Acute Pediatric Stroke
Contributors to Institutional Cost

Colin M. Turney, BS; Wei Wang, MS, MAS; Eric Seiber, PhD; Warren Lo, MD

Background and Purpose—Recent studies examined the overall cost of pediatric stroke, but there are little data regarding the sources of these costs. We examined an administrative database that collected charges from 24 US children’s hospitals to determine the sources of costs for acute hospital care of stroke.

Methods—We used International Classification of Diseases, 9th Revision codes to search the Pediatric Health Information System. From 2003 to 2009 there were 1667 patients who had a primary diagnosis of stroke, 703 of which were hemorrhagic and 964 were ischemic. Individual costs, excluding physician charges, were gathered under 7 categories that were ranked to determine which contributed the most to total cost. Individual costs were ranked within their categories. We analyzed costs based on stroke type. Total costs were adjusted using the US Consumer Price Index to compare increases with the rate of inflation.

Results—Median total cost for any stroke was $19 548 (interquartile range, $10 764–$40 721). The category “other/nursing” contributed the most to hospital costs followed by imaging, laboratory, and pharmacy. Brain MRI and CT contributed the most to imaging costs. Hemorrhagic strokes (median $24 843) were more expensive than ischemic strokes (median $16 954). Total cost increased from 2003 to 2009, but no overall annual trend emerged after controlling for gender, age, race, and hospital.

Conclusions—This is the first in-depth analysis of cost for pediatric stroke care. The highest cost categories are potential targets for cost containment but are also crucial for effective diagnosis and treatment. Necessary yet prudent use of imaging technologies and inpatient stays may be strategies for cost containment. (Stroke. 2011;42:00-00.)

Key Words: economics ■ health care ■ neuropsychiatrics ■ pediatric neurology ■ stroke care ■ stroke in children

Strokes in children often have significant neurological and financial impacts. Usually, the clinician depends on imaging technology to differentiate between the uncommon pediatric stroke and relatively more prevalent diseases that mimic stroke. Many sites that manage a child with an acute stroke see few cases in a year, so there is a lack of familiarity with the steps needed for evaluation and treatment. The need to arrive at a prompt, accurate diagnosis and an appropriate treatment plan sets up an uneasy situation in which controlling costs is difficult.

The costs related to stroke care have been analyzed many times in adults. Although the exact dollar amounts vary based on the sample and methodology, estimates for acute care generally run in the thousands of dollars.1,2 For example, in a study of patients with stroke from a consortium of US hospitals from 1991 to 1997, the average hospital cost for stroke without pneumonia in 2000 US dollars was $6206.3 Yoneda reported that average hospital costs for ischemic and hemorrhagic stroke in 10 Japanese stroke centers in 2000 to 2001 were US $8662 and $10 260, respectively.4 Qureshi analyzed a US database and reported that 2000 to 2001 average hospital charges for ischemic stroke were $16 200 and for intracerebral hemorrhage were $28 800.5 These studies have identified variables at a macroscopic level that influence cost such as age, length of hospital stay, type of stroke, and teaching status of the hospital.4,7 Other studies have identified direct (diagnostic care, inpatient care, rehabilitation care) and indirect (social care, social benefits, productivity losses) costs to society.8

Although the cost of pediatric stroke has received far less attention than adult stroke, stroke care for children and adults is comparably expensive. Analyses of US national data sets have provided a macroscopic view and show that mean charges for acute pediatric stroke care range from $15 003 for ischemic stroke to $31 653 for hemorrhagic stroke.9 An analysis of a different US national data set for adult stroke yielded similar results.5 Studies that have examined the cost of acute care and rehabilitation found that 1-year costs at a
single institution averaged $42,338,\textsuperscript{10} whereas the median 5-year cost of acute care and rehabilitation in a health maintenance organization was $135,161.\textsuperscript{11} The studies undertaken thus far have focused on total costs but provided little insight into the source of these costs. Any attempt to consider cost-effectiveness must begin with an understanding of where costs occur. To address that aim, we have analyzed an anonymized data set that allowed us to examine costs at an individual patient level. If physicians treating children for acute stroke are aware of the sources of these costs, that knowledge can assist their attempts to deliver cost-effective care.

Methods

Data Collection and Processing

We used an administrative database, the Pediatric Health Information System (PHIS), to review patients treated at 24 different children’s hospitals across the United States. This data set has been used to analyze practice patterns in a number of pediatric disorders.\textsuperscript{12,13} The PHIS compiles data from inpatient, emergency, and ambulatory surgery departments from 40 of 42 participating hospitals that are affiliated with the Child Health Corporation of America. All data are deidentified on submission. Discharge and encounter data, demographics, diagnoses, and procedure data are recorded from all participating hospitals. Resource utilization data such as pharmacy, imaging, and laboratory charges are collected from the participating hospitals. Because the PHIS does not collect physician charges, this article focuses on hospital or institutional costs. The Child Health Corporation of America, along with the participating hospitals, is responsible for reliability and validity checks to ensure the quality of the data. Thomson Reuters is responsible for the data warehouse function.

