly, the parameters used by quality assurance groups really reflect our practice.

One limitation of the study is its emphasis on mortality, perhaps because mortality data are the most readily available. It is likely that morbidity rates are also lower in big centers. The increased costs of rehabilitation and new neurological deficits should be quantifiable in future studies. Also, this study does not assess the degree of resection or the neurological effectiveness of the operation. More experienced surgeons in larger centers may resect tumors more effectively with image-guided techniques and may be pressured by their colleagues in oncology to perform full resections.

These data have several interesting implications. In the first place, they do not say that surgeons practicing at big centers are "better" than surgeons at smaller sites. There may be excellent surgeons in small hospitals and mediocre surgeons in academic centers. The findings merely indicate that, in Maryland, in the hospitals studied, considering the group of surgeons as a whole, the results tended to be better in high-volume hospitals. Secondly, the data do not define how many patients are truly necessary to provide surgeons with the experience needed for effective treatment. Fifty patients was taken as the necessary number in this study, but more patients may provide for greater expertise and fewer may still be enough.

The data do suggest that decreased morbidity comes at greater cost, if hospitalization alone is considered. What would this mean to contractors for a large insurance group? Is cheaper treatment, but at higher risk, worth it?

Finally, the data support the concept of neurosurgical oncology as a specialty. Cerebrovascular neurosurgery, pediatric neurosurgery, complex spine neurosurgery, and functional neurosurgery all have recognition as subspecialties in neurosurgery. With the increasing use of image-guided surgery, radiosurgery, cranial base techniques, novel delivery methods for chemotherapy, and applications of molecular biology to the understanding of brain tumors, the subspecialty of neurosurgical oncology is becoming specialized enough to warrant its addition on the list of these subspecialties. This indication is now being recognized in the preparation of guidelines for neurosurgical oncology fellows, but it is buttressed by findings such as those of Long et al. Academic centers tend to be high-volume centers because they have neurosurgical oncology specialists.

Long et al. used public health and care improvement parameters to make an important statement about neurosurgical care for patients with brain tumors. Such care is less dangerous and more efficient in high-volume centers. This study is a valuable contribution to modern concepts of neurosurgery.

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The authors report on the outcomes and hospital charges for adult patients who underwent surgery from January 1990 to December 1996 at 33 hospitals in Maryland. On the basis of the number of craniotomies performed in a given year, and using 50 craniotomies or more per year to define a high-volume hospital, it becomes quite clear that high-volume centers achieve better outcomes with regard to mortality in patients undergoing brain tumor operations. However, there are a number of other issues that need to be considered to completely interpret the meaning of this study. The two high-volume centers in the study are academic medical centers with neurosurgical training programs, which define an entirely different level of care given to patients. These particular types of institutions also have strong commitments to facility infrastructure, including subspecialists who care for these types of patients. These considerations are another advantage for undergoing surgery of this type in a high-volume center. The operations are performed by neurosurgeons who specialize in tumor surgery, most of whom have access to neurosurgical intensive care units, advanced imaging, and strong subspecialty consultants. Thus, one can see the advantages of having a brain tumor operation in such a high-volume center. However, the question remains: how can patients and third-party payors be convinced that a high-volume medical center is the best choice? I suspect it will be easier to convince patients of the value of having their operation in an excellent, high-volume center. Reduction in mortality, as well as in length of stay, is reason enough to convince a patient and the patient's family to travel a little bit farther for a better outcome. However, third-party payors may argue that increasing the volume of operations in such a high-volume center will drive up the costs associated with the procedure because of the advanced operating room technology and the expense of an operation at a tertiary medical facility that trains residents and fellows and has all the "bells and whistles." Nevertheless, it is my contention that this is a small price to pay, considering the mortality rates in low-volume hospitals, especially when this cost is defined with the adjusted relative risk. Although physicians and patients may agree that the added cost of a high-volume hospital is justified by the opportunity for a better outcome, only published data such as this study will swing the pendulum toward high-volume facilities. That will result in the best possible outcome for any patient having to undergo a brain tumor operation.

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Long et al. compared the outcomes and costs of craniotomies performed in institutions in which there were high and low volumes of these operations. This work is part of a growing literature indicating that high-risk surgical procedures have better outcomes when performed at institutions that do them frequently. The article cites published works indicating that outcomes for treatment of neurotrauma, craniotomies for cerebral aneurysms, coronary angioplasty, resection of pancreatic malignancies, and laparoscopic cholecystectomies were all better in institutions that treated high volumes of these illnesses. In addition, a recent study found that this was also true for colectomy, gastrectomy, and lung lobectomy in cancer treatment (1). The similar findings presented in this article regarding craniotomies therefore are not surprising.

