The Cost of Pediatric Stroke Care and Rehabilitation

Warren Lo, MD; Khaled Zamel, MD; Kavita Ponnappa, BS; Antoni Allen, BS; Deena Chisolm, PhD; Monica Tang; Bryce Kerlin, MD; Keith O. Yeates, PhD

Background and Purpose—There is little data regarding the cost of pediatric stroke care or the elements that contribute to these costs. We examined costs for poststroke care during the first year after diagnosis and compared these costs with the volume of the cerebral infarct and the level of neurological and functional outcome.

Methods—We identified 39 children who sustained nontraumatic ischemic or hemorrhagic strokes and confirmed the diagnoses by review of medical and radiology records. Medical costs were tabulated for the year after the diagnosis of stroke. Cerebral infarct volumes were measured from MRI or CT scans. Neurological outcome was assessed by telephone with a modification of the Pediatric Stroke Outcome Measure (PSOM), and functional outcomes were assessed with a standardized quality-of-life measure.

Results—The median cost for poststroke care during the year after diagnosis was $42,338 for the entire group. The cost for stroke care was higher for hemorrhagic stroke than for ischemic stroke. Cost had a significant positive correlation with neurological impairment. The modified PSOM score positively correlated with impairments of physical, emotional, social, and school function.

Conclusions—The cost of stroke care may be one measure of stroke severity, with more extensive strokes resulting in greater medical costs. In addition, stroke appears to impair children’s social ability along with their neurological function. (Stroke. 2008;39:161-165.)

Key Words: cost ■ infarct volume ■ outcome ■ pediatric ■ quality of life ■ stroke

Pediatric stroke is an important cause of chronic morbidity in children and can leave a child with disabilities that span motor, cognitive, and behavior functions. Although pediatric stroke is uncommon, the incidence ranges from 2 to 4 per 100,000, so that pediatric stroke is more common than primary childhood brain tumors.1,2 Interest in the causes of pediatric strokes has increased dramatically.3-6 The need for rehabilitation and the growing number of diagnostic studies obviously contribute to the cost of care after a stroke; surprisingly, the costs of care after pediatric stroke have not been studied in detail.

A number of studies have examined the cost of stroke care in adults. Some have examined the detailed costs (inpatient care, medications, physician services, outpatient therapy) of adult stroke care in specific institutions,7-10 while others examined the cost of adult stroke care at a national level.11-13 Additional studies of adult stroke care have developed projections of expenditures at national levels to inform national health policymakers.14-16 Cost-effectiveness analyses of adult stroke care have been used to guide the selection of treatments such as anticoagulation in nonrheumatic atrial fibrillation,17 antiplatelet therapy,18 acute thrombolysis,19 and the use of early discharge and stroke team coordination.20 Taken together, the adult studies demonstrate that the analysis of stroke-care costs can provide guidance for the development of healthcare policy and help guide the selection of treatments.

The costs of care have been studied for other common pediatric illnesses, such as asthma,21-23 cerebral palsy,24 traumatic brain injury,25 and sickle cell disease.26 The impact of clinical pathways on hospital-based costs and length of stay in pediatric asthma has been examined.27,28 In contrast, only 1 report indicated that the mean cost of the initial hospitalization for acute pediatric ischemic stroke was $38,700, but few details were provided.29

Because of this knowledge gap, we examined the cost of pediatric stroke care at 1 children’s hospital for 1 year after the diagnosis of a stroke. We sought to determine what component of stroke care contributed to the greatest proportion of costs, and whether the nature of the stroke (ie, hemorrhagic versus ischemic), volume of the cerebral infarct, or clinical outcome influenced costs.

Methods
The collection of patient data and outpatient follow-up information was approved by the Columbus Children’s Hospital Institutional Review Board. Patients were identified through hospital discharge records at the Children’s Hospital, Columbus, Ohio for the years 2001 through 2004. We screened discharge records of patients who were older than age 1 month on the basis of ICD-9 codes (430-438,438) that pertained to stroke or cerebral palsy. The text of...
inpatient MRI and CT scan reports were searched for terms (stroke, infarction, thrombosis, CVA, and ischemia) that pertained to stroke. The majority of the scans were MRI although in 2 subjects only CT scans were available. The diagnosis was confirmed by a review of hospital discharge records, radiology reports, and actual brain scans. Potential subjects were identified who had both a clinical neurological deficit and an abnormal diffusion-weighted image sequence or radiological evidence of intracranial hemorrhage. We selected subjects who were admitted to the hospital inpatient service for the evaluation of stroke after the neonatal period, and who had a confirmed diagnosis of nontraumatic arterial ischemic, sinovenous thrombosis with infarction, or hemorrhagic stroke. Potential subjects were included only if they had at least 2 outpatient follow-up visits for stroke care. We reasoned that if the patient had <2 follow-up visits, they would likely not have received any poststroke care at the Children’s Hospital. Potential subjects were excluded if they died during the initial hospital admission or within 1 year after diagnosis.

