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Predictors of Acute Hospital Costs for Treatment of Ischemic Stroke in an Academic Center

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Background and Purpose—We sought to determine predictors of acute hospital costs in patients presenting with acute ischemic stroke to an academic center using a stroke management team to coordinate care.

Methods—Demographic and clinical data were prospectively collected on 191 patients consecutively admitted with acute ischemic stroke. Patients were classified by insurance status, premorbid modified Rankin scale, stroke location, stroke severity (National Institutes of Health Stroke Scale score), and presence of comorbidities. Detailed hospital charge data were converted to cost by application of department-specific cost-to-charge ratios. Physician's fees were not included. A stepwise multiple regression analysis was computed to determine the predictors of total hospital cost.

Results—Median length of stay was 6 days (range, 1 to 63 days), and mortality was 3%. Median hospital cost per discharge was $4408 (range, $1199 to $59 799). Fifty percent of costs were for room charges, 19% for stroke evaluation, 21% for medical management, and 7% for acute rehabilitation therapies. Sixteen percent were admitted to an intensive care unit. Length of stay accounted for 43% of the variance in total cost. Other independent predictors of cost included stroke severity, heparin treatment, atrial fibrillation, male sex, ischemic cardiac disease, and premorbid functional status.

Conclusions—We conclude that the major predictors of acute hospital costs of stroke in this environment are length of stay, stroke severity, cardiac disease, male sex, and use of heparin. Room charges accounted for the majority of costs, and attempts to reduce the cost of stroke evaluation would be of marginal value. Efforts to reduce acute costs should be monitored for potential cost shifting or a negative impact on quality of care. **(*Stroke*. 1999;30:724-728.)**

Key Words: costs and cost analysis ■ outcome ■ stroke, ischemic ■ stroke management

Stroke imposes a major economic burden on our healthcare system. The cost estimate of stroke is approximately $30 billion each year, over half of which is attributed to direct medical costs.[1] Shrinking federal healthcare resources and pressures from the private sector have led to a critical look at the resources utilized in caring for stroke patients. It is generally agreed that the goal of this process should be reducing expenditures while maintaining quality of care.

A number of studies have begun to address resource utilization in stroke. Several of the initial studies investigated resource utilization outside the United States,[2–5] where practice patterns and costs are different. Others have used data obtained from Medicare databases,[6] relied on diagnosis related groups to identify patients, identified patients by *International Classification of Diseases, Ninth Revision* codes,[7] or simply evaluated total hospital charges and costs.[7,8] All these approaches are subject to limitations. No study has provided detailed financial data or prospectively collected clinical data. Such data would allow identification of specific areas of resource consumption and clinical factors that might influence resource utilization.

Recently, the use of specialized stroke teams has been introduced, and they have been effective in reducing length of stay (LOS) and cost.[9] This has largely been accomplished empirically, through the elimination of obvious inefficiencies. Any further cost reductions will be more difficult. The determination of whether they are possible and in what areas they should be targeted requires more detailed analysis.

The first step in this process is a systematic assessment of what specific resources are being utilized. The economic impact of stroke includes the direct (acute hospitalization, rehabilitation, subsequent medical complications) and indirect (lost productivity and caregiver burden) costs. Careful analysis of each component should be performed independently and then in relationship to the entire continuum of care.

Several forms of financial data have been used to describe resource utilization. Charge data[10,11] are determined from the hospital charges that appear on patient bills. These data are easily obtained; however, because charges are designed to maximize reimbursement, they do not accurately reflect resource utilization. Charges to insurance companies are

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often inflated to recoup the expense of caring for both insured and uninsured patients, and hospitals shift expenses among departments to maximize third party reimbursement.[12] Cost is generally considered a more valid estimate of resources utilized[13,14] and can be defined either in terms of economic cost or accounting cost. Economic cost is the actual price paid by the healthcare institution for resources expended.[12] Accurately calculating economic cost is difficult because it must take into account capital investments, supplies, equipment, labor, and support services. Most hospital financial systems therefore define cost as accounting cost. Accounting cost is determined by applying department-specific charge-to-cost ratios, which take into account overhead and capital expenditures, to charge data.

The present study was designed to provide a more detailed look at resource utilization in acute ischemic stroke in the setting of a tertiary care academic medical center that employs a stroke management team. We examined clinical and financial data to determine what resources were utilized and what factors predicted high resource consumption.