In the PHIS data set, charges were recorded from 24 hospitals for children with a primary diagnosis of stroke from 2003 through 2009. Cases were included for analysis if the primary discharge diagnosis field contained an International Classification of Disease, 9th Revision (ICD-9) code for arterial ischemic or hemorrhagic stroke. We used ICD-9 codes 430 (subarachnoid hemorrhage) and 431 (intracerebral hemorrhage) to identify cases of hemorrhagic stroke and 433.xx and 434.xx to identify cases of arterial ischemic stroke. PHIS is anonymized so we could not review the records to verify the stroke diagnosis and we could not exclude the possibility that cases were inaccurately classified. ICD-9 coding of adult stroke may be inaccurate and insensitive.\textsuperscript{14–16} In children, ICD-9 codes may be insensitive for cases of arterial ischemic stroke.\textsuperscript{17,18} In 1 pediatric study, the 433 code in any position had a 79% accuracy of identifying arterial ischemic stroke; the 434 code had an accuracy of 52% and a yield of 47%.\textsuperscript{17} When these codes were restricted to the primary position, accuracy increased but yield decreased. To increase the likelihood we were dealing with strokes, we only analyzed cases with a primary diagnosis of stroke and cases in which stroke was a secondary diagnosis were excluded. We analyzed cases in which the diagnosis of stroke was made after age 1 month so we did not address neonatal stroke. Patients aged <28 days at discharge were excluded to minimize including children with perinatal stroke or neonatal intraventricular hemorrhage. To minimize the inclusion of children who had trauma or injury as a cause of stroke, we excluded those whose diagnostic fields contained ICD-9 codes for trauma or injury ("E" codes).

This selection strategy initially identified 1990 discharges from an acute hospital admission for stroke. Initial review of the data identified that in the early years of the data set, cases from a minority of institutions lacked charge data. When these cases were excluded, 1813 discharges remained. These 1813 discharges corresponded to 1667 unique patients.

Individual subject charges were recorded in PHIS. These charges were grouped into 7 broad categories: supplies, clinical services, imaging, laboratory, pharmacy, procedures, and other/nursing. Physician charges were not available. Charges for these categories were calculated along with total charges for each discharge. Procedures were treated separately because they were not listed with a specific dollar charge but whether they were performed (ie, “yes” or “no”). The effect of individual charges on a category of charge was handled in a similar fashion.

We selected the individual charges based on their importance for evaluation and treatment as described in recent reviews of pediatric stroke and published guidelines.\textsuperscript{19} For example, intracranial pressure monitors were deemed important because severe stroke may result in increased intracranial pressure.\textsuperscript{20} Imaging studies have a major role in stroke evaluation, and clinicians depend heavily on MRI brain scans and vascular imaging studies.\textsuperscript{21} Charges for nursing care were allocated according to the unit where the subject received care (emergency room, intensive care unit, general medical or surgical ward). Many subjects received care in an intensive care unit, but after the intensive care unit, the subjects could have received nursing care on a general medical or surgical ward, a subspecialty service ward, or a rehabilitation unit. An initial review of laboratory charges determined that no specific laboratory test stood out as particularly notable; consequently, laboratory charges were only examined at the category level. A complete list of the specific items analyzed is contained in Supplemental Table I (http://stroke.ahajournals.org).

Conversion of Charges to Costs

Invalid charges such as negative charges or charges that exceeded the value for their upper-level category were treated as missing values. Charges were adjusted to account for regional differences. A hospital-specific cost-to-charge ratio for each year was applied to transform charges to total hospital costs. Costs were adjusted to 2009 US dollars using the Consumer Price Index for All Urban Consumers (www.bls.gov/cpi/tabs.htm, accessed August 17, 2010).

Relative Effects on Cost

We determined that 93% of subjects were admitted once, so that for these subjects, the total hospital cost associated with a discharge was equivalent to a cost per subject. Of the 122 subjects who were admitted multiple times, 106 were admitted twice, and the remaining 16 were admitted from 3 to 6 times. We performed the following analysis twice, first using only the initial discharge for each patient and then using the summed hospital costs across all discharges for patients who were admitted more than once.

The cost for each category was divided by total hospital cost to generate a ratio and a percent of total hospital cost for each patient. The ratios for each patient were then averaged. A similar approach was used for the selected items within each category. Mean values, medians, and interquartile ranges were generated for total hospital costs and 6 broad categories (procedures were excluded). Preliminary inspection of the data showed that costs at all levels (total, categories, individual items) were skewed with most costs clustering toward the low end of the range and a few costs at the higher range.

Procedure category data were limited to whether a procedure was performed (no cost information was provided). Therefore, we stratified total hospital cost data using the 75th percentile to define those admissions with high cost. This percentile was selected based on an initial inspection of the data: the 75th percentile tended to define the shoulder of the cost curve. Chi-square tests were used to test the association between the performance of specific procedures and high cost. Those procedures that were associated with high cost were then entered into a multivariate regression model to identify which retained significance.

