Association Between Subarachnoid Hemorrhage Outcomes and Number of Cases Treated at California Hospitals

Naomi S. Bardach, BA; Shoujun Zhao, MD, PhD; Daryl R. Gress, MD; Michael T. Lawton, MD; S. Claiborne Johnston, MD, PhD

Background and Purpose—Studies of several complex medical conditions have shown that outcomes are better at hospitals that treat more cases. We tested the hypothesis that patients with subarachnoid hemorrhage treated at high-volume hospitals have better outcomes.

Methods—Using a database of all admissions to nonfederal hospitals in California from 1990 to 1999, we obtained discharge abstracts for patients with a primary diagnosis of subarachnoid hemorrhage who were admitted through the emergency department. Hospital volume, defined as the average number of subarachnoid hemorrhage cases admitted each year, was divided into quartiles. Rates of mortality, adverse outcomes (death or discharge to long-term care), length of stay, and hospital charges were computed by univariate analysis and by multivariable general estimating equations, with adjustment for demographic and admission characteristics.

Results—A total of 12,804 patients were admitted for subarachnoid hemorrhage through the emergency departments of 390 hospitals. Hospital volumes varied from 0 to 8 cases per year in the first quartile to 19 to 70 cases per year in the fourth quartile. The mortality rate in the lowest volume quartile (49%) was larger than that in the highest volume quartile (32%, P<0.001). In multivariable analysis, the difference persisted (odds ratio comparing highest with lowest volume quartiles 0.57, 95% CI 0.48 to 0.67; P<0.001). At higher volume hospitals, lengths of stay were longer, and hospital charges were greater in univariate and multivariable models (all P<0.001). Only 4.8% of those admitted to hospitals in the lowest volume quartile were transferred to hospitals in the highest quartile.

Conclusions—In this study of discharge abstracts in California, hospitals that treated more cases of subarachnoid hemorrhage had substantially lower rates of in-hospital mortality. Few patients with subarachnoid hemorrhage are being transferred to high-volume centers. (Stroke. 2002;33:1851-1856.)

Key Words: cerebral aneurysm ■ outcome assessment ■ quality of health care ■ subarachnoid hemorrhage

For several complex medical conditions, such as coronary artery bypass surgery,1 carotid endarterectomy,2 and treatment of HIV,3,4 mortality rates are lower at hospitals that treat a larger number of cases. Better outcomes at these high-volume hospitals could be due to specialized services or greater physician or staff expertise. Policies discouraging coronary artery bypass surgery at low-volume hospitals have been credited with contributing to a substantial decline in mortality associated with this procedure in New York and Canada.5

The association between hospital treatment volume and outcome is generally stronger for medical conditions that require more complex management.6 Subarachnoid hemorrhage, with its frequent complications and high fatality rate, requires this type of complex management.7 There have been few studies of the association between subarachnoid hemorrhage outcome and hospital treatment volume, with variable results.8–12 Methodologies of these prior studies have differed in several important respects. First, most have not evaluated the possible differences in pretreatment prognosis at high- and low-volume hospitals that could account for outcome differences. Second, the populations studied have varied; eg, one study population only included patients treated at academic medical centers,8 which resulted in a restricted range of hospital treatment volume. Third, the definition of high-volume has varied, with cut points ranging from >5 cases per year to >45 cases per year in different studies, and definitions may have been set to optimize the differences between groups, thereby increasing the likelihood of finding a significant effect.

We sought to test the hypothesis that there is an association between outcomes for patients with subarachnoid hemorrhage and hospital treatment volume in California. We limited our analysis to those arriving through the emergency department.
department, adjusted for demographic characteristics, and defined treatment volume a priori to reduce the likelihood that differences could be attributed to factors unrelated to hospital care.

Subjects and Methods

Study Cohort

Abstracts of patient discharges from all nonfederal hospitals in California are recorded in a database of the state’s Office of Statewide Health Planning and Development (OSHPD). The database was established in January 1990, and complete hospital participation began after June 1990. The cohort of patients in the present study was developed by searching the OSHPD hospital discharge database from January 1990 through December 1999 for patients with a primary diagnosis of subarachnoid hemorrhage (International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM] code 430).

