Background and Purpose—Pediatric acute stroke teams are a new phenomenon. We sought to characterize the final diagnoses of children with brain attacks in the emergency department where the pediatric acute stroke protocol was activated and to describe the time to neurological evaluation and neuroimaging.

Methods—Clinical and demographic information was obtained from a quality improvement database and medical records for consecutive patients (age, ≤20 years) presenting to a single institution’s pediatric emergency department where the acute stroke protocol was activated between April 2011 and October 2014. Stroke protocol activation means that a neurology resident evaluates the child within 15 minutes, and urgent magnetic resonance imaging is available.

Results—There were 124 stroke alerts (age, 11.2±5.2 years; 63 boys/61 girls); 30 were confirmed strokes and 2 children had a transient ischemic attack. Forty-six of 124 (37%) cases were healthy children without any significant medical history. Nonstroke neurological emergencies were found in 17 children (14%); the majority were meningitis/encephalitis (n=5) or intracranial neoplasm (n=4). Other common final diagnoses were complex migraine (17%) and seizure (15%). All children except 1 had urgent neuroimaging. Magnetic resonance imaging was the first study in 76%. The median time from emergency department arrival to magnetic resonance imaging was 94 minutes (interquartile range, 49–151 minutes); the median time to computed tomography was 59 minutes (interquartile range, 40–112 minutes).

Conclusions—Of pediatric brain attacks, 24% were stroke, 2% were transient ischemic attack, and 14% were other neurological emergencies. Together, 40% had a stroke or other neurological emergency, underscoring the need for prompt evaluation and management of children with brain attacks. (Stroke. 2015;46:2328-2331. DOI: 10.1161/STROKEAHA.115.009961.)

Key Words: child ■ pediatrics ■ stroke

Recognizing acute stroke in a child requires a high index of suspicion and rapid diagnostic evaluation. Many children with stroke-like symptoms will have other nonstroke diagnoses, and even at primary pediatric stroke centers, readiness for rapid acute stroke care is challenging. Therefore, an interdisciplinary team at our tertiary children’s hospital developed a pediatric stroke team in 2011 (online-only Data Supplement) with leadership from Pediatric Emergency Medicine, Critical Care Medicine, Neurology, and Radiology. This study aimed to assess the speed with which pediatric stroke alert evaluations took place and to characterize the final diagnoses of children with brain attacks in the emergency department (ED) when the pediatric acute stroke protocol was activated; this protocol triggers urgent evaluation by a neurologist and consideration of urgent magnetic resonance imaging (MRI) of the brain.

Methods

Our freestanding children’s hospital serves a referral area of ≥2000000 people, with >50000 ED visits annually. Clinical and demographic information was obtained from a quality improvement database and medical records for consecutive patients (age, ≤20 years) first presenting to the pediatric ED where the pediatric acute stroke protocol was activated between April 2011 and October 2014. Pediatric stroke alerts are paged through a central paging system and logged prospectively. Patients were identified from this log and from a record of emergent neurology consults placed by the pediatric ED for possible stroke.
A pediatric stroke alert is activated at our institution when children present with signs and symptoms of transient ischemic attack (TIA) or acute stroke for <48 hours, as diagnosis of stroke within this time window may dramatically change a child’s management. This protocol is not activated for neonatal/perinatal stroke. A neurology resident observes the child within 15 minutes, an intravenous line is placed, labwork is drawn, intravenous line fluids are started, and urgent MRI is available. Occasionally, a head computed tomography may be performed first instead of MRI. MRI technicians and neuroradiologists receive stroke alert pages and are aware that an urgent MRI may be needed. An order set for children evaluated in the pediatric ED with possible acute stroke became available in February 2012 that includes a dedicated stroke protocol MRI (online-only Data Supplement) with approximate scan time ranging from 14 to 16 minutes. A neurologist and a neuroradiologist are usually present in the MRI suite during the scan, providing an instantaneous read and tailoring the examination if an alternative diagnosis is evident on the stroke protocol MRI.

Data Collection and Analysis
To avoid confounding for previous stroke, only the initial stroke alert for each patient in the quality improvement database was included. The final clinical diagnosis was determined by a pediatric stroke neurologist (L.C.J.), who reviewed neuroimaging with the radiologist, as well as medical records. This study was approved by the institutional review board. Consent was not required.

Statistical analysis was performed using IBM SPSS Statistics 21 (IBM, Armonk, NY). Statistical significance was defined as P<0.05. Clinical and demographic information was summarized descriptively and compared between patients with a final diagnosis of stroke/TIA versus no stroke/TIA using χ²/Fisher exact test and t test as appropriate. Variables with a non-normal distribution were described using median and interquartile range (IQR). Time between symptom onset and ED arrival was compared between patients with a final diagnosis of stroke versus all other diagnoses using Mann–Whitney U test. Time between symptom onset and ED arrival was compared between patients with a final diagnosis of stroke/TIA versus no stroke/TIA using χ²/Fisher exact test and t test as appropriate. Variables with a non-normal distribution were described using median and interquartile range (IQR). Time between symptom onset and ED arrival was compared between patients with a final diagnosis of stroke versus all other diagnoses using Mann–Whitney U test. Three-month outcome for patients with stroke was measured via the pediatric stroke outcome measure, assessed prospectively in 12 (40%) and retrospectively in 18 (60%).

Results

Patient Characteristics and Presenting Symptoms
Of 136 cases of brain attack where a stroke alert was activated, 124 were first-time stroke alerts. Among these alerts (age, 11.2±5.2 years; 63 boys/61 girls), 30 children had a stroke and 2 had a TIA (Table 1). Forty-six (37%) children had no significant medical history. Of all confirmed cases of stroke/TIA, 4 (13%) were in patients with previous sickle cell anemia or congenital heart disease. The most common presenting signs/symptoms were hemiparesis/weakness (65%), altered mental status (44%), and headache (37%).