These authors examined death rate, days of hospitalization, and average costs during a 7-year period. They concluded that the low-volume institutions (<200 cases) had twice the death rate and 23% longer hospital stays than the high-volume institutions (>1000 cases), when normalizing for severity of disease. The better outcomes seen at the high-volume institutions were not without added expense, however. The price differential for craniotomies between the two groups indicates that the improved outcomes at high-volume institutions cost an additional $1800 per patient.

Not factored into this equation is the frequent occurrence of subtotal resections of tumors at low-volume institutions followed closely by more complete resections at high-volume institutions. This course of treatment ultimately doubles the risk and cost to achieve the final goal. There is an obvious economic drive for the insurance companies to minimize costs, but all things considered, it is not clear that the cost to society for treating brain tumor patients in low-volume institutions is really cheaper in the long run. If the government mandates seat belts and airbags (at considerable cost) because they reduce the mortality and morbidity associated with automobile accidents, it is surprising that there is much debate regarding the value of care at high-volume centers when it costs relatively little to reduce the death rate of craniotomies for tumors by 50%.

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1. Hannan EL, Radzyner M, Rubin D, Dougherty J, Brennan MF: The influence of hospital and surgeon volume on in-hospital mortality for colectomy, gastrectomy, and lung lobectomy in patients with cancer. **Surgery** 131:6–15, 2002.

The authors studied the impact on mortality of concentrating surgical treatment of brain tumors in high-volume centers. They demonstrated that in-hospital mortality was clinically reduced significantly for patients with benign and metastatic brain tumors when they were treated in high-volume centers as compared with low-volume centers within the same state. They carefully examined and controlled for obvious differences in patient populations (age, race, payment source, comorbidity), and the differences remained. Therefore, the fact that the large-volume centers tended to have younger patients with better insurance and more benign tumors cannot fully explain the mortality differences.

The study was somewhat limited in subgroup analyses (such as the type of tumor), which naturally reduce the sample size and, therefore, the power of the analysis. This explains why the clinically significant relative risk of 1.9 for death from benign tumors (low- versus high-volume centers) was not statistically significant. The authors attributed these differences to the expertise and experience of the high-volume centers, the interdisciplinary approach at these centers, the availability of advanced technology, and research protocols. Of course, it is impossible, in a study of this nature, to sort out which factors are actually responsible for the outcome. Although the authors' speculations seem reasonable, they are unproven—and perhaps unprovable.

The study also raises many important questions. The authors mention the issues of neurological and functional status, in addition to mortality. The posthospitalization survival of the patients is also important to consider. Although I do not believe it to be the case, the data are consistent with a situation in which the high-technology care available at high-volume hospitals keeps patients alive long enough to be transferred to skilled nursing facilities, where they rapidly die, but their deaths are not counted as in-hospital mortality. This alternative interpretation could easily be assessed by including longer posthospitalization follow-up in future studies.

In short, the authors carefully and appropriately studied the value of concentrating surgery for brain tumors in high-volume centers and documented the short-term advantages for patients with benign and metastatic tumors. It remains to be demonstrated that these benefits outlast the hospital stay.

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The authors present evidence for lower postoperative mortality for brain tumor surgery at hospitals with a high volume of tumor surgery, as compared with hospitals with a low volume of surgery. The authors provide a thoughtful discussion of the confounding factors involved in drawing absolute conclusions from such studies. They also discuss the additional costs likely to be associated with regionalization of certain procedures and the possible strains on existing facilities if regionalization is carried out.

Robert G. Grossman
Houston, Texas

Publisher Changes:

Welcome James R. Mulligan

James R. Mulligan has assumed the responsibilities of Publisher of NEUROSURGERY. Jim Mulligan's career with Lippincott Williams & Wilkins (LWW) spans nearly 25 years. Within his current position as Publisher for the company, he manages several of LWW's largest society-affiliated publications including Journal of the American Society of Nephrology, Plastic & Reconstructive Surgery, and Transplantation. Over the years he has managed several key areas in the organization including account management, publication design, copyright law, licensing, trademarking, and direct mail services. His career began as Art Director for Waverly Press, Inc., the parent company for Williams & Wilkins; he transitioned from the print side of the business to the growth area of publishing in the early 1980s.

Jim earned a Bachelor of Science degree in Fine Arts and Business Administration from Frostburg State University, a school of the University of Maryland. He earned an additional Master of Fine Arts degree from the Maryland Institute of Art in Baltimore.

The Journal welcomes Jim to the position of Publisher of NEUROSURGERY. His education, diverse experience and long-standing tenure with publishing and Lippincott Williams & Wilkins will all prove valuable assets to the ongoing evolution of NEUROSURGERY in particular and to the furthering of neurosurgical literature and education in general.

Michael L.J. Apuzzo, M.D.