Characteristics of Academic Medical Centers and Ischemic Stroke Outcomes

Leslie Allison Gillum, MD; S. Claiborne Johnston, MD, MPH

Background and Purpose—Data supporting the efficacy of stroke center characteristics are limited.
Methods—A questionnaire detailing stroke treatment practices was sent to 42 academic medical centers in the University Health Systems Consortium. In-hospital mortality of all emergency department admissions for ischemic stroke at these institutions was evaluated in a database of discharge abstracts during 1997–1999. Institutional characteristics were evaluated as predictors of in-hospital mortality after adjustment for age, sex, race, hospital treatment volume of ischemic stroke, and admission status (emergent, urgent, elective). Length of stay (LOS), total hospital charges, and frequency of tissue plasminogen activator (tPA) administration were evaluated as secondary outcomes. We used a multivariable method called generalized estimating equations, which broadens confidence intervals to adjust for clustering of variables at institutions.
Results—Thirty-two institutions completed the questionnaire, and 29 of these were included in the database of discharge abstracts. In-hospital deaths occurred in 758 (7.0%) of the 10 880 ischemic stroke patients admitted through the emergency department. In-hospital deaths were less frequent at hospitals with a vascular neurologist (odds ratio [OR] 0.51; 95% CI, 0.36 to 0.74; \( P < 0.0001 \)) and at those with guidelines stating that only neurologists could administer tPA (OR, 0.65; 95% CI, 0.49 to 0.88; \( P = 0.004 \)). There was a trend toward fewer deaths at hospitals with a dedicated stroke team available by pager (OR, 0.76; 95% CI, 0.56 to 1.04; \( P = 0.09 \)). The presence of a dedicated neurological intensive care unit, stroke unit, and written clinical pathway for stroke were not significantly associated with in-hospital death. LOS was shorter at hospitals with a vascular neurologist (\( P = 0.01 \)).
Conclusions—Academic medical centers with a vascular neurologist and those with written guidelines limiting tPA administration to neurologists had lower rates of in-hospital mortality for ischemic stroke patients. (Stroke. 2001;32:2137-2142.)

Key Words: delivery of health care, integrated stroke, acute stroke, ischemic stroke, stroke management, stroke outcome, stroke unit

During the past decade, there has been increasing interest in the development of specialized stroke care. Recently, the Brain Attack Coalition (BAC) was formed from a group of major professional organizations with the goal of improving stroke care. In 2000, the BAC published recommendations to establish minimal criteria for acute stroke centers. These included requirements for acute stroke teams, stroke units, written care protocols, neurosurgical services, emergency medical services, and emergency departments. Other requirements included designation of a stroke center director, neuroimaging and laboratory services, outcome and quality improvement activities, and ongoing continuing medical education. These criteria were meant to produce more systematic care, to encourage early treatment, and to optimize functional outcomes and survival. However, the BAC acknowledged that there were few studies evaluating the efficacy of the types of stroke centers proposed.

Of the elements of stroke centers proposed by the BAC, only the establishment of stroke units has been supported by clear data showing improvement in outcomes. Stroke units have been loosely defined as areas of the hospital served by staff specializing in stroke care. A recent Cochrane Collaboration meta-analysis found reduced death and long-term institutionalization in patients admitted to stroke units. Other studies have shown that more systematic stroke care improves efficiency, but few have evaluated mortality or functional outcomes.

The BAC recognized the importance of outcome-based research to establish the efficacy of stroke centers. In an attempt to evaluate the elements of stroke centers recommended by the BAC, we examined their effects on ischemic stroke outcomes in a cohort of patients admitted to academic medical centers throughout the United States.
Methods
The University Health System Consortium administrative database contains patient information from 84 large academic health centers and their associate hospitals, with >2.1 million discharges each year.7 We obtained University Health System Consortium discharge abstracts for all ischemic stroke patients admitted through emergency departments during 1997–1999. Patients were identified by International Classification of Diseases, Ninth Revision (ICD-9) codes that were previously recognized as accurate indicators of acute ischemic stroke (ICD-9 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, 434.91, 436).8–10 We limited the cohort to emergency department admissions to reduce the likelihood of referral bias.