Several exclusion criteria were applied. To reduce possible referral bias, patients admitted as transfers, from nursing homes, or through a clinic were excluded. In addition, patients with a secondary diagnosis of arteriovenous malformation (ICD-9-CM 747.81) or of head trauma (ICD-9-CM 800 to 803.9 and 850 to 854.9) and patients who were not California residents were excluded. Treatment courses with total lengths of stay >180 days and charges >$500 000, constituting 1% of all admissions, likely encompassed nonacute care because many of the admissions for these patients were to hospitals with long-term care facilities; thus, these patients were excluded. Patients discharged to home after lengths of stay of 0 or 1 day were not considered to represent new incidences of subarachnoid hemorrhage and were also excluded.

Because the treatment at each hospital affects the patient’s final outcome, we analyzed multiple contiguous admissions as 1 treatment course for patients treated at >1 hospital. To create a unified treatment course, a unique patient identifier was used to link these contiguous admissions for aneurysm treatment in a given patient. For this single course of therapy, hospital length of stay and charges were summed, and outcome was taken as the most adverse during the treatment course.

Predictor Variables and Outcomes

Hospital volume was calculated as the average annual number of subarachnoid hemorrhage admissions, regardless of admission source. Hospital volume quartile designations were made after exclusion criteria were applied but before analysis was performed to avoid post hoc definitions of cut points.

The primary outcome measure was in-hospital mortality, which was defined as the portion of cases at the hospital of first admission who died at any point during the treatment course. We defined adverse outcome as in-hospital death or discharge to a nursing home or rehabilitation facility; this definition was chosen as a surrogate for treatment outcome because prediagnosis disability is unusual and discharge to a nursing home or rehabilitation hospital has been shown to be correlated with the Rankin scale score. Because hospitals providing more aggressive care might not withdraw support in those who were destined for severe long-term disability, it was important to evaluate adverse outcomes to determine whether mortality reductions were accompanied by overall increases in those discharged home. Hospital charges were recorded as the total amount billed to insurance companies or other payers. Because length of stay and charges may be lower for patients who die while in the hospital and because this could result in the appearance of more efficient care at hospitals with poorer outcomes, these variables were compared only for patients who survived to discharge.

Treatment for subarachnoid hemorrhage was defined as surgical clipping (ICD-9 39.51) or endovascular treatment (ICD-9 39.52). The length of time until first treatment was calculated only for patients who were not transferred to another hospital because this measure is a proxy for the aggressiveness of the treating hospital. In a prior study of academic medical centers, the portion of cases treated by endovascular therapy at the hospital of treatment was a predictor of outcomes after subarachnoid hemorrhage.

We evaluated the same variable in the present analysis by using a cut point of 5% of cases treated by endovascular therapy to define those hospitals that used endovascular therapy as a viable treatment option (n=5); because only 1 hospital used endovascular therapy in ≥10% of cases, we did not evaluate a higher cut point.

Statistical Analysis

Volume quartile for each patient was designated according to the hospital of the patient’s first admission if there were multiple admissions. This allowed us to incorporate the impact of transfer decisions on the ultimate outcome of the patient. Dichotomous outcomes and variables were compared in univariate analyses by the Pearson χ² test. Because the categorical variables age, hospital charges, length of stay, and time to treatment were not normally distributed, the nonparametric Wilcoxon rank sum test was used to compare the highest and lowest volume quartiles.

Patient age, sex, ethnicity, admission acuity, payment source, and year of treatment were included in all multivariable analyses. Because variables were expected to show correlation between patients at a given institution, logistic regression, which ignores the covariance structure used was compound symmetry (equal correlation between all interhospital observations). For length of stay and hospital charges, natural logarithmic transformations better approximated normal distributions by reducing positive skew. The distributions of these transformed variables were compared with idealized normal distributions by the use of quantile plots, with some residual positive skew demonstrated for charges but not for lengths of stay. Results of these log-linear models were expressed as adjusted ratios of geometric means.

