Analysis of the Costs and Payments of a Coordinated Stroke Center and Regional Stroke Network

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Background and Purpose—An earlier study demonstrated significantly improved access, treatment, and outcomes after the implementation of a progressive, comprehensive stroke program at a tertiary care community hospital, Saint Luke’s Neuroscience Institute (SLNI). This study evaluated the costs associated with implementing such a program.

Methods—Retrospective analysis of total hospital costs and payments for treating patients with ischemic stroke at SLNI (n=1570) as program enhancement evolved over time (2005, 2007, and 2010) and compared with published national estimates. Analyses were stratified by patient demographic characteristics, patient outcomes, treatments, time, and comorbidities.

Results—Controlling for inflation, there was no difference in SLNI total costs between 2005 and either 2007 or 2010, suggesting that while SLNI provided an increased level of services, any additional expenditures were offset by efficiencies. SLNI total costs were slightly lower than published benchmarks. Consistent with previous stroke care cost estimates, the median overall differential between total hospital costs and payments for all ischemic stroke cases was negative.

Conclusions—SLNI total costs remained consistent over time and were slightly lower than previously published estimates, suggesting that a focused, streamlined stroke program can be implemented without a significant economic impact. This finding further demonstrates that providing comprehensive stroke care with improved access and treatment may be financially feasible for other hospitals. (Stroke. 2013;44:2254-2259.)

Key Words: cost ■ guidelines ■ stroke ■ thrombolytic ■ tissue-type plasminogen activator

Stroke is a devastating disease that in 2007 accounted for 1 of every 18 deaths in the United States.1,2 The direct medical cost from stroke in 2007 was $25 billion in the United States.3

Despite multiple studies confirming efficacy,3 use of intravenous tissue-type plasminogen activator (tPA) was used in only 3.4% to 5.2% of stroke cases in 2009.4 In response to this important clinical challenge, Saint Luke’s Hospital, a tertiary care community hospital in Kansas City, Missouri, systematized acute stroke care and organized a regional stroke network. An analysis comparing access and outcomes for stroke cases at Saint Luke’s in 2005, 2007, and 2010 showed (1) an increased ischemic stroke volume of 23% because of the increase in transfers from an enlarging network of referring hospitals and (2) an increased use of intravenous tPA from 13.6% in 2005 (n=59) to 28.5% in 2010 (n=135).5 These gains resulted from incremental changes in the Saint Luke’s Stroke Program that grew the regional referral network to >70 hospitals and improved the efficiency of care once the patient reached Saint Luke’s:

1. proactive-focused stroke education on patient outcomes for referring emergency department staffs and regional emergency medical services personnel initiated in 2006 by 2 stroke team nurses.
2. Streamlined transfer process initiated in 2007, including 1 phone number to reach a stroke neurologist and standardized faxed order sets for administration of tPA and transport protocols.
3. 24/7 coverage by a neurocritical care nurse (2008) who is the first responder and coordinator of care for stroke cases in the emergency department.
4. Expansion of standardized order sets and care paths on the basis of guidelines.5

However, 24/7 access to stroke expertise and technologies to provide cutting-edge treatments to a large regional network requires both clinical and administrative support, and hospitals must address significant financial questions before undertaking efforts to improve stroke care. The financial burden and clinical implications of stroke treatment are worldwide concerns.6–25 Brinjikji et al26 have demonstrated...
with a US hospital discharge database, the National Inpatient Sample, that the costs of treating patients with acute ischemic stroke with intravenous tPA significantly exceed the Medicare payments hospitals receive for this treatment. Guzaukas et al.7 found that setting up a primary stroke center was more costly than not having specialty care, but noted that primary stroke centers were quite cost effective in treating acute ischemic stroke. The National Stroke Association and local health systems have also provided information to help build the financial case for hospitals to improve their stroke care.28,29

In our previous article, we described the access and outcome improvements of stroke management at Saint Luke’s Hospital in Kansas City.5 To further make the case for the feasibility of a comprehensive stroke program, this follow-up study demonstrates the costs and payments of such a program from a hospital perspective, and compares these costs with a national published benchmark and examines how they change over time, as enhancements of the program evolved and the referral network widened. To the authors’ knowledge, this is the first evaluation of stroke treatment costs and payments for a US community hospital and regional stroke network.

Methods

This study was conducted retrospectively using Saint Luke’s Neuroscience Institute (SLNI) database that evaluated actual hospital costs and payments received from all payers. The study was approved by the Saint Luke’s Health System Institutional Review Board.