Effect of Stroke Researcher Status and Stroke Diagnosis on Cost

We hypothesized that the presence of a stroke clinical researcher at a given hospital would result in increased cost of stroke care. We determined that at 5 of 24 hospitals, a child neurologist enrolled cases in an international registry, the International Pediatric Stroke Study.\textsuperscript{22} We stratified hospitals based on this participation status and...
compared the respective log-transformed means of total cost and the 6 categories of cost with paired \( t \) tests. The same approach was used to examine the effect of stroke diagnosis (hemorrhagic versus ischemic) on total hospital cost and cost in the broad categories. The PHIS data set did not include outcome data and the patient data were anonymized; therefore, we could not compare cost with quality of outcome.

### Acute Care Cost Change Over 2003 to 2009

We examined the change in the total cost of hospital care over the years 2003 to 2009 using costs adjusted to 2003 values. Total costs were log-transformed before linear regression versus year while controlling for gender, age, hospital, and race. Statistical significance was set at a \( P < 0.05 \).

All data analysis was performed using SAS 9.1.3 (SAS Institute Inc, Cary, NC).

### Results

A total of 1813 discharges were identified, which corresponded to 1667 unique patients. A total of 92.68% of cases were associated with only 1 discharge. A total of 6.36% of patients had 2 discharges, 0.72% had 3, 0.06% had 4, 0.12% had 5, and 0.06% had 6. Median age at admission was 10 years (interquartile range, 5–14 years). Seven hundred seventy-eight patients were female and 889 were male. Seven hundred three patients (42%) were diagnosed with hemorrhagic strokes, and 964 patients (58%) were diagnosed with ischemic strokes. Ethnic backgrounds of the patients were 1073 white, 383 black, 29 Asian, 59 missing, and 123 other. Twenty cases received alteplase.

Histograms were generated for total hospital cost and all categories of cost except procedures, which were handled separately due to the lack of specific cost data (Figure 1). When examining the first discharge of all patients, median hospital cost in 2009 US dollars was $19,548 with an interquartile range of $10,764 to $40,721. The most expensive category of cost with respect to percent of total hospital cost was other/nursing followed by imaging, laboratory, pharmacy, clinical, and then supplies (Table 1). For patients who were admitted multiple times, median total hospital cost for all discharges was $39,451 with an interquartile range of $23,622 to $77,859.

When we examined individual costs within a category, we found that specific items had a substantial contribution to cost. For example, within the category of other/nursing, care in an intensive care unit accounted for the largest portion of cost followed by care on a general medical ward. (Table 2) Care on subspecialty medical wards, general surgical wards, the emergency ward, operating room, and rehabilitation ward accounted for relatively small percentages of total other/nursing costs. As another example, most children had brain MRI scans and CT scans. MR angiography of the head and neck were the next most frequently performed studies followed by heart ultrasound, catheter angiography, and CT angiography of the head and neck (Table 3). Children who had higher imaging costs had greater numbers of procedures. For example, the 346 admissions with imaging costs in the highest 20th percentile had 380 MRI brain studies (mean cost $1610), whereas the 1388 admissions with the lower costs had 1126 MRI brain studies (mean cost $1221). This difference was even more striking for catheter-based angiograms in which the 346 admissions with imaging costs in the highest 20th percentile had 974 studies (mean cost $1730), whereas the 1388 admissions with lower imaging costs had 399 studies (mean cost $990).

Because specific cost data were not provided for procedures, we analyzed procedure costs using a \( \chi^2 \) test. We found 4 variables, inserting endotracheal tubes, continuous invasive mechanical ventilation, ventriculostomy, and brain procedures (diagnostic biopsies, excision of lesions, and brain incisions), associated with total costs above the 75th percentile. When applying a multivariate regression analysis to these procedures, they remained significantly associated with costs above the 75th percentile (\( P < 0.0001 \)). We tested for multicollinearity between endotracheal intubation and continuous mechanical ventilation, because they might be highly correlated, but the correlation was only 0.37. To confirm this finding, we tested for tolerance and found that tolerance for inserting endotracheal tubes was 0.85 and tolerance for continuous invasive mechanical ventilation was 0.79. These results indicated that endotracheal intubation and continuous mechanical ventilation were not highly correlated.

Contrary to our expectation, stroke researcher status was not associated with higher total cost and nursing costs. There was a trend toward higher costs, but this did not reach significance after accounting for multiple comparisons. Stroke researcher status was associated with significantly higher costs for clinical services and supplies, but these represented a minor contribution to overall cost (Supplemental Table I). Patients diagnosed with a hemorrhagic stroke incurred a significantly higher total cost than patients diagnosed with ischemic stroke (Table 4). Patients with hemorrhagic stroke also incurred significantly higher costs for nursing, pharmacy, and supplies. The presence of conditions associated with stroke increased the cost of care for hemorrhagic and ischemic stroke (Supplemental Table II). The median length of stay for all subjects was 5 days (mean, 10 days). If a subject had an associated diagnosis of condition that increased the propensity for stroke, the median length of stay was 6 days (mean, 12 days). Subjects who had hemorrhagic stroke had a median length of stay of 6 days (mean, 12 days).