**Costs of Stroke Care**

Costs for the acute stroke and for the year after the initial diagnosis were identified from the Children’s Hospital’s cost accounting system. These costs include direct and indirect costs incurred across the health system. Cost data used in this analysis included inpatient, outpatient, surgical, laboratory, and imaging at any Children’s Hospital-associated site. This analysis did not include costs incurred in other healthcare systems, durable medical equipment, out-of-pocket expenses, or opportunity costs (eg, time taken off work). We attempted to exclude costs for care that appeared to be unrelated to poststroke care on the basis of primary diagnosis codes, but the difference in costs after this step was insignificant.

**Cerebral Infarct Volume**

The volumes of the cerebral infarcts were determined from brain scans that were obtained predominantly 1 year after the stroke. In 6 subjects only acute scans were available, and in 4 subjects follow-up scans were available 3 to 4 months after the stroke occurred. The volumes were manually traced from T2-weighted axial and FLAIR coronal sequences of MRI scans or from CT scans because this method has low intraobserver variability and high reproducibility. The area of the infarct was determined for a given slice with proprietary software (GE Healthcare), and the infarct volume per section was calculated by multiplying the area by the thickness of the section. The section volumes were summed to yield the volume of the cerebral infarct. Intracranial volumes varied according to the age of the child, and the intracerebral volumes measured by MRI scan were larger than those measured by CT scan. Therefore, we expressed the cerebral infarct volumes as a ratio (infarct ratio) of the infarct volume to the volume of the brain (cerebral hemispheres, cerebellum, brain stem, and ventricles) similar to what has been previously reported. The infarct ratios were not normally distributed, so the ratios were reported as a median value and range.

**Clinical Outcomes**

Clinical outcomes were assessed by telephone interview with caregivers of 19 subjects who agreed to participate in an Institutional Review Board–approved protocol. We modified the Pediatric Stroke Outcome Measure (PSOM), which has been used to quantify the neurological outcome after stroke. The original PSOM was developed for use in a clinical examination, so we modified it so that the measures could be assessed by telephone interview (supplemental Table I, available online at http://stroke.ahajournals.org). The summary measurements of the original PSOM elicited the caregiver’s assessment of the child’s level of function (for example: “Has your child recovered completely from the stroke?”) and distinguished deficits found on neurological examination within specific subcategories (ie, Sensormotor function, Language Comprehension, Language Production, Cognitive or Behavioral deficits). Functional outcomes were also measured by a more general measure of health-related quality of life (generic PedsQL) that has been used in a previous study of pediatric stroke.

### Table 1. Costs by Stroke Subtype and Sources of Costs

<table>
<thead>
<tr>
<th>Setting</th>
<th>Hemorrhagic (n=10)</th>
<th>Ischemic (n=29)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inpatient</td>
<td>49 948 (14 241–480 965)</td>
<td>21 666 (1891–176 802)</td>
</tr>
<tr>
<td>Outpatient</td>
<td>3002 (1267–48 221)</td>
<td>3005 (223–39 942)</td>
</tr>
<tr>
<td>Emergency</td>
<td>1923 (622–8200)</td>
<td>966 (34–28 312)</td>
</tr>
<tr>
<td>Total</td>
<td>67 860 (20 479–486 515)</td>
<td>31 678 (3070–202 862)</td>
</tr>
</tbody>
</table>

Costs for hemorrhagic and ischemic stroke by setting (Median and Range). Costs for care after hemorrhagic stroke were significantly greater than costs for ischemic stroke care. The largest proportion of costs for care came from the inpatient component.

**Data Analysis**

Because of the limited sample size and skewed cost data, the nonparametric Wilcoxon Rank Sum Test was used to compare costs for hemorrhagic versus ischemic stroke, involvement of the basal ganglia, history of a prior stroke, and idiopathic versus symptomatic stroke. Correlations between costs, clinical outcome measures, and infarct ratios were calculated using Spearman $\rho$ for ranked correlations. The scores from the PedsQL were transformed before analysis to a 0 to 100 scale ($0=$poorest level of function, $100=$highest level of function) according to the supplier’s guidelines.

**Results**

We identified 42 potential subjects who had an arterial ischemic or hemorrhagic stroke occurring from January 1, 2001, through December 31, 2004. Of the potential subjects, 2 died either from the acute stroke (subarachnoid hemorrhage) or from an associated illness (congenital heart disease) before 1 year had elapsed. One other potential subject had decreased water diffusion on an initial MRI that was not detectable 24 hours later; that individual was considered to have had a transient ischemic attack. The ages at the time of stroke for the remaining 39 subjects ranged from 3 months to 19 years. The caregivers of 19 subjects agreed to participate in an outcome study. The outcomes were assessed 2 to 5 years after the stroke. The remaining 20 declined, could not be reached, or were excluded because English was not their primary language.