SLNI has created a registry for all patients treated for acute ischemic stroke that contains demographic characteristics, treatments received (including intravenous tPA, intra-arterial tPA, and mechanical embolectomy), discharge disposition, comorbidities, and clinical outcomes. Clinical data were collected during hospitalization and after hospital discharge. These data were integrated with financial data for each patient to evaluate the impact of a comprehensive regional stroke program on health system costs and hospital financial operations. Specific metrics include total hospital costs (defined as total direct hospital costs plus indirect hospital overhead costs), actual payments to the hospital from all payers, contribution margin (defined as actual payments received less total direct costs), and profit or loss (defined as actual payments received less total hospital direct and indirect costs). It should be noted that the analysis perspective rests on acute stroke hospitalization care delivery and operation. Physician fees independent from hospital costs were not included in this analysis. The no reperfusion attempt cohort did not receive treatment with tPA or have embolectomy procedures during the time period of the analysis.

Registry and financial data from 2005, 2007, and 2010 were included to examine changes over time. Cost data for 2005 and 2007 were adjusted to 2010 dollars using the Bureau of Labor Statistics consumer price index for hospital and related services. Patient level financial data were obtained from SLNI and summary tables created medians and 25% to 75% quartile ranges for these nonparametric data. All statistical analyses were conducted using Stata version 12.1. Wilcoxon rank-sum tests were used to determine statistical significance between 2 groups, and Kruskal–Wallis tests were used for more than 2 groups. A multivariate generalized linear model with a γ distribution was used to examine changes over time. Cost data for 2005 and 2007 were inflated to 2010 costs using the consumer price index for hospital services. Secondary analyses stratified patients by discharge status and age to evaluate costs by outcome and potential payer groups, respectively. Independent variables included in the regression analyses were whether the patient was discharged to home or home healthcare, aged ≥65 years, sex, comorbidities (diabetes mellitus, coronary artery disease, and atrial fibrillation), stroke severity using the National Institutes of Health Stroke Scale (NIHSS) score, hospital length of stay, intra-arterial tPA or embolectomy treatment received, no reperfusion attempt cohort, and year of treatment.

Of note, all costs captured in this analysis, and in the comparative Brinjikji literature, reflect the acute hospitalization and do not include the costs of skilled nursing or rehabilitation facilities.

Results

Financial and clinical registry data were available for 1570 patients with SLNI with an acute ischemic stroke. The median total cost (direct+indirect costs) per patient was $12812 for all patients (both treatment and no reperfusion attempt cohorts). Table 1 summarizes the total costs for patients that received intravenous tPA. These data demonstrate similar values between men and women and between those aged <65 and ≥65 years. Patients who were discharged to home or home healthcare were associated with lower costs than other discharge groups (P=0.022). Similar relationships between patient demographic subgroups were observed with intra-arterial tPA or embolectomy, although the median values for each group were higher than intravenous tPA (data not shown). Overall, the total cost results in Table 1 are generally lower
for SLNI, but consistent with the relevant literature, 2012 publication of Brinjikji et al\textsuperscript{26} using national data. The current study found a median total cost of $18,190 for men and $15,907 for women, compared with $19,681 and $19,826 for men and women, respectively, in the literature. Patients \textlessthan}65 had median costs of $18,099 in the current study compared with $19,969 in the literature. For patients aged \textgreater{}65 years, the current study found a median cost of $17,929 compared with $19,672 in the literature. Similarly, total costs were lowest for patients discharged to home or home healthcare ($14,247 in the current study compared with $16,613 in the literature) and highest for patients discharged to a skilled nursing facility or rehabilitation facility (=21,300 in the current study compared with $22,214 in the literature). Patients who died or were discharged to hospice had a median cost of $20,355, compared with $22,536 for patients who died in the literature. Similar themes were noted when these total cost categories were stratified by patients aged \textlessthan}65 and \textgreater{}65 years. For patients who had a secondary intracranial hemorrhage, the total cost in the present study was $20,339, compared with $26,470 in the literature.

For patients receiving intra-arterial tPA or embolectomy, the median actual payments were $20,705 (interquartile range, $13,219–$32,224), median total direct costs $14,985 ($10,580–$22,000), contribution margin $2752 ($1548 to $12,442), total indirect costs $8616 ($6364–$12,260), total costs $23,526 ($16,833–$33,976), and profit or loss of $–4596 (–$12,287 to 22,85).

Table 3 summarizes the multivariate analysis of total costs (defined as direct costs+indirect costs) for treating acute ischemic stroke. Patients who were aged \textgreet}65 years were less costly (by $1883) than younger patients. Higher baseline NIHSS scores were associated with higher total costs ($103) for each 1-U increase in NIHSS after controlling for other independent variables in the regression model. For example, the hospital cost for a patient with a baseline NIHSS of 15 was $1030 higher compared with a patient with a baseline NIHSS score of 5 after controlling for other independent variables in the model. Longer stays were associated with an increased cost of $1705 per day. Patients receiving intra-arterial tPA or an embolectomy were associated with a $9727 higher cost than patients who did not receive these treatments. As expected, no reperfusion attempt patients (ie, patients with acute ischemic stroke who did not receive intravenous tPA, intra-arterial tPA, or embolectomy) were $4578 less costly than treated patients.