Variables in the discharge database were validated by comparison with a detailed medical record review. Between June and December 1999, 42 institutions participating in a quality improvement project identified 30 consecutive ischemic stroke cases. Information on demographics, medical history, and treatment was abstracted by trained analysts and clinicians. Variables from medical record review were directly compared with those in the discharge database for all patients included in both groups. κ statistics were calculated for categorical variables, and continuous variables were compared with correlation coefficients.

All institutions participating in the record review were sent a questionnaire in 1999 to ascertain local institutional practices related to stroke treatment. Surveys were completed by a hospital administrator or a specialist in stroke care at each center. Data were collected on the organization of physicians and staff, use of a written clinical pathways, and guidelines for administration of thrombolytic therapy. Questionnaire responses were tested for internal validity by comparing responses to similar questions. On the basis of these results and outcomes of previous studies,2,6,11–17 several specific institutional characteristics were chosen as treatment variables for further study. All institutional questionnaire responses demonstrating internal consistency and variability were tested for their effect on outcomes. Pearson correlation coefficients were calculated to examine relationships between institutional characteristics. We calculated the averaged yearly volume of ischemic strokes treated at an institution from discharge abstracts, including admissions from all sources since all treated cases would be expected to increase physician experience.

In-hospital mortality was chosen as the primary outcome because of its frequency, importance, and coding reliability. Univariate predictors of in-hospital mortality were identified by the Pearson χ² test for dichotomous variables and Wilcoxon rank sum test for others.18 The secondary outcomes, length of stay (LOS) and total hospital charges, were compared with the Wilcoxon rank sum test. LOS and charge calculations included only those patients surviving to discharge; otherwise, hospitals with greater rates of in-hospital mortality would appear to have shorter hospital stays and lower charges. To evaluate variability between institutions, we determined the range of the variables at the institutional level.

In multivariable analysis, we assessed institutional characteristics as predictors of individual patients’ in-hospital mortality, LOS, total charges, and receipt of tissue plasminogen activator (tPA) after adjustment for demographic characteristics, admission status (emergent, urgent, elective), and annual institutional treatment volume of ischemic stroke. This approach allowed more accurate specification of individual outcomes and covariates compared with an analysis that simply compares institutions’ characteristics and their outcomes.19

Generalized estimating equations were used to perform all multivariable analyses to account for clustering of predictor variables and outcomes at the institutions. This method is similar to logistic regression but produces broader CIs when there is clustering because logistic regression ignores the possibility that individuals at institutions are more similar to each other than would be expected by chance alone. As a result of the multilevel modeling techniques we used, limited variability in institutional characteristics could lead to false-positive results. Therefore, we required that a specific characteristic be represented by at least 3 institutions for that variable to be entered into the model.

Results
To confirm the validity of the database, we compared variables in the discharge database with medical record review in 927 patients. Individual characteristics were classified with a high degree of accuracy in the discharge database, with 97% to 100% agreement for age (κ=0.98), sex (κ=0.98), and ethnicity (varying between Native Americans with κ=0.35 to blacks with κ=0.99) compared with medical record review. Source of admission was classified with 85% agreement (κ=0.58). Outcome variables were highly reliable, with in-hospital mortality demonstrating 100% agreement (κ=1.00) and 98% agreement in LOS (κ=0.98). Hospital charges could not be validated because they were not available from the medical record review.

Study Cohort
A total of 10 880 patients with ischemic strokes were admitted through the emergency department at 29 institutions.
participating in the study. Institutions varied widely in the demographics of treated patients (Table 1). Institutional annual case volume of all ischemic strokes ranged from 54 to 400. Mortality rates, mean LOS, and mean hospital charges also varied broadly between institutions (Table 1).