Subjects and Methods

The population included all patients admitted to the neurology service with acute ischemic stroke seen by the Stroke Management and Rehabilitation Team at a tertiary care academic hospital during the first half of 1996. The team did not direct medical management but acted to reduce LOS by expediting rapid diagnostic evaluation and discharge planning. The team made early referrals to acute rehabilitation services (physical, occupational, and speech therapy) and facilitated transfer to inpatient rehabilitation or chronic care facilities, when appropriate. The team included codirectors (C.Y.H., A.W.D.), a nurse coordinator (C.W.S.), stroke fellows (P.T.A.), and dedicated therapists. Any patient with significantly depressed level of consciousness, who required continuous cardiac monitoring, or who was hemodynamically unstable was admitted to the Neurology/Neurosurgery Intensive Care Unit (NNICU). Only patients admitted for an acute ischemic stroke were included in this study.

Each patient was prospectively evaluated to determine demographics (age, sex, and race), insurance status (Medicare, Medicaid, private commercial, managed care), and clinical characteristics that might influence amount of resources utilized during the acute hospital admission (see below). The presence of a previous stroke was determined on the basis of history and review of medical records. The existence of the following concurrent medical illness was determined by history, physical examination, laboratory data, and review of medical records: hypertension, atrial fibrillation, ischemic cardiac disease, congestive heart failure, diabetes mellitus, and chronic obstructive pulmonary disease. Premorbid functional status was defined according to the modified Rankin scale scored at the time of admission by interviewing the patient and family. A National Institutes of Health Stroke Scale (NIHSS) score was obtained on admission. Patients were admitted directly to the NNICU if they had significantly impaired level of consciousness, suspected cardiac ischemia, new or unstable arrhythmias, or concern about airway protection. Outcome was defined on the basis of mortality and discharge location of survivors, which was characterized as being discharged to home, home with help (requiring assistance from family or paid caregivers with activities of daily living), inpatient rehabilitation, or a nursing home.

Hospital financial data were obtained from the Clinical Financial Information System, which is a national database sponsored by the Voluntary Hospitals of America. Line item charges from each patient's hospital bill and hospital department–specific charge-to-cost ratios are supplied by the hospital. Charges were aggregated into 42 specific categories. The Clinical Financial Information System compiles the charge-to-cost ratios from participating medical centers and produces an average regional charge-to-cost ratio. Charges are then converted to costs on the basis of these ratios. Since the ratios differ across hospital departments, areas with high charges are not necessarily high-cost areas to the hospital. To determine the specific types of resources consumed, the cost of each item was calculated, and the items were combined to organize costs in categories that are most relevant to the care of acute stroke patients (Table 1). Since physicians in this institution bill patients independently, there was no way to reliably determine physicians' fees through the hospital accounting system; therefore, they were not included.

TABLE 1. Categories for Classification of Hospital Costs and Charge/Cost Ratios

Category	Charge/Cost Ratio
Room costs	
Ward bed	1.22
ICU bed	1.13
Stroke evaluation	
Cranial imaging (CT/MRI)	1.93
Angiography	1.25
Cardiac imaging (echocardiograms)	4.57
EEG	1.13
Other imaging (carotid Dopplers)	2.56
Management	
Laboratory studies	5.46
Medication	5.88
Medical supplies	3.91
Operating room (tracheotomy)	6.25
Dialysis	5.08
Respiratory therapy (oxygen, ventilators)	10.60
Chest radiography	2.61
ECG	14.30
Pulmonary function testing	3.01
Interventional radiology (G-tube placement)	2.04
Specimen collection	6.71
Preadmission	
Ambulance	0.94
Emergency department	4.27
Rehabilitation	
Physical, occupational, and speech therapies	1.55

EEG indicates electroencephalography.

The patients were divided into the following groups: good versus poor premorbid function according to a modified Rankin scale of 0 to 1 versus 2 to 5 based on the approach taken in the National Institute of Neurological Disorders and Stroke (NINDS) t-PA Stroke Trial[15]; independent versus dependent according to a modified Rankin scale of 0 to 2 versus 3 to 5; and the presence or absence of a previous stroke. They were also classified by stroke severity according to the NIHSS score divided into the 4 categories (0 to 9, 10 to 14, 15 to 20, and >20) used in a subgroup analysis of the NINDS t-PA Stroke Trial.[16] In addition, patients were compared on the basis of the presence or absence of hypertension, atrial fibrillation, ischemic cardiac disease, congestive heart failure, diabetes mellitus, and chronic obstructive pulmonary disease.