After controlling for inflation, there was no difference in total hospital costs between 2005 and 2007 or 2010.

The multivariate analysis of actual payments to the hospital is summarized in Table 4. These data demonstrate that the hospital received $6755 less for each patient aged \textgreet}65 years compared with patients aged \textlessthan}65 years. Longer stays were associated with increased payment of $766 per day. Intra-arterial tPA or embolectomy was associated with higher ($9309) payments. However, the hospital was paid $7114 per patient less for the no reperfusion attempt cohort. After controlling for inflation, the hospital received $8918 per patient more in payments in 2010 compared with 2005. There was no difference in payments between 2005 and 2007.

**Discussion**

Because the current clinical guidelines for acute ischemic stroke recommend tPA where appropriate, it is useful to assess the financial data of a tertiary care community hospital that provides such care. Rymer et al\textsuperscript{3} previously demonstrated that SLNI has been successful in increasing access to stroke care at a comprehensive stroke center and improving stroke management according to national guidelines. SLNI is a successful example of cross-community collaboration between hospitals to improve
stroke care. The cost analysis demonstrates that SLNI costs are consistent with the national analysis; while estimates were not available to compare total costs aggregated across all patients with stroke with national estimates published by Brinjikji et al., simple comparisons illustrated SLNI total costs may be 4% to 23% lower across stratified patient populations. Although caution must be used in interpreting such findings, as multivariate analyses were not able to evaluate the relative populations directly, the SLNI cost results suggest that facilities focused on streamlined stroke care processes may be effective in managing the costs of stroke care. This finding is further supported by the fact that there was no difference in total costs (after accounting for inflation) between 2005 compared with either 2007 or 2010. SLNI continuously focuses on reducing non-value-added costs and reinvesting those dollars into new processes and programs, which contributes to a fairly flat cost structure over time (adjusting for inflation). Thus, although further research would be needed to confirm more definitively, it is likely that SLNI’s efforts to improve quality metrics as demonstrated in an earlier study also contributed to greater efficiencies, shorter lengths of stay, and reduced costs. This analysis indicates that SLNI has successfully implemented a comprehensive program with coordinated regional care, dedicated high-level staffing, state-of-the-art technology, and process efficiencies that results in better access, care, and outcomes while overall total hospital costs remained unchanged. The implication is that the increase in costs for personnel and technology was offset by improved efficiencies in process, although this analysis did not allow identification of the cost savings attributable to a specific change in process.

It is important to note that a specialized facility, such as SLNI, continues to lose money for each patient treated. These analyses support the finding by Brinjikji et al. in their analysis of intravenous tPA that noted hospital costs for intravenous tPA were substantially higher than Medicare payments. Because tPA has been associated with improved clinical outcomes, it may be appropriate for Medicare and private insurers to assess the overall cost savings associated with better outcomes resulting from acute stroke therapy and modify reimbursements to incentivize treatment. If evidence is established that intra-arterial tPA or embolectomy yields better outcomes in patients with large vessel occlusions, payment coverage should be even higher than intravenous tPA because this analysis noted that the financial losses were greater when intra-arterial tPA or embolectomy were used. Yet these treatments were administered to patients with the most severe cases that, if untreated, were most likely to have longer hospital stays, more likely to go to skilled nursing facilities, less likely to return to work, and more likely to increase long-term costs.

Multivariate analysis of the actual payments received by SLNI is intriguing. To the authors’ knowledge, this is the first article to present data on hospital payments received to manage patients with acute ischemic stroke across all payers. These data demonstrate that the hospital received $6755 less for patients aged ≥65 years compared with patients <65, which suggests that Medicare pays lower rates for acute stroke care than private insurance companies, even when controlling for patient characteristics such as Medicare status.

Multivariate analysis of the actual payments received by SLNI continues to lose money for each patient treated. These data demonstrate that the hospital received $6755 less for patients aged ≥65 years compared with patients <65, which suggests that Medicare pays lower rates for acute stroke care than private insurance companies, even when controlling for patient characteristics such as Medicare status.