We wanted to determine if increases in hospital cost outpaced inflation. Using the first discharge of each patient, total hospital costs were adjusted by the annual Consumer Price Index for 2003 to 2009 and then standardized to 2003 dollars. Hospital costs were log-transformed before regression analysis and then the antilog of the mean values was plotted by year (Figure 2). No overall annual trend emerged after controlling for gender, age, race, and hospital fixed effects with only 2009 significantly higher than stroke costs in 2003 (\( P = 0.04 \)).

### Discussion

Our results for the total hospital cost of stroke in this cohort are similar in magnitude with our previous results using a US national administrative database, KID2003, in which we found the mean cost of acute hospital care for all childhood strokes was $20,927 in 2003 dollars. Our results are similar to those of Gardner and colleagues who examined the cost.
of stroke care for neonates and children in a US managed care network. In that study, in which diagnoses were validated by neurologist review of the records, the median acute cost for childhood ischemic stroke was $21,144 with an interquartile range of $7,879 to $56,190 and for childhood hemorrhagic stroke median cost was $34,256 with an interquartile range of $10,992 to $133,545. That our results are similar to those of Gardner et al that suggests that the 2 studies identify a range for the acute hospital cost of childhood stroke care in the United States.

Figure 1. A. Total cost per discharge. Cost is displayed in increments of $25,000 dollars on the horizontal axis, whereas numbers of discharges are plotted on the vertical axis. Most discharges had a total cost <$50,000. There was a heavy skew to the right with a small number of discharges with total costs > $250,000 up to a maximum of $780,177. B. Imaging costs per discharge. Cost is displayed in increments of $2,000 on the horizontal axis and numbers of discharges are displayed on the vertical axis. Imaging costs are also heavily skewed to the right. The costs of other categories showed a similar distribution pattern.
Table 1. Contribution to Total Cost of Various Services by Category

<table>
<thead>
<tr>
<th>Category</th>
<th>All Cases</th>
<th>Stroke + Associated Diagnoses</th>
<th>Stroke-Associated Diagnoses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median Cost</td>
<td>Interquartile Range</td>
<td>Percent of Total Cost</td>
</tr>
<tr>
<td>Total cost</td>
<td>$19,548</td>
<td>$10,764–$40,721</td>
<td>100</td>
</tr>
<tr>
<td>Other/nursing</td>
<td>$7,181</td>
<td>$3,408–$15,975</td>
<td>38</td>
</tr>
<tr>
<td>Laboratory</td>
<td>$2,377</td>
<td>$1,121–$4,878</td>
<td>14</td>
</tr>
<tr>
<td>Pharmacy</td>
<td>$1,482</td>
<td>$486–$4,549</td>
<td>10</td>
</tr>
<tr>
<td>Clinical services</td>
<td>$1,415</td>
<td>$478–$4,282</td>
<td>10</td>
</tr>
<tr>
<td>Supplies</td>
<td>$691</td>
<td>$182–$2,291</td>
<td>5</td>
</tr>
</tbody>
</table>

Categories are ranked from highest to lowest by percent of total cost. For each patient, the cost of each category was divided by the total cost. The resulting ratios for all patients were averaged to generate the average percent of total cost. The middle columns and columns on the right demonstrate the effect that additional diagnoses associated with stroke have on total cost.

No previous studies have analyzed the components that contribute to the cost of stroke care for children. A limited number of studies used categories such as diagnostic tests and location of care to calculate the initial cost of adult stroke care.\(^1,23–25\) Only a very few actually reported the categories that contribute to the cost of stroke care for children. A limited number of studies used categories such as diagnostic tests and location of care to calculate the initial cost of adult stroke care.\(^1,23–25\)

The cost of imaging presents a conundrum. Brain MRI contributed the most to imaging costs, but this is not surprising because brain MRI is a crucial diagnostic tool. The frequency of stroke mimics and the low frequency of pediatric stroke compel the clinician to rely on imaging technology to assist with the diagnosis.\(^26\) Delays in obtaining imaging contribute to delays in diagnosing childhood stroke.\(^27,28\) For this reason, limiting brain MRI costs is not a straightforward option. Brain CT was the second highest source of imaging cost; this may reflect that 42% of the stroke cases were hemorrhagic. Median costs for invasive head and neck arteriography, heart ultrasound, and CT arteriography were low, suggesting few patients had these tests. Because invasive head and neck arteriography is the gold standard for cerebrovascular examination\(^21\) and heart ultrasound is key to evaluating sources of embolism,\(^13,20\) we expected these studies would have been ordered more frequently.

Our results confirm our previous findings\(^10,29\) and the findings of others\(^11,30\) that hemorrhagic stroke is far more frequent than ischemic stroke. The frequency of stroke mimics and the low frequency of pediatric stroke compel the clinician to rely on imaging technology to assist with the diagnosis.\(^26\) Delays in obtaining imaging contribute to delays in diagnosing childhood stroke.\(^27,28\) For this reason, limiting brain MRI costs is not a straightforward option. Brain CT was the second highest source of imaging cost; this may reflect that 42% of the stroke cases were hemorrhagic. Median costs for invasive head and neck arteriography, heart ultrasound, and CT arteriography were low, suggesting few patients had these tests. Because invasive head and neck arteriography is the gold standard for cerebrovascular examination\(^21\) and heart ultrasound is key to evaluating sources of embolism,\(^13,20\) we expected these studies would have been ordered more frequently.