To determine an optimum cut point for defining high-volume hospitals, the odds ratio for in-hospital mortality was calculated for each possible cut point, comparing the hospitals with volumes above the cut point with the hospitals with volumes below the cut point. CIs were calculated by using the Woolf method. The Microsoft Excel spreadsheet program was used to calculate these odds ratios and CIs (version 2000, Microsoft Corp). The Stata statistical package was used for all other analyses (version 7.0, Stata Corp).

Results

Patients and Hospitals

During 1990 to 1999, a total of 21 540 patients were admitted for subarachnoid hemorrhage. Given prior estimates of out-of-hospital deaths and the number of nonveterans in California, this incidence is approximately equivalent to 8 cases per 100 000 person-years. Of these, 8736 were excluded on the basis of criteria established a priori: admission source other than the emergency department (n=7302), diagnosis of arteriovenous malformation (n=158), diagnosis of head trauma (n=148), state of residence other than California (n=534), length of stay >180 days or charges >$500 000 (n=145), and live discharge within 2 days (n=449).

The final cohort consisted of 12 804 patients. The average age was 59 years, and 62% were females. Whites accounted for 59%, 10% were black, 14% were Hispanic, and 11% were Asian. Overall in-hospital mortality was 40%, and adverse outcomes occurred in 66%.

The average number of cases treated annually at hospitals ranged from <1 case to 70 cases. When hospitals were divided into quartiles, hospitals in the lowest volume quartile treated <8 cases annually, and hospitals in the highest...
quartile treated >19 cases annually. Of the 390 admitting hospitals, 262 were in the lowest volume quartile, 62 were in the second quartile, 39 were in the third quartile, and 27 were in the highest volume quartile. Several demographic characteristics differed in the treatment-volume quartiles (Table 1).

Outcomes
In univariate analysis, mortality and adverse outcomes were more frequent in low-volume hospitals (Figure 1). Median length of stay and median total charges for treatment courses were greater at high-volume hospitals (Table 2). Mean values of length of stay and total charges were measured to give point estimates for comparing resource consumption. The mean length of stay for each volume quartile from lowest to highest volume was 17.97, 18.46, 19.57, and 18.03 days, respectively ($P<0.001$ comparing lowest with highest volume quartile). The mean number of days from admission until aneurysm treatment was greater at lower volume hospitals (first versus fourth volume quartile, 4.8% of patients in the first quartile, 3.4% of patients in the second quartile, 3.0% in the third quartile, and 4.2% of patients in the third quartile). Although the proportion of patients transferred to the highest volume hospitals was small for all quartiles (4.8% of patients in the first quartile and 3.1% for the following quartiles), the proportion of patients transferred to the highest volume hospitals was still small for all quartiles (4.8% of patients in the first quartile and 3.1% for the following quartiles). The proportion of patients transferred to the highest volume hospitals was still small for all quartiles (4.8% of patients in the first quartile and 3.1% for the following quartiles). The proportion of patients transferred to the highest volume hospitals was still small for all quartiles (4.8% of patients in the first quartile and 3.1% for the following quartiles).

In multivariable analysis, after controlling for age, sex, ethnicity, year, payment source, and acuity of admission, the reduction in adverse outcomes and in mortality persisted in high-volume hospitals (Table 3). The positive association between hospital volume and length of stay and charges also persisted.

For any given annual case volume used to divide hospitals into high- and low-volume groups, the calculated odds ratio of in-hospital mortality shows a decreased risk of death in the high-volume hospitals (Figure 2). Odds ratios of in-hospital mortality calculated for each definition of high-volume as >21 cases were similar, regardless of which cut point was used for the definition of high and low volume. As long as the definition of high-volume was ≥21 cases, there was at least 40% lower odds of mortality at high-volume hospitals.