Since the financial data were not normally distributed, a log transformation was performed. The transformed data were normally distributed; therefore, all comparisons for continuous variables between groups were performed with independent *t* tests or 1-way ANOVA, as appropriate. Post hoc comparisons were performed with the Duncan test. A value of $P \leq 0.05$ was considered statistically

TABLE 2. Demographics, Clinical Status on Presentation, and Outcome for 191 Patients Included in the Study

Age	
Mean±SD	70±14.0
Range	20–92
Sex	
Male	81
Female	110
Race	
White	102
Black	87
Other	1
Premorbid condition	
Rankin 0–1	142
Rankin 2–5	43
Previous stroke	59
NIHSS	
Mean±SD	10.4±10.8
Range	1–60
Atrial fibrillation, n	14
Ischemic heart disease, n	36
Received heparin, n	67
Hospital disposition	
Home	81
Rehabilitation	75
Other medical	4
Nursing home	26
Dead	5
LOS	
Median	6
Range	1–63

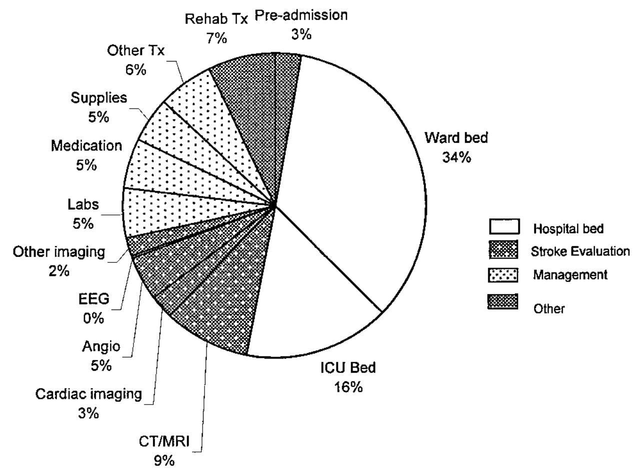
Not all categories sum to 191 because of missing data.

significant. Data are presented as mean±SD, except financial data that are presented as median and range.

A stepwise multiple regression analysis was computed to determine the predictors of total hospital cost. A stepwise selection method was used to fit the model. For a variable to be included in the multiple regression analysis, its F statistic on univariate analysis had to be significant at the $P<0.50$ level. The criterion for retention of a variable in the model was $P<0.15$. With this technique, each variable included in the final model makes a unique contribution to the total cost. Mallow's $C_{(p)}$ criteria was used to prevent overfitting the data. All data analyses were computed with the use of SAS version 6.12 for Windows. The study was approved by the institution's institutional review board.

Results

A total of 191 patients were included in the study. The demographics, premorbid conditions, and outcomes are presented in Table 2. Of the total, 114 patients (60%) had supratentorial and 67 had infratentorial (brain stem or cerebellar) strokes. One hundred forty-two patients (74%) were classified as having little or no functional limitations before the admission (modified Rankin scale score, 0 to 1). Eighty-one percent had a good outcome (discharged to home or inpatient rehabilitation). Median LOS was 6 and ranged from 1 to 63 days. Mortality was 3%. Median total hospital cost per discharge was $4408 (range, $1199 to $59 799).



Distribution of acute hospital costs for 191 patients admitted to a neurology service for acute ischemic stroke. Tx indicates therapy.

The distribution of costs into categories for the entire group is presented in the Figure. Fifty percent of the costs were attributed to room charges, 19% were associated with diagnostic tests used to evaluate the etiology of the stroke, 21% were for medical management, and 7% were for acute rehabilitation therapies. Ninety-one percent of the patients underwent diagnostic imaging studies (CT or MRI), 81% echocardiograms, 48% noninvasive evaluation of the carotid arteries, 20% angiography, and 6% electroencephalography. Sixteen percent were admitted to an intensive care unit (ICU), and 98% received rehabilitation therapies during the acute hospital stay.