Our results confirm our previous findings\(^10,29\) and the findings of others\(^11,30\) that hemorrhagic stroke is far more frequent than ischemic stroke.

Table 2. Patient Ward Contribution to Other/Nursing Costs for All Admissions

<table>
<thead>
<tr>
<th>Patient Ward</th>
<th>Median Costs</th>
<th>Interquartile Range</th>
<th>Mean Costs</th>
<th>Percent of Other/Nursing Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensive care unit</td>
<td>$2834</td>
<td>$0–$8032</td>
<td>$7667</td>
<td>39%</td>
</tr>
<tr>
<td>General medical</td>
<td>$0</td>
<td>$0–$1922</td>
<td>$2124</td>
<td>19%</td>
</tr>
<tr>
<td>Specialty medical</td>
<td>$0</td>
<td>$0–$0</td>
<td>$928</td>
<td>9%</td>
</tr>
<tr>
<td>General surgical</td>
<td>$0</td>
<td>$0–$0</td>
<td>$652</td>
<td>5%</td>
</tr>
<tr>
<td>Emergency</td>
<td>$197</td>
<td>$0–$458</td>
<td>$280</td>
<td>5%</td>
</tr>
<tr>
<td>Operating room</td>
<td>$0</td>
<td>$0–$364</td>
<td>$1061</td>
<td>5%</td>
</tr>
<tr>
<td>Rehabilitation</td>
<td>$0</td>
<td>$0–$0</td>
<td>$633</td>
<td>3%</td>
</tr>
</tbody>
</table>

Patient nursing charges were ranked from highest to lowest based on their contribution to overall percent of category costs as calculated for Table 1. The median costs for multiple patient ward types was $0, which reflects the pronounced right skew for costs and that not every patient was admitted to every ward. For comparison, costs for each ward were fitted to a normalized curve to generate a mean value to illustrate the magnitude of cost for each patient ward.

Table 3. Contribution to Imaging Costs by Study Type

<table>
<thead>
<tr>
<th>Study Type</th>
<th>Median Costs per Admission</th>
<th>Interquartile Range</th>
<th>Proportion of Children With Study</th>
<th>Median Cost per Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain MRI</td>
<td>$1013</td>
<td>$0–$1468</td>
<td>72%</td>
<td>$1174</td>
</tr>
<tr>
<td>Brain CT</td>
<td>$572</td>
<td>$0–$1265</td>
<td>70%</td>
<td>$706</td>
</tr>
<tr>
<td>MRI head and neck arteriography</td>
<td>$616</td>
<td>$0–$1218</td>
<td>60%</td>
<td>$908</td>
</tr>
<tr>
<td>Heart ultrasound</td>
<td>$0</td>
<td>$0–$610</td>
<td>45%</td>
<td>$229</td>
</tr>
<tr>
<td>Catheter head and neck angiograph</td>
<td>$0</td>
<td>$0–$0</td>
<td>23%</td>
<td>$1178</td>
</tr>
<tr>
<td>CT head and neck arteriography</td>
<td>$0</td>
<td>$0–$0</td>
<td>13%</td>
<td>$801</td>
</tr>
</tbody>
</table>

Study types were ranked from highest to lowest based on the percent of imaging cost. The median imaging cost for invasive head and neck arteriography, heart ultrasound, and CT head and neck arteriography during an admission was $0 because fewer than half the patients received these studies. Mean values were generated as in Table 2.

MRI indicates magnetic resonance imaging; CT, computed tomography.
common among children than in adults\textsuperscript{5} and more expensive overall than childhood ischemic stroke.\textsuperscript{11} The current study extends our previous work by showing that hemorrhagic and ischemic stroke costs differ significantly in the categories of other/nursing services, pharmacy, and supplies, but not in imaging, laboratory, and clinical services. This finding is consistent with our study of national stroke costs\textsuperscript{9} that showed the length of stay was considerably longer for childhood hemorrhagic stroke when compared with ischemic stroke. The current result suggests that the largest contribution to hemorrhagic stroke care cost is in the duration of inpatient treatment rather than differences in diagnostic evaluation. We anticipated that neurologists who contributed cases to a pediatric stroke study might influence practice patterns of stroke care but found this not to be the case.

Given the current popular concern regarding the rapid increase in healthcare costs, we fully expected to show that the cost of stroke care increased faster than the overall rate of inflation. Costs for 2009 were greater than those for 2003, but there was no overall annual trend when compared with the rate of inflation after we controlled for gender, age, race, and hospital. How recent legislative changes in the United States will affect these costs is uncertain, but those changes will occur gradually and are unlikely to have much short-term impact.