The portion of all patients with an aneurysm treated was 29%; when patients who experienced in-hospital death were excluded, the portion treated was 41%. Lower volume hospitals treated aneurysms in a smaller proportion of subarachnoid hemorrhage patients (first versus fourth volume quartile, 17% versus 37%; $P<0.001$). This finding persisted when patients who experienced in-hospital death were excluded (first versus fourth volume quartile, 25% versus 48%; $P<0.001$). Endovascular therapy was used in 143 patients (1.1%), with a smaller portion of patients treated with endovascular therapy at lower volume hospitals (first versus fourth volume quartile, 0.6% versus 2.5%; $P<0.001$; Figure 3). The mortality rate for patients ($n=12337$) who were admitted to hospitals that treated ≤5% of the cases with endovascular coiling was higher than the mortality rate for patients ($n=467$) admitted to hospitals that treated >5% of cases by endovascular coiling (41% versus 33%, respectively; $P<0.001$). However, this difference did not persist in multivariable analysis after adjustment for volume ($P=0.84$).

### Hospital Transfers for Acute Care
Overall, only 4.2% of the patients treated at hospitals in the first 3 quartiles were transferred to the highest volume quartile ($n=402$). The proportion of patients transferred to the highest volume hospitals was small for all quartiles (4.8% of patients in the first quartile, 3.4% of patients in the second quartile, and 4.2% of patients in the third quartile). Although the lowest volume quartile had the largest proportion of patients transferred anywhere (15%), those patients were most often transferred to another hospital in the lowest quartile (5.8%) rather than being transferred to a hospital in the highest volume quartile (4.8%).

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**Table 1. Characteristics of Patients by Hospital Volume**

<table>
<thead>
<tr>
<th>Volume Quartile</th>
<th>1st Quartile (N=3154)</th>
<th>2nd Quartile (N=3322)</th>
<th>3rd Quartile (N=3207)</th>
<th>4th Quartile (N=3121)</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean±SD), y</td>
<td>61.9±17.8</td>
<td>58.9±17.0</td>
<td>57.2±17.3</td>
<td>56.0±17.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>1989 (63)</td>
<td>2094 (63)</td>
<td>1962 (61)</td>
<td>1843 (59)</td>
<td>0.001</td>
</tr>
<tr>
<td>Ethnicity, n (%)</td>
<td>White: 2001 (63)</td>
<td>1839 (55)</td>
<td>1853 (58)</td>
<td>1804 (58)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Black: 260 (8)</td>
<td>298 (9)</td>
<td>397 (12)</td>
<td>346 (11)</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Hispanic: 399 (13)</td>
<td>529 (16)</td>
<td>420 (13)</td>
<td>435 (14)</td>
<td>0.133</td>
</tr>
<tr>
<td></td>
<td>Asian American: 346 (11)</td>
<td>415 (13)</td>
<td>337 (11)</td>
<td>319 (10)</td>
<td>0.335</td>
</tr>
<tr>
<td></td>
<td>Others: 147 (5)</td>
<td>241 (7)</td>
<td>200 (6)</td>
<td>216 (7)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Comparing 1st and 4th quartiles (Wilcoxon rank sum test for age and Pearson χ2 test for others).
The mortality rate for patients who were transferred to the highest volume hospitals was lower than the mortality rate for patients who were not transferred (transferred versus not transferred was, respectively, 36% versus 51%, 20% versus 44%, and 26% versus 41% mortality from the first, second, and third quartile; \( P \leq 0.001 \) for all comparisons).

### Discussion

In this analysis of discharge abstracts from California, rates of mortality and adverse outcomes after subarachnoid hemorrhage were lower at hospitals treating more cases, and patients were rarely transferred to these high-volume hospitals. The difference between in-hospital mortality rates in highest and lowest quartile hospitals was large (32% versus 49%, respectively). If these findings are correct, policies encouraging transfer to high-volume hospitals could significantly reduce overall mortality for subarachnoid hemorrhage. However, the potential impact of such policies may be attenuated because transferring patients from low- to high-volume hospitals is not always feasible and because instability during transfer itself could worsen the outcome for some patients. In addition, we found that hospital charges and length of stay were greater at high-volume hospitals. These added costs, as well as those directly associated with transfer (not examined in our analysis), could be prohibitive. However, given the high costs of long-term care, an intervention that produces even a modest reduction in disability is often cost-effective when lifetime impacts are considered.15 Therefore, a policy encouraging the transfer of patients with subarachnoid hemorrhage to high-volume hospitals could reduce both mortality and costs.