### Table 3. Multivariate Analysis of Total Costs for All Patients With Acute Ischemic Stroke

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Total Costs</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharged to home/home healthcare</td>
<td>$−780</td>
<td>0.4000</td>
</tr>
<tr>
<td>Age ≥65 y</td>
<td>$−1883</td>
<td>0.0100</td>
</tr>
<tr>
<td>Men</td>
<td>$−413</td>
<td>0.5300</td>
</tr>
<tr>
<td>History of diabetes mellitus</td>
<td>$−387</td>
<td>0.5700</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>$511</td>
<td>0.4100</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>$−387</td>
<td>0.6700</td>
</tr>
<tr>
<td>Baseline National Institutes of Health Stroke Scale</td>
<td>$103</td>
<td>0.0500</td>
</tr>
<tr>
<td>Hospital length of stay (per day)</td>
<td>$1705</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Intra-arterial tissue plasminogen activator or embolectomy treatment received</td>
<td>$9727</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>No reperfusion attempt cohort</td>
<td>$−4578</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Year=2007</td>
<td>$−1341</td>
<td>0.2300</td>
</tr>
<tr>
<td>Year=2010</td>
<td>$2835</td>
<td>0.0600</td>
</tr>
<tr>
<td>Constant</td>
<td>$11450</td>
<td>&lt;0.0001</td>
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<tr>
<td>No. of observations</td>
<td>482</td>
<td></td>
</tr>
</tbody>
</table>

### Table 4. Multivariate Analysis of Actual Payment Received for All Patients With Acute Ischemic Stroke

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Actual Payments</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharged to home/home healthcare</td>
<td>$−661</td>
<td>0.9500</td>
</tr>
<tr>
<td>Age ≥65 y</td>
<td>$−6755</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Men</td>
<td>$−87</td>
<td>0.9200</td>
</tr>
<tr>
<td>History of diabetes mellitus</td>
<td>$−160</td>
<td>0.8600</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>$−179</td>
<td>0.8000</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>$608</td>
<td>0.5400</td>
</tr>
<tr>
<td>Baseline National Institutes of Health Stroke Scale</td>
<td>$34</td>
<td>0.5200</td>
</tr>
<tr>
<td>Hospital length of stay (per day)</td>
<td>$766</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Intra-arterial tissue plasminogen activator or embolectomy treatment received</td>
<td>$9309</td>
<td>0.0200</td>
</tr>
<tr>
<td>No reperfusion attempt cohort</td>
<td>$−7114</td>
<td>0.0300</td>
</tr>
<tr>
<td>Year=2007</td>
<td>$−257</td>
<td>0.8200</td>
</tr>
<tr>
<td>Year=2010</td>
<td>$8918</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Constant</td>
<td>$18842</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>No. of observations</td>
<td>446</td>
<td></td>
</tr>
</tbody>
</table>
such as hemorrhagic stroke (intracerebral hemorrhage and subarachnoid hemorrhage), diagnoses requiring craniotomies (eg, brain tumors, aneurysms, subdural hematomas), epilepsy monitoring, and spine surgery. There may also be hospital marketing benefits in differentiating neurological specialty care from other facilities, and potentially the increasing loyalty of a growing senior population.28

There are several important limitations with this study. First, these cost data are from 1 institution and may not generalize to other hospitals or health systems. Second, this study was not a randomized clinical trial for patients in the treatment or no reperfusion attempt cohorts. Instead, the data were taken from a registry that documented when patients received tPA or embolectomy (or were not eligible to receive these treatments), and represent the operation of a stroke program in a tertiary community hospital in a real-world setting. Third, this was a retrospective registry analysis, and fourth, although the costs were adjusted for inflation to compare with published literature, the original data years were distinct and may be slightly different. Finally, indirect overhead costs (ie, electricity, laundry, administration, etc) were imputed on the basis of standard calculations and assumptions used by hospital administrators.

Conclusions
This study demonstrates that SLNI, which has instituted an innovative, comprehensive, and regional stroke program with demonstrable improvements in access, treatment, and outcomes,2 maintained total costs during the time period of implementation, and had total hospital costs that were slightly lower than previously published national estimates.26 However, the differential between total costs and payments suggests that payers should further consider reimbursement levels for acute stroke hospitalizations. The changes at SLNI were introduced incrementally over time to increase the quality and efficiency of stroke care, representing changes that could be incorporated by other tertiary care community hospitals. These results suggest that a comprehensive stroke care program with improved access, stroke care, and outcomes may be financially feasible for hospitals to implement.

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Disclosures
Dr Rymer is on the Speaker’s Bureau for Covidien Medical and consults for Medtronic, Inc. Drs Armstrong and Meredith are consultants to GE Healthcare through Strategic Therapeutics, LLC for the project. Dr Pham is an employee of Saint Luke’s Hospital and received no outside funding for his role in the project. Dr Kruzikas is employed by GE Healthcare, which provides medical imaging, diagnostic, patient monitoring, and information technologies, including computed tomography scanners and electronic medical record systems.

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