Our study has several limitations. As we noted earlier, ICD-9 codes have limitations in accurately identifying cases of stroke. We chose to analyze those cases in which stroke was a primary diagnosis, which increases the accuracy but decreases the yield. Therefore, our analysis likely missed cases of stroke. It is possible that our search strategy was skewed toward the less complicated cases, which has been the case in adult studies when searches for ischemic stroke were limited to the primary diagnosis.\textsuperscript{14} In that case, our findings may represent an underestimate of the true cost. PHIS is anonymized so we could not verify the accuracy of the stroke diagnosis. To increase the likelihood that we were genuinely dealing with strokes, we only analyzed cases in which the stroke code was the primary diagnosis. This approach has been shown to be sensitive for hemorrhagic strokes\textsuperscript{16} and has been suggested as 1 approach to increase the specificity for ischemic stroke.\textsuperscript{15} We analyzed cases in which the diagnosis of stroke was made after age 1 month so we did not address neonatal stroke. PHIS only recorded acute admissions and direct hospital costs. Physician charges, long-term rehabilitation costs, and indirect costs were not available. Costs of care limited to the outpatient setting such as for children with presumed perinatal stroke were not available. In the United States, physician fees may comprise 15\% to 19\% of the total hospital admission costs. An analysis of a subset of adult beneficiaries in the 2001 to 2003 Medical Expenditure Panel Survey found that physician reimbursements for inpatient care were 19\% of Medicare reimbursements for an inpatient hospital stay.\textsuperscript{31} In an analysis of Medicare reimbursements for adults admitted for cerebral infarction in 1991, physician reimbursements ranged from 15\% to 17\% of overall inpatient hospitalization costs.\textsuperscript{32}

Only data from 24 US children’s hospitals were included; therefore, our results may not generalize to other settings or countries. For example, a recent study on antithrombotic treatment indicated that practices differ among the United States, Canada, Europe, South America, and Australia.\textsuperscript{33} Previous investigators have recommended that cost studies of cerebrovascular disease be based on an unselected sample,\textsuperscript{8} but that will be difficult to accomplish with an uncommon disorder such as childhood stroke. Despite these limitations,

<table>
<thead>
<tr>
<th>Source of Charge</th>
<th>Hemorrhagic Stroke</th>
<th>Ischemic Stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median IQR</td>
<td>Median IQR</td>
</tr>
<tr>
<td>Total</td>
<td>$24,843 $11,739–$53,729</td>
<td>$16,954 $10,310–$30,663</td>
</tr>
<tr>
<td>Nursing</td>
<td>$9,585 $3,913–$22,501</td>
<td>$6,673 $3,089–$12,030</td>
</tr>
<tr>
<td>Imaging</td>
<td>$4,441 $2,099–$8,001</td>
<td>$3,895 $2,604–$6,766</td>
</tr>
<tr>
<td>Laboratory</td>
<td>$2,276 $685–$6,634</td>
<td>$2,416 $1,309–$4,197</td>
</tr>
<tr>
<td>Pharmacy</td>
<td>$2,708 $933–$7,698</td>
<td>$1,053 $360–$2,745</td>
</tr>
<tr>
<td>Clinical</td>
<td>$1,874 $507–$5,683</td>
<td>$1,248 $468–$3,146</td>
</tr>
<tr>
<td>Supplies</td>
<td>$1,247 $329–$4,696</td>
<td>$457 $115–$1,351</td>
</tr>
</tbody>
</table>

Only costs relating to the first discharge of each patient were considered.

*Cost differences between stroke diagnosis were significant at P<0.007 after correction for multiple comparisons.
we believe that our estimates illustrate the magnitude of acute care cost in the United States.

In summary, we have identified the major categories of cost for acute stroke care in children. Given that other/nursing and imaging are the greatest contributors to hospital costs, future studies addressing cost containment should examine these areas. However, modern imaging technology has enabled physicians to diagnose strokes more accurately than ever and to more effectively plan treatments. Costs from other/nursing are a result of inpatient care and are necessary for the treatment and recovery of patients. Thus, efforts to contain costs in these areas have the potential to regress quality of care. It may be, however, that certain aspects of imaging and inpatient care are used inappropriately or overused. If this is the case, these areas may be excellent targets for cost containment. In short, to deliver the most effective and efficient care for stroke, imaging techniques and inpatient care must be delivered judiciously but simply be used in a manner that maximizes benefits for patients.

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Disclosures
None.

References
Supplemental Material

ICD-9 Codes used to identify cases of stroke

Hemorrhagic Stroke

430 Subarachnoid hemorrhage
431 Intracerebral hemorrhage

Ischemic Stroke

433.xx Occlusion and stenosis of precerebral arteries
434.xx Occlusion of cerebral arteries

Search parameters for 2003-2005 and 2006-2009 “Other Details”
Link to specific patient with 2003-2005 and 2006-2009 “Patient Detail” spreadsheet

Medical units

600105 - Peds unit unspecified
600115 - Ped general medical unit
600295 - Other ped med/surg unit

Specialty medical units

600145 - Ped hem/oncology unit
600155 - Ped neurology unit

Surgical units

600205 - Ped surgical unit
600245 - Ped orthopedic unit

ICUs

600605 – PICU
600655 - Ped neurosurgery ICU
600705 - Ped step-down unspec
600715 - Ped inten care step-down