**Basic Demographics and Costs for Stroke Care**

The cohort included 26 males and 13 females, a male predominance similar to that reported in recent series of pediatric stroke. The ethnic composition of the cohort was 67% white, 18% blacks, and 15% white Hispanic or unidentified, which is similar to the ethnic population of the region. There were 28 arterial ischemic strokes, 1 sinusovenous thrombosis with infarction, and 10 hemorrhagic strokes. The subjects who participated in the outcome study ranged in age from 5 to 21 years.

The payer mix was 41% government (ie, Medicaid or Medicaid-managed care) insurance, and the remaining 59% was a blend of commercial, other, or self-payers. The median cost for all 39 subjects was $36 132 with a range of $3070 to $486 514. The largest component of the cost came from inpatient care, which accounted for 81% of the total cost (Table 1). The 2 next largest components were outpatient care, which accounted for 14% of the total costs, and emergency room costs, which accounted for 4%. The costs were significantly greater ($P<0.01$ for hemorrhagic stroke (median cost $49 948) compared with ischemic stroke (me-
Table 2. Correlations of Infarct Ratios and Costs With Outcome, and the PSOM Outcome Measure With the PedsQL Outcome Measures

<table>
<thead>
<tr>
<th>PSOM</th>
<th>PedsQL Physical Function</th>
<th>PedsQL Emotional Function</th>
<th>PedsQL School Function</th>
<th>PedsQL Social Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Infarct ratios did not correlate with PSOM and PedsQL functional outcomes (n=19)</td>
<td>0.21</td>
<td>-0.26</td>
<td>0.15</td>
<td>-0.01</td>
</tr>
<tr>
<td>B. Costs correlated with physical and social function impairment (n=19)</td>
<td>0.62*</td>
<td>-0.79*</td>
<td>-0.22</td>
<td>-0.24</td>
</tr>
<tr>
<td>C. The PSOM outcome correlated with PedsQL outcome (n=19)</td>
<td>-0.89*</td>
<td>-0.69*</td>
<td>-0.80*</td>
<td>-0.76*</td>
</tr>
</tbody>
</table>

A. Infarct ratios did not correlate with neurological outcome measured by the PSOM or functional outcomes measured by the PedsQL. The correlation coefficients between the infarct ratios and the outcome measures are displayed.

B. Costs inversely correlate with neurological and physical functional outcomes. The panel shows the correlations between costs for stroke care and outcomes assessed by the PSOM and the PedsQL measures. A greater PSOM score indicates more neurological impairment. A greater PedsQL score indicates more functional impairment. The correlation coefficients are listed for each comparison. *P<0.05; **P<0.01.

C. PSOM scores correlated with all PedsQL functional outcomes measures. The correlation coefficients are listed for each comparison, all of which reached statistical significance. *P<0.05.

It was noteworthy that the scores from the modified PSOM inversely correlated with measures of physical (r=−0.89, P<0.01), emotional (r=0.69, P<0.01), social (r=−0.80, P<0.01), and school function (r=−0.76, P<0.01) of the PedsQL (Table 2C). The inverse correlation of the PSOM scores with multiple functional measures of the PedsQL suggested that neurological impairment was related to reduction in the overall quality of life after stroke.

Discussion

This is the first report of direct costs for poststroke care in children during the first year of recovery. Many analyses of the cost of adult stroke care have been conducted, and one aspect of these analyses, cost analysis, has been used to evaluate the efficacy of adult stroke treatments. Analysis of pediatric stroke care could be used as one parameter to measure the effectiveness of treatment options. Recent calls for multicenter clinical trials of pediatric stroke raise the possibility that opportunities will exist to examine cost data prospectively. Until now, no information has been available that could be used to develop a cost-analysis model; the current report provides a first step in this process.

The findings of this study were similar in several aspects to what has been previously reported. We found that the median cost for care was $42,338 for 1 year. This figure is consistent with a recent report that the mean cost for the initial hospitalization for acute ischemic stroke in children is $38,700.29 We found that costs were higher for hemorrhagic stroke than for ischemic stroke, as has been reported in adult studies.53-46 The inpatient hospitalization accounted for the largest portion of costs in the year after the stroke, consistent with what has been reported in adult studies.9,16,47,48 Also consistent with what has been reported in adult stroke is that the cost of pediatric stroke care correlated with the degree of physical and social functional impairment. One notable difference was that the size of cerebral infarcts did not correlate with outcome, in contrast to reports that in adults larger infarcts correlate with greater disability and poorer out-

dian cost $21,666). Costs did not vary significantly if the infarct involved the basal ganglia, it there was a prior stroke, or if a cause for the stroke was identified.