In-hospital deaths occurred in 758 cases (7.0%; Table 1). In univariate analysis, older age was associated with greater risk of death ($P < 0.0001$). No other patient characteristic was significantly predictive of mortality. White ethnicity was associated with a nonsignificant trend toward increased mortality (OR, 1.16; 95% CI, 0.99 to 1.35; $P = 0.07$). Risk of death was greater at institutions treating a larger number of ischemic strokes annually ($P = 0.003$).

We evaluated the effects on in-hospital mortality of several characteristics for acute stroke centers recommended by the BAC (Table 2). The percentage of institutions possessing each characteristic ranged from 38% to 100%. Several of the criteria were present at all institutions, and we were therefore unable to evaluate their effects on outcome. Several institutional characteristics significantly reduced mortality risk in univariate analysis. In multivariable models adjusted for patient characteristics and treatment volume, patients with ischemic strokes were less likely to die at hospitals with a neurologist who specialized in vascular disease ($P = 0.001$) and at those where written protocols for tPA administration required neurologist evaluation ($P = 0.004$). A dedicated stroke team available by pager also tended to decrease the risk of a fatal outcome ($P = 0.09$).

Several institutional characteristics were significantly correlated. The presence of a stroke team responding to urgent pages was associated with 24-hour availability of a stroke team ($R = 0.48, P = 0.01$), the presence of a vascular neurologist ($R = 0.60, P = 0.001$), and written guidelines requiring neurologist administration of tPA ($R = 0.41, P = 0.049$). A neurological intensive care unit was correlated with 24-hour availability of a stroke team ($R = 0.43, P = 0.02$) and presence of a stroke unit ($R = 0.81, P < 0.0001$).

Incorporating all 3 predictors identified in multivariable models, we created a final, adjusted multivariable model (Table 2). The risk of in-hospital death was lower at hospitals with a vascular neurologist ($P = 0.0001$) and written guidelines requiring neurologist administration of tPA ($P = 0.04$). In this final model, risk was also associated with increasing age ($P < 0.0001$), emergent ($P < 0.0001$) and urgent ($P = 0.04$).
admissions compared with elective admissions, and higher institutional annual case volume ($P<0.0001$).

We also examined predictors of LOS (Table 3) and hospital charges (Table 4). Natural-log transformations of LOS and hospital charges were modeled in multivariable analyses, and results were therefore expressed as the ratio of geometric means. LOS was shorter at hospitals with a vascular neurologist ($P=0.01$). Total charges were nonsignificantly higher when neurologist administration of tPA was required ($P=0.051$). No other institutional characteristics were important predictors of LOS or hospital charges.

In 1999, 79 ischemic stroke patients (2.73%) received tPA at the 22 universities that ever coded tPA use. Patients treated at hospitals with a vascular neurologist ($P=0.08$) and neurological intensive care units ($P=0.08$) tended to have a higher likelihood of receiving tPA (Table 5). None of the other institutional characteristics were significantly associated with tPA use.

## Discussion

We evaluated the elements of acute stroke centers recommended by the BAC for their impact on outcomes in patients with ischemic stroke. Patients hospitalized at institutions with a neurologist specializing in vascular disease and with written guidelines requiring neurologist administration of tPA were at lower risk of in-hospital death. While no other institutional characteristics identified by the BAC were important predictors of mortality in this study, more detailed studies that include nonacademic medical centers are required.

Many studies have investigated the effect of specialist care on patient outcomes, and several studies have shown improved survival in ischemic stroke patients treated by neurologists rather than generalists. The analysis indicates that patients treated at institutions employing at least 1 vascular neurologist had a lower risk of in-hospital death, shorter LOS, and a nonsignificant increase in frequency of tPA administration. A vascular neurologist likely serves as a