Rehab units

600805 - Ped rehab unit

Operating room units
611110 - Operating room service

Emergency room units

613100 - ER service unspec
613130 - ER level III service
613140 - ER level IV service
613150 - ER level V service

ICD-9 Codes used to identify propensity factors

Congenital Heart Disease  648.5, 745.xx, 746.xx, 747.xx,
Cardiomyopathy          425.x
Valvular Heart Disease   424.0-424.3
Aneurysm                437.3
Arteriovenous malformations 747.81, 228.02
Moyamoya disease        437.5
Brain tumors (malignant and benign)  191.x, 225.x, 239.6, 198.3, 237.5, 237.6
Coagulation defects     286.x, 790.92
Hypercoaguable states   289.8, 289.81, and 289.82
Leukemia, Lymphocytic   204.x
Sickle Cell disease     282.6x
Meningitis/encephalitis 003.21, 013.x, 036.xx, 047.x-049.x, 053.0-
                      053.1x, 054.3, 054.72, 056.01, 062.x, 064,
                      066.2, 063.x, 072.1-072.2, 090.42, 091.81,
                      094.2, 094.81, 098.82, 100.81, 112.83, 114.2,
                      115.01, 115.11, 115.91, 130.0, 136.2, 139.0,
                      320.xx-322.xx, 323.xx
Endocarditis            036.42, 074.22, 098.84, 093.20-24, 112.81,
                      115.04, 115.14, 115.94, 391.1, 421.x, 424.91,
Sepsis/bacteremia       038.xx, 790.7, 771.8x
Dissection of carotid artery 443.21
Dissection of vertebral artery 443.24
Shock 785.50

Search terms
Supplies

241310 - CSF shunt unspec
241315 - CSF flow control valve
241319 - Other CSF shunt
244105 - Vasc angiographic cath
244248 – Neuroendoscope
246065 - Anesthesia supply
255551 - Intracran press monitor

Clinical Services Screen

521166 - Mechanical ventilation
535011 - Physical tx evaluation
535012 - Occupational tx evaluat
535013 - Speech/language evaluat
535014 - Swallowing evaluation
535110 - Physical therapy
535019 - Other evaluation
535120 - Occupational therapy
535301 - Ambulation training
535303 - Orthotic/prosth training
535307 - Gait training
535311 - Neuromuscr reeducat
535315 - ADL training
535317 - Speech/language therapy
535321 - Swallowing therapy
535353 - Orthotic equipment svc
535399 - Other rehab service
551010 - Psych testing/assessment
551099 - Other psych service
551059 - Other therapy

Imaging

411051 Brain CT
411052 Brain MRI
471051 Head arteriography CT
472051 Neck arteriography CT
471052 Head arteriography MRI
472052 - Neck arteriography MRI
400053 - MR spectroscop unsp site
470000 - Arteriography unsp tech
471018 - Head arteriograph angiog
471118 - Carotid arteriog angiog
471318 - Vertebral arteriog angio
472118 - Cerv arteriography angio
411045 - Brain Doppler
463040 - Heart nonstress US
463045 - Heart nonstress Doppler
463046 - Hrt nonstress Dopp color

Lab Screen

312202 - Homocysteine
331004 - Platelet aggregation
332040 - Factor V assay
332050 - Factor VII assay
332060 - Factor VIII assay
332070 - Factor IX assay
332120 - Factor VIII antigen
332130 - FDP 332150 - PTT
332170 - PT
332176 - DRVVT
332230 - D-Dimer
333001 - Fibrinogen level
333011 - Protein C
333021 - Protein S
334001 - Antithrombin III
341015 - Anticardiolipin antibody
341015 - Anticardiolipin antibody
382050 - PCR
382060 - Molecular dx interpretat
382010 - Molecular extraction
382020 - Enzymatic digestion
382030 - Molecular separation

Pharmaceuticals

Thrombosis coagulation

Alteplase
Enoxaparin
Clopidogrel
Aspirin
Phytonadione (K1)
Factor VIIa
Heparin sodium
Warfarin

*Radiological*

Gadopentetate dimeglumine
Radiopaque agents unspecified
Nonionic contrast media unspecified

*Anti-epileptics*

Fosphenytoin sodium
Levetiracetam
Carbamazepine
Phenytoin (extended) (prompt) (sodium)
Oxcarbazepine
Topiramate
Phenobarbital

*Immunosuppressive*

Dexamethasone
Immune globulin
Methylprednisolone (actate) (base) (sodium succinate)
Tacrolimus