The median inpatient length of stay for hemorrhagic stroke was 8.5 days and for ischemic stroke was 5 days. This group difference did not reach statistical significance (P=0.10). The sample size was not sufficient to determine whether the difference in inpatient length of stay was the primary influence on cost differences, but length of stay was certainly a major contributor. We were unable to examine whether differences in treatment strategies affected costs.

Cerebral Infarct Volumes

For both the entire cohort and the subjects in the outcome study, the volume of the infarct was a small proportion of the intracerebral volume. The median value for the infarct ratio of the entire cohort was 0.0027 with a range from 0.0000 to 0.1708. For the group that participated in the outcome study, the median infarct ratio was 0.0027 with a range from 0.0001 to 0.0617. There was a significant positive association between the costs for stroke care and the infarct ratios for the 19 subjects in the outcome study (r=0.60, P=0.01). However, the correlation between cost and the infarct ratios for the entire group of subjects did not reach significance (r=0.11). There was no correlation between infarct ratios and the PSOM or the PedsQL outcome measures (Table 2A).

Costs Correlated With Increasing Disability

The PSOM is scaled so that the greater the score, the greater the level of impairment, whereas the PedsQL is scaled so the greater the score, the higher the level of function. Costs for the subjects in the outcome study correlated positively with neurological impairment measured with the modified PSOM score (r=0.62, P<0.01; Table 2B). Costs for the subjects correlated with the PedsQL measure of poorer physical function (r=−0.79, P<0.01) and were marginally associated with poorer social function (r=−0.42, P=0.08). Therefore, the greater costs for stroke care correlated with lower levels of physical and social function.
comes.50–53 Our finding that infarct volume did not correlate with outcome is similar to the result of a study of middle cerebral artery distribution infarction in children.31

The modified version of the PSOM yielded information about neurological outcome that could be obtained by telephone interview. Measures of neurological impairment on the modified PSOM score correlated not only with PedsQL measures of physical, emotional, and school impairment, but also with a measure of impaired social function. This last finding suggests that future studies of pediatric stroke should measure social function as an outcome. The results of this study also illustrate the need for functional outcome measures for children that are analogous to scales that are widely used in adult-stroke studies, but which take into account the developing nature of children.

This study has limitations. Children that were never admitted to the hospital because of a delayed diagnosis or a silent infarct would not have been identified. Those children would have lower costs for their evaluation and treatment. The use of an infarct ratio limits the ability to compare our results with those of adult studies that reported infarct volumes54; however, the infarct ratio was necessary in a pediatric study that examined children with a range of ages. The study cohort was small in the number of subjects and heterogeneous in composition. A larger study would have sufficient power to eliminate type II errors, but will need to be multicenter to recruit a sufficient number of subjects. The data were gathered at a single tertiary care pediatric hospital; therefore, the results may not readily generalize to other medical institutions, regions, or countries.

A number of assumptions were necessary to estimate the costs. Although costs for care provided outside the hospital system could not be captured, few other providers of pediatric subspecialty care exist in the area, so the majority of costs pertaining to poststroke care are likely to be reflected in these data. Children could have received outpatient care such as physical or occupational therapy at other facilities or general hospitals so that the costs may underestimate the total costs experienced by the caregivers and insurers. Nevertheless, because the cases were characterized precisely and the cost data were collected in a comprehensive fashion, the results provide a more accurate “bottom-up” description of costs than what could be derived from other sources.

In summary, the cost of pediatric stroke care is greater for hemorrhagic stroke than ischemic stroke, but is not affected by the presence of pre-existing strokes or the presence of an underlying cause of the stroke. The cost of stroke correlates with the extent of physical and functional impairment, so that the cost of stroke care may be considered a proxy for stroke severity. Future outcome studies of pediatric stroke should evaluate social function as well as cognitive and behavioral functions. A prospective study to confirm these findings is warranted.

Sources of Funding
This work was funded by the Children’s Research Institute. Ms Kawita Ponnappa was supported by a Samuel J. Roessler Fund Fellowship.

Disclosures
None.

References


The Cost of Pediatric Stroke Care and Rehabilitation
Warren Lo, Khaled Zamal, Kavita Ponnappa, Antoni Allen, Deena Chisolm, Monica Tang, Bryce Kerlin and Keith O. Yeates

Stroke. 2008;39:161-165; originally published online November 21, 2007;
doi: 10.1161/STROKEAHA.107.497420
Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2007 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

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/39/1/161

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/