Median total cost for patients with severe stroke (NIHSS score >20) was more than twice that of patients with mild strokes (Table 3). The higher cost of severe strokes was associated with increased LOS, with means of 5 (range, 1 to 63), 6.5 (range, 2 to 47), 6 (range, 1 to 33), and 12.5 (range, 2 to 45) days for NIHSS scores of 0 to 9, 10 to 14, 15 to 20, and >20, respectively. The higher cost of severe strokes was also associated with greater use of the ICU and its associated costs (medications, laboratories, respiratory therapy, supplies, and other medical treatments). When adjusted for LOS, the median cost per hospital day for NIHSS scores of 0 to 9, 10 to 15, 16 to 20, and >20 was $576, $466, $729, and $512, respectively. The cost of diagnostic tests did not vary with stroke severity.

The 14 patients with atrial fibrillation had higher total cost associated with a higher NIHSS and longer LOS. Total cost was higher in the 34 patients with ischemic cardiac disease, but there were no differences in NIHSS scores or LOS.

There was no relationship between age, insurance status, premorbid condition, and total cost. The 5 patients who died used significantly more resources than the survivors, at $9754 (range, $2714 to $41 879) versus $3961 (range, $878 to $59 800) ($P<0.0004$). Total cost varied by discharge location, with those discharged to nursing homes having a considerably higher cost: $8490 (range, $1998 to $41 879) versus home cost of $3074 (range, $878 to $11 549); home

TABLE 3. Hospital Cost in Dollars by Stroke Severity

	NIHSS 0–9 (n=125)		NIHSS 10–14 (n=24)		NIHSS 15–20 (n=15)		NIHSS >20 (n=27)	
	Median	Range	Median	Range	Median	Range	Median	Range
Ward bed	1618	0–7040	1682	673–5419	2355	1009–12 718	3364	0–8190
ICU bed	0	0–6108	0	0–4886	0	0–24 431	0	0–31 762
CT/MRI	256	0–1737	197	0–1314	203	0–1511	372	0–1463
Angiography	0	0–2946	0	0–2874	482	0–1065	0	0–3372
Echocardiogram	157	0–1018	155	0–305	170	0–455	0	0–1269
EEG	0	0–688	0	0–150	0	0–150	0	0–150
Other imaging	0	0–650	32	0–624	59	0–1385	268	31–1798
Laboratories	179	0–980	168	14–1642	254	14–1835	576	105–2769
Medications	108	0–1112	102	13–2076	155	46–2544	452	139–5152
Supplies	66	0–1423	102	3–2144	85	15–2377	518	56–4215
Other treatments	70	0–1317	55	4–947	93	6–2500	285	12–5845
Preadmission	70	0–6518	69	0–1937	39	0–1010	39	0–3806
Rehabilitation therapies	341	0–1017	470	156–1037	482	182–1212	537	0–1430
Total cost	2865	878–13 682	3032	1278–24 115	4377	1715–41 879	6411	2521–59 800

with help cost of $4071 (range, $993 to $59 800); and rehabilitation cost of $6611 (range, $2170 to $8209) ($P<0.00002$).

A summary of the stepwise multiple regression model is presented in Table 4. LOS accounted for 43% of the variance in total cost. Other independent predictors included stroke severity, atrial fibrillation, ischemic cardiac disease, male sex, poor functional status before the stroke, and use of heparin.

Discussion

Using prospectively collected clinical data, we determined predictors of the acute hospital cost of patients presenting with ischemic stroke to a self-managed academic stroke center. Independent predictors of total hospital costs were LOS, stroke severity (based on NIHSS), atrial fibrillation, ischemic cardiac disease, male sex, and use of heparin.

The use of stroke teams and stroke units has already been shown to have a significant impact on costs of care.[9,17,18] Much of this cost saving has been the result of empiric identification of barriers to efficient diagnosis and management, elimination of inefficiencies, and more aggressive discharge planning. Thus, in this setting, most of the "fat" has already been "trimmed." To determine whether further saving is possible and in what areas, detailed analyses of clinical and financial data are required.

There are several approaches to understanding the cost of stroke. Some have addressed the question through analysis of large databases to determine the total cost of stroke across the continuum of care. This approach provides a "bird's-eye" view of the various components of care, but its utility is hampered by the limited and imprecise clinical data available. On the other end of the spectrum are systematic analyses of small, relatively homogeneous populations during one segment of the continuum of care. This approach is more useful to the individual institutions and practitioners who are charged with the responsibility of reducing healthcare costs while maintaining quality. Both approaches are necessary to reduce the cost of care for patients with acute ischemic stroke. While detailed evaluations of small, carefully characterized cohorts can provide insight into how to reduce the cost of acute care, the larger view is needed to determine whether the result is simply to shift cost to other areas, such as rehabilitation, or result in more readmissions and worse outcome.