### Table 3. Institutional Characteristics and Mean LOS (n=10 122)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>LOS, d, by Characteristic</th>
<th>Adjusted Ratio*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td><strong>Patient care areas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute stroke teams</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team responding to pager</td>
<td>7.6</td>
<td>7.9</td>
</tr>
<tr>
<td>Team available all times</td>
<td>7.5</td>
<td>8.2</td>
</tr>
<tr>
<td>Written care protocols</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guidelines requiring neurologist...</td>
<td>7.4</td>
<td>7.5</td>
</tr>
<tr>
<td>Clinical pathway</td>
<td>7.4</td>
<td>8.1</td>
</tr>
<tr>
<td>Stroke unit</td>
<td>7.0</td>
<td>8.4</td>
</tr>
<tr>
<td>Neurological intensive care unit</td>
<td>6.7</td>
<td>8.6</td>
</tr>
<tr>
<td><strong>Support services</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of a vascular neurologist</td>
<td>7.6</td>
<td>9.4</td>
</tr>
</tbody>
</table>

*Adjusted for age, sex, ethnicity, admission status, and institutional annual ischemic stroke treatment volume. Adjusted results are derived from generalized estimating equations and expressed as ratios of geometric means.

### Table 4. Institutional Characteristics and Mean Total Charges (n=9656)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total Charges by Characteristic</th>
<th>Adjusted Ratio*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td><strong>Patient care areas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute stroke teams</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team responding to pager</td>
<td>$19 500$</td>
<td>$15 000$</td>
</tr>
<tr>
<td>Team available all times</td>
<td>$18 000$</td>
<td>$17 000$</td>
</tr>
<tr>
<td>Written care protocols</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guidelines requiring neurologist...</td>
<td>$19 500$</td>
<td>$14 500$</td>
</tr>
<tr>
<td>Clinical pathway</td>
<td>$16 500$</td>
<td>$19 500$</td>
</tr>
<tr>
<td>Stroke unit</td>
<td>$18 500$</td>
<td>$17 000$</td>
</tr>
<tr>
<td>Neurological intensive care unit</td>
<td>$18 500$</td>
<td>$17 500$</td>
</tr>
<tr>
<td><strong>Support services</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of a vascular neurologist</td>
<td>$17 500$</td>
<td>$21 000$</td>
</tr>
</tbody>
</table>

*Adjusted for age, sex, ethnicity, admission status, and institutional annual ischemic stroke treatment volume. Adjusted results are derived from generalized estimating equations and expressed as ratios of geometric means.
leader in stroke care, potentially fulfilling 2 important roles identified by the BAC: (1) as a designated medical director, the vascular neurologist may coordinate institutional support, and (2) as a staff physician, he or she may contribute to the care of individual patients. Additional studies will be required to determine whether vascular neurologists directly improve care of individual patients since we did not determine the attending subspecialty for each hospital admission.

Written guidelines have been used to coordinate ischemic stroke care and ensure a minimal standard of care. For example, institutional guidelines for tPA administration may improve outcomes since violation of standard treatment protocols have been associated with increased risk of complications.\textsuperscript{11,14,25,26} In our study there were fewer in-hospital deaths at institutions with written guidelines specifying that only a neurologist could administer tPA. This association may be due to stricter adherence to guidelines when neurologists are involved. Alternatively, institutions that restrict tPA administration to neurologists may simply have greater neurologist commitment to stroke care since centers with less active neurologist involvement would be more likely to allow other physicians to administer tPA. Given the low rate of tPA administration in our study, which is consistent with that found in previous reports, this positive effect is unlikely to be due to more appropriate patient selection.\textsuperscript{14}

Clinical pathways (written guidelines outlining the sequence of in-hospital care) were not associated with ischemic stroke outcomes in our study. Implemented in 34\% of hospitals according to a recent survey,\textsuperscript{27} clinical pathways have been found to reduce hospital charges, LOS, and complication rates.\textsuperscript{5,6,16,17,28,29} A recent prospective randomized trial of a clinical pathway in stroke rehabilitation units failed to show a difference in mortality or LOS.\textsuperscript{4} The authors suggested that implementation of a clinical pathway may not be beneficial when care has been previously well coordinated. A high standard of systematized care at academic medical centers may account for the absence of an effect of clinical pathways in our study.