Mannitol

*Chemotherapeutic*

Mesna
Methotrexate
Thioguanine
Hydroxyurea
Cyclophosphamide
Mercaptopurine

*Procedures*

0032  CAS w MR/MRA
0061  PERC ather precereb vess
0063  PERC insert CAR stent
0102  Ventriculopuncture via cath
0109  Cranial puncture NEC
0110  IC pressure monitoring
0114  Open biopsy of brain
0118  Dxtic px brain/cereb NEC
0124  Craniotomy NEC
0127  Rmvl cath cranial cavity
0131  Inc cerebral meninges
0139  Brain incision NEC
0159  Exc/destr brain les NEC
0212  REP cerebral mening NEC
0222  Ventriculostomy
0234  Vent shunt to abd cavity
0239  Ops to estab vent drain
0241  Irrig & expl vent shunt
0242  Repl ventricular shunt
0243  Rmvl ventricular shunt
0371  Subarach-periton shunt
3812  Head/nk endarterect NEC
3831  IC vessel resect w anast
3861  IC vessels exc NEC
3881  Occlusion IC vessels NEC
3891  Arterial catheterization
3928  EC-IC vascular bypass
3951  Clipping of aneurysm
3952  Aneurysm repair NEC
3972  Endov REP HN vessel
3974  Endov rmvl HN vess obstr
8703  CAT scan head
8841  Cerebral arteriogram
8861  Contr phlebogram-hd/neck
8891  Brain & brain stem MRI
9211  Cerebral scan
9338  Combined PT NOS
9339  Physical therapy NEC
9359  Immob/press/WND attn NEC
9374  Speech defect training
9375  Speech therapy NEC
9383  Occupational therapy
9604  Insert endotracheal tube
9671  Cont mech vent-<96 hours
9672  Cont invas MV->95 hrs
9739  Rmvl head/neck dev NEC
9901  Exchange transfusion
9910  Inject thrombolytic
9914  Inject gamma globulin
Other

Medical units
600105 - Peds unit unspecified
600115 - Ped general medical unit
600295 - Other ped med/surg unit

Specialty medical units
600145 - Ped hem/oncology unit
600155 - Ped neurology unit

Surgical units
600205 - Ped surgical unit
600245 - Ped orthopedic unit

ICUs
600605 - PICU
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Supplemental Table 1

Effect of stroke researcher status on cost

<table>
<thead>
<tr>
<th>Category of Cost</th>
<th>Stroke Researcher</th>
<th>Non-Stroke Researcher</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>Interquartile Range</td>
<td>Median</td>
</tr>
<tr>
<td>Total</td>
<td>$20,543</td>
<td>$11,689-$41,783</td>
<td>$18,597</td>
</tr>
<tr>
<td>Nursing</td>
<td>$7,610</td>
<td>$4,039-$16,271</td>
<td>$6,734</td>
</tr>
<tr>
<td>Imaging</td>
<td>$4,066</td>
<td>$2,332-$7,325</td>
<td>$4,188</td>
</tr>
<tr>
<td>Lab</td>
<td>$2,617</td>
<td>$1,216-$4,957</td>
<td>$2,258</td>
</tr>
<tr>
<td>Pharmacy</td>
<td>$1,417</td>
<td>$486-$4,638</td>
<td>$1,526</td>
</tr>
<tr>
<td>Clinical</td>
<td>$1,801</td>
<td>$580-$5,024</td>
<td>$1,267</td>
</tr>
<tr>
<td>Supplies</td>
<td>$782</td>
<td>$222-$2,328</td>
<td>$624</td>
</tr>
</tbody>
</table>

*Cost differences between stroke researchers and non-stroke researchers were significant at p < 0.007 after correction for multiple comparisons.
### Supplemental Table 2

<table>
<thead>
<tr>
<th>Source of charge</th>
<th>All Hemorrhagic Strokes</th>
<th>Hemorrhagic Strokes with Assoc. Diagnoses</th>
<th>Hemorrhagic Strokes without Assoc. Diagnoses</th>
<th>Ischemic Strokes with Assoc. Diagnoses</th>
<th>Ischemic Strokes without Assoc. Diagnoses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>Inter-quartile Range</td>
<td>Median</td>
<td>Inter-quartile Range</td>
<td>Median</td>
</tr>
<tr>
<td>Total</td>
<td>$24,843</td>
<td>$11,739-$53,729</td>
<td>$31,082</td>
<td>$14,582-$70,017</td>
<td>$21,325</td>
</tr>
<tr>
<td>Nursing</td>
<td>$9,585</td>
<td>$3,913-$22,501</td>
<td>$10,805</td>
<td>$4,272-$26,173</td>
<td>$8,845</td>
</tr>
<tr>
<td>Imaging</td>
<td>$4,441</td>
<td>$2,099-$8,001</td>
<td>$4,442</td>
<td>$2,050-$8,393</td>
<td>$4,441</td>
</tr>
<tr>
<td>Lab</td>
<td>$2,276</td>
<td>$685-$6,334</td>
<td>$3,306</td>
<td>$1,336-$8,018</td>
<td>$1,491</td>
</tr>
<tr>
<td>Pharmacy</td>
<td>$2,708</td>
<td>$933-$7,698</td>
<td>$3,388</td>
<td>$1,260-$9,839</td>
<td>$2,127</td>
</tr>
<tr>
<td>Clinical</td>
<td>$1,874</td>
<td>$507-$5,683</td>
<td>$2,539</td>
<td>$854-$6,801</td>
<td>$1,364</td>
</tr>
<tr>
<td>Supplies</td>
<td>$1,247</td>
<td>$329-$4,696</td>
<td>$1,494</td>
<td>$483-$6,218</td>
<td>$1,068</td>
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</tbody>
</table>