The limitations of the data used in the present study must be acknowledged. Administrative databases, such as the OSHPD compilation of discharge abstracts, are subject to coding errors. Death and hospital charges are less subject to these coding errors because the database is used to bill payers. In addition, a previous validation using a similar administrative database showed that demographic and outcome variables are likely to be correctly coded. However, there has been limited validation of these data, and coding procedures may have improved throughout the time period.

In addition, observational studies are subject to possible undetected biases. Prior studies evaluating the association between subarachnoid hemorrhage outcome and hospital treatment volume have not attempted to control for referral biases that could produce differences in pretreatment prognosis in those treated at high- and low-volume hospitals. We reduced the likelihood of referral bias by including only patients who were admitted through the emergency department and by adjusting for demographic and admission characteristics in multivariable models. Even so, it is possible that systematic differences in pretreatment prognosis remain. A more detailed prospective study would be required to reduce the possibility of residual bias.

The definition of high volume has varied in prior studies, with cut points varying from >5 cases per year to >45 cases per year. We divided patients into quartiles of treatment volumes to eliminate the potential to introduce bias by choosing an optimum cut point post hoc. In-hospital mortality and adverse event rates were lower with each increase in the volume among the quartiles. Furthermore, the analysis comparing outcomes for the entire range of possible volume cut

### Table 2. Univariate Comparison of Treatment Outcomes

<table>
<thead>
<tr>
<th></th>
<th>1st Quartile (N=3154)</th>
<th>2nd Quartile (N=3322)</th>
<th>3rd Quartile (N=3207)</th>
<th>4th Quartile (N=3121)</th>
<th>( P^* )</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-hospital deaths (%)</td>
<td>48.5%</td>
<td>41.2%</td>
<td>39.0%</td>
<td>32.3%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Adverse outcomes (%)</td>
<td>76.4%</td>
<td>67.7%</td>
<td>64.3%</td>
<td>55.9%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length of stay, d</td>
<td>11 (3–41)</td>
<td>12 (4–40)</td>
<td>13 (4–43)</td>
<td>13 (4–38)</td>
<td>0.001</td>
</tr>
<tr>
<td>Hospital charges, $1000s</td>
<td>36 (7–150)</td>
<td>51 (13–170)</td>
<td>54 (13–190)</td>
<td>64 (15–230)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Adverse outcomes were defined as deaths or discharges to a nursing home or rehabilitation hospital. Values for adverse outcomes and in-hospital deaths are percent total of patients in the volume quartile. Values for length of stay and hospital charges are median, with 10th to 90th percentile range. Length of stay and hospital charges were analyzed for patients who survived the hospital stay.

*Comparing 1st and 4th quartiles (Pearson \( \chi^2 \) test for dichotomous variables and Wilcoxon rank sum test for continuous variables).

### Table 3. Multivariable Comparison of Treatment Outcomes

<table>
<thead>
<tr>
<th></th>
<th>1st Quartile</th>
<th>2nd Quartile</th>
<th>3rd Quartile</th>
<th>4th Quartile</th>
<th>( P^* )</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-hospital deaths (odds ratio)</td>
<td>Ref</td>
<td>0.78 (0.70–0.88)</td>
<td>0.75 (0.64–0.87)</td>
<td>0.58 (0.49–0.68)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Adverse outcomes (odds ratio)</td>
<td>Ref</td>
<td>0.67 (0.58–0.78)</td>
<td>0.59 (0.49–0.71)</td>
<td>0.44 (0.36–0.53)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length of stay (ratio of days)</td>
<td>Ref</td>
<td>1.18 (1.09–1.28)</td>
<td>1.26 (1.15–1.37)</td>
<td>1.21 (1.09–1.33)</td>
<td>0.001</td>
</tr>
<tr>
<td>Charges (ratio of $)</td>
<td>Ref</td>
<td>1.51 (1.33–1.72)</td>
<td>1.66 (1.44–1.91)</td>
<td>1.94 (1.60–2.35)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Ref indicates reference. Adverse outcomes were defined as deaths or discharges to a nursing home or rehabilitation hospital. Length of stay and hospital charges were analyzed for patients who survived the hospital stay.