It is important to note that physicians' fees were not included in this analysis, which focused on hospital cost. Since we did not have access to physicians' fees, they were estimated to provide some indication of how they would influence the total cost of acute stroke. We surveyed the billing practices of neurologists on our stroke service and, on the basis of median LOS and local Medicare reimbursement, estimated physician "cost" at $492 or 11% of median hospital cost.

An important strength of this analysis is the prospective collection of clinical data. Each patient was seen by a stroke fellow to determine the diagnosis, collect clinical data, and perform the NIHSS. Additionally, unlike studies that use Medicare data, our study is not limited by age.

TABLE 4. Stepwise Multiple Regression Analysis Predicting Total Hospital Cost*

Variable	β	SE β	Model R^2	P
LOS	0.03	0.003	0.43	<0.0001
NIHSS score	0.03	0.004	0.53	<0.001
Heparin	0.41	0.087	0.55	<0.006
Atrial fibrillation	0.16	0.171	0.57	<0.01
Male Sex	−0.22	0.08	0.59	<0.03
Ischemic cardiac disease	0.23	0.10	0.60	<0.08

*The following variables were entered into the model: age, race, sex, LOS, NIHSS score, prior stroke, hypertension, atrial fibrillation, ischemic cardiac disease, diabetes, congestive heart failure, and heparin. The significance level for entry into the model was 0.50; the significance level for inclusion in the model was 0.15.

This study does, however, have limitations. Since our intent was to study a tertiary care academic center that employs self-management to expedite care, the ability to generalize our results is limited. The impact of this approach may help to explain the differences in LOS, total cost, and outcome between our study and previously published reports. The mean LOS for patients admitted with acute ischemic stroke in other US studies ranged from 9.2 to 11.6 days,[6–8] considerably longer than the 8 days in our study. Similarly, average total cost in most studies ranged from $7220 to $13 149, again higher than in our study. These differences are probably a result of our use of self-management.[9,17] Finally, our 3% mortality was considerably lower than in these studies.

Although LOS accounted for more of the variance in total cost than all other variables entered into the multiple regression model, most previous studies demonstrated a higher correlation between total cost and LOS than we found in our study. This is a consequence of the shorter LOS in our cohort. In acute stroke patients, there are significant fixed costs, such as imaging and diagnostic studies, that are independent of LOS. As LOS shortens, the contribution of these fixed costs to the total rises, and the correlation between LOS and total cost falls. Thus, the cost per day is highest on the first day and falls to approximately half that by day 3.[19]

We found that the cost of acute care rose with stroke severity, but only in areas related directly to LOS and intensity of care. The cost of evaluating the etiology of stroke only accounted for 19% of the total cost and did not differ by stroke severity. These data suggest that efforts directed at reduced utilization of diagnostic tests will be of limited value in reducing overall cost. Attempts to expedite performance of diagnostic tests to reduce LOS may be more fruitful, an approach currently being taken by stroke teams.[9,17]

The relationship between heparin use and cost is complex, with many potential covariates. This issue deserves particular attention, given the recent trials that failed to show a benefit of acute anticoagulation in the treatment of ischemic stroke.[20,21] Thus, we may be faced with the possibility that the use of an unproven therapy is of no benefit but drives up cost. This question deserves careful analysis.

Age, insurance status, and premorbid condition did not influence total cost. Stroke severity had a major influence on cost. The cost of more severe strokes was higher because of increased LOS and increased intensity of care. When these same factors were examined in the multiple regression analysis, however, stroke severity emerged as an independent predictor of cost after we accounted for the effects of LOS and cost of medical management. Similarly, atrial fibrillation, male sex, and cardiac disease were independent predictors of increased cost. Patients with atrial fibrillation tended to have more severe strokes and a longer LOS, which may have influenced the impact of atrial fibrillation on total cost. Male patients were more likely to have had a prior stroke and had more comorbidities. While none of these differences were significant, the combined impact of these factors may have resulted in higher costs for male patients.

Although these data may be useful in reducing the cost of the acute care of ischemic stroke, implementation of such measures must be accomplished in conjunction with a more global view of the consequences. This is necessary to ensure that they do not simply result in shifting of costs to follow-up care, resulting in poor quality of care, more complications, or more frequent readmissions.

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