Acute stroke teams have been proposed as a means to deliver timely ischemic stroke care,\textsuperscript{30,31} in part driven by the success of trauma centers.\textsuperscript{32–34} In a national survey, nine tenths of institutions had such a team, at an annual cost generally <$5,000.\textsuperscript{12} Nearly 70\% of institutions in our study had a stroke team available by pager, and patients treated at these institutions tended to have a lower risk of in-hospital death in our study, but the association did not reach significance. The lack of a clear definition of a stroke team in our study may have obscured an effect. A number of prior studies have shown that acute stroke teams shorten in-hospital treatment delays\textsuperscript{33,35,36} and minimize LOS and cost.\textsuperscript{3,17,37}

Numerous studies have examined the efficacy of stroke units in improving ischemic stroke outcomes, recently reviewed in a meta-analysis from the Cochrane Collaboration.\textsuperscript{2} In fact, this is the only element of the BAC criteria extensively supported by studies examining mortality and functional outcome. However, in-hospital mortality, LOS, and total charges in our study were not different at institutions with stroke units or neurological intensive care units. The absence of well-specified definitions of these terms, as discussed for acute stroke teams, may have prevented us from detecting true associations with outcome. The definition of a stroke unit varies considerably in the literature, and establishing a consistent definition for this term will improve future studies of the impact of stroke units on outcomes.

Our study included only academic medical centers, which limited our ability to evaluate the BAC criteria designed for primary stroke centers. We attempted to minimize referral bias due to the transfer of refractory stroke cases to academic medical centers by restricting our study population to emergency department admissions, but there may still remain important patient population differences between the academic and community medical centers. Furthermore, many of the institutions incorporated a number of the characteristics recommended by the BAC, and others may have provided comprehensive services that could effectively substitute for the specific criteria. Thus, the impact of the BAC recommendations may be less apparent at academic medical centers. It

### TABLE 5. Institutional Characteristics and tPA Administration (n=2895)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Unadjusted</th>
<th>Adjusted*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient care areas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute stroke teams</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team responding to pager</td>
<td>1.37 (0.83–2.24)</td>
<td>0.22</td>
</tr>
<tr>
<td>Team available all times</td>
<td>0.88 (0.52–1.48)</td>
<td>0.63</td>
</tr>
<tr>
<td>Written care protocols</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guidelines requiring neurologist admin.</td>
<td>0.58 (0.37–0.92)</td>
<td>0.02</td>
</tr>
<tr>
<td>Clinical pathway</td>
<td>0.78 (0.48–1.25)</td>
<td>0.30</td>
</tr>
<tr>
<td>Stroke unit</td>
<td>1.66 (1.03–2.67)</td>
<td>0.04</td>
</tr>
<tr>
<td>Neurological intensive care unit</td>
<td>1.82 (1.14–2.89)</td>
<td>0.01</td>
</tr>
<tr>
<td>Support services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of a vascular neurologist</td>
<td>2.01 (0.83–4.88)</td>
<td>0.13</td>
</tr>
</tbody>
</table>

*Adjusted for age, sex, ethnicity, admission status, and institutional annual ischemic stroke treatment volume. Adjusted results are derived from generalized estimating equations and expressed as odds ratios.
will be important to test the BAC criteria for primary stroke centers in a large sample of community hospitals.

We found that patients admitted to centers with a vascular neurologist have a lower rate of in-hospital mortality and shorter LOS compared with those cared for at other academic medical centers. Written guidelines requiring neurologist administration of tPA were also associated with better outcomes. Establishing the crucial elements of medical centers to improve outcomes for stroke, as proposed by the BAC, may produce important reductions in the burden of this common and devastating disease.

Acknowledgement

This work was supported in part by the National Institutes of Health/National Institute of Neurological Disorders and Stroke (NS 02042).

References


Characteristics of Academic Medical Centers and Ischemic Stroke Outcomes
Leslie Allison Gillum and S. Claiborne Johnston

Stroke. 2001;32:2137-2142
doi: 10.1161/hs0901.094260

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/32/9/2137

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Stroke can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Stroke is online at:
http://stroke.ahajournals.org//subscriptions/