*Results are derived from generalized estimating equations and were adjusted for age, sex, ethnicity, year of treatment, payment source, and admission acuity. \( P \) value was generated from comparison of 1st and 4th quartiles.
points illustrates that the decreased risk of mortality is a robust finding for any definition of high volume as >2 admissions per year, with a particularly large difference for definitions of high volume as >21 admissions per year (Figure 2).

We found that a large portion of patients presenting to emergency departments with nontraumatic subarachnoid hemorrhage had never had an aneurysm repaired. Early death might explain some of the untreated cases, but the overall portion treated remained at 41% when those experiencing in-hospital death were excluded. Patients admitted to low-volume hospitals were even less likely to have an aneurysm treated, with only 25% with an aneurysm repair among those surviving to discharge. Failed attempts at aneurysm treatment did not explain the apparent undertreatment: craniotomy without aneurysm treatment occurred in only 2% of the cases. Nonaneurysmal subarachnoid hemorrhage is an unlikely explanation because prior studies have estimated that this occurs in only 7% to 17% of nontraumatic cases. However, cerebral imaging in community practice may not be as sensitive as reported in the literature, so some aneurysms may be missed.

Possible reasons for the better outcomes in high-volume hospitals include more aggressive treatment of the ruptured aneurysm, availability of specialized and experienced physicians and staff, and the presence of specialized facilities (designated neurological intensive care units or endovascular services). We found that patients with subarachnoid hemorrhage were more likely to have an aneurysm repaired if they presented to a high-volume hospital, and this treatment occurred more rapidly after admission. Early aneurysm treatment, recommended in published guidelines, could improve the outcome by reducing the likelihood of aneurysm rupture and may account for some of the difference between high- and low-volume hospitals. Although the OSHPD database does not provide enough information to assess the treatment of vasospasm, more aggressive treatment in high-volume hospitals for this complication may also account for differences in outcome and cost. Further investigation of specific costs associated with treatment of diagnosis and treatment of the complications of subarachnoid hemorrhage may help elucidate these differences.

Endovascular therapy was also more frequent at high-volume hospitals and, similar to findings in a previous study, its presence was associated with improved outcome. However, only a small number of patients received endovascular treatment (n = 143) as primary therapy, so it could not account for the large discrepancy in results between high- and low-volume hospitals.

Acknowledgments
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References


Editorial Comment

Practice Makes Perfect

Practice makes perfect. At least that is what we have always been told. In this article, patients fared better in hospitals with large numbers of subarachnoid hemorrhages (SAH) than in those with smaller numbers. The implication, of course, is that the hospitals dealing with large numbers of SAH are more skilled at treating these patients, but unfortunately, they are also more expensive.

The article has all the trappings of class III evidence noted by the authors; coding errors and undetected biases may corrupt the data. Certainly prospective collection and analysis of similar data would corroborate the conclusions, but the likelihood of such a study anytime in the immediate future is small.

If hospitals and medical centers abide by the conclusions of the article, regionalization of medical care (especially for SAH) will occur. Most people who deal with complex medical problems such as SAH applaud such a paradigm shift. Regional medical centers have the resources to provide such medical care, and practice really does make perfect. However, as the care pendulum shifts in the direction to large-volume centers, caution should be exercised. There will still be patients whose only chance of survival will be immediate attention at local facilities, as in the case of a patient with a large temporal lobe clot after an SAH from a posterior communicating artery aneurysm evolving through a herniation syndrome. Therefore, training and recurrent refreshment of skills need to be continued in many if not all small-volume hospitals. The key to this scenario is knowing when and when not to refer and will remain the most challenging goal for the future.

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