Time to Presentation for Children With Stroke-Like Symptoms
Time from symptom onset to presentation was accurately documented for 61 of 124 (49%) children and was a median of 2.1 (IQR, 1–7.4) hours. This time was longer in patients with stroke, 5.2 (IQR, 2.2–12.2) hours versus all other diagnoses, 1.7 (IQR, 0.9–4.7) hours (P=0.02). Onset to presentation was longer in ischemic (9.8 [IQR, 5.7–14] hours) versus hemorrhagic stroke (2.9 [IQR, 0.8–4.9] hours; P=0.01); only 1 child among 8 (13%) ischemic stroke cases with known symptom onset presented within 4.5 hours.

Neurological Evaluation
Time to neurological evaluation was documented in 62 (50%) cases. Median time between ED arrival and neurological consultation was 28 (IQR, 18–61) minutes. Median time from ED arrival to stroke page was 17 (IQR, 7–37) minutes, and stroke page to neurologist at-bedside was 7 (IQR, 4–16) minutes. Time to stroke alert activation was not associated with a final diagnosis of stroke (P>0.90). The Pediatric National Institutes of Health Stroke Scale was completed in 52 (42%) cases; the median score was 2 (IQR, 1–6).

Neuroimaging
All children had urgent neuroimaging except 1 (stroke alert cancelled by neurology). MRI was the first study in 93 of 123 (76%). Median time from ED arrival to MRI was 94 (IQR, 49–151) minutes and for computed tomography, 59 (IQR, 40–112) minutes. The overall time to first scan (any) was 79 (IQR, 45–422) minutes. After removing outliers >180 minutes (n=23, 19%; 18/23 of these had MRI not computed tomography), the median time to first scan was 65 (IQR, 41–104) minutes. Factors in cases with longer latencies were low suspicion for stroke (13, 57%), outside acute intervention window (10, 43%), need for anesthesia (4, 17%), and medical instability (3, 13%). Anesthesia was required for 9 of 93 (10%) children with MRI. The majority of MRI scans were within 120 minutes

Table 1. Pertinent Past Medical History and Risk Factors

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Stroke/TIA, n=32</th>
<th>No Stroke/TIA, n=92</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y, mean±SD</td>
<td>10±5</td>
<td>11±5</td>
<td>0.504</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>12 (38%)</td>
<td>49 (53%)</td>
<td>0.13</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>20 (63%)</td>
<td>43 (47%)</td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White, Non-Hispanic/Latino, n (%)</td>
<td>21 (66%)</td>
<td>58 (62%)</td>
<td>0.40</td>
</tr>
<tr>
<td>White, Hispanic/Latino, n (%)</td>
<td>1 (3%)</td>
<td>4 (4%)</td>
<td></td>
</tr>
<tr>
<td>Black, n (%)</td>
<td>9 (29%)</td>
<td>27 (29%)</td>
<td></td>
</tr>
<tr>
<td>Asian/Pacific Islander, n (%)</td>
<td>0 (0%)</td>
<td>3 (3%)</td>
<td></td>
</tr>
<tr>
<td>American Indian/Alaska native, n (%)</td>
<td>1 (3%)</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Pertinent medical history*</td>
<td>22 (69%)</td>
<td>56 (61%)</td>
<td>0.43</td>
</tr>
<tr>
<td>Cardiac, n (%)</td>
<td>5 (16%)</td>
<td>10 (11%)</td>
<td>0.48</td>
</tr>
<tr>
<td>Congenital heart disease</td>
<td>2 (6%)</td>
<td>4 (4%)</td>
<td>0.67</td>
</tr>
<tr>
<td>Hematologic/oncologic, n (%)</td>
<td>8 (25%)</td>
<td>12 (13%)</td>
<td>0.11</td>
</tr>
<tr>
<td>Sickle cell anemia, n (%)</td>
<td>2 (6%)</td>
<td>5 (5%)</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>Immunologic/rheumatologic, n (%)</td>
<td>0 (0%)</td>
<td>2 (2%)</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>Infectious, n (%)</td>
<td>1 (3%)</td>
<td>0 (0%)</td>
<td>0.26</td>
</tr>
<tr>
<td>Chronic/systemic disease, n (%)</td>
<td>5 (16%)</td>
<td>7 (8%)</td>
<td>0.19</td>
</tr>
<tr>
<td>Genetic/metabolic disease, n (%)</td>
<td>5 (16%)</td>
<td>7 (8%)</td>
<td>0.19</td>
</tr>
<tr>
<td>Trauma/noncardiac surgery, n (%)</td>
<td>3 (9%)</td>
<td>4 (4%)</td>
<td>0.29</td>
</tr>
<tr>
<td>Neurological, n (%)</td>
<td>11 (34%)</td>
<td>36 (39%)</td>
<td>0.63</td>
</tr>
<tr>
<td>Vascular, n (%)</td>
<td>6 (19%)</td>
<td>12 (13%)</td>
<td>0.43</td>
</tr>
</tbody>
</table>

*Some children had >1 area of pertinent past medical history; percentages do not add to 100%.
of ED arrival. The majority of computed tomographic scans were within 60 minutes of ED arrival. From 2011 to 2012, the median time to first scan was 67 (IQR, 44–166) minutes, and from 2013 to 2014, this time was 94 (IQR, 53–136) minutes (Table 2); however, this was not significantly different ($P=0.53$).

### Final Diagnosis

Thirty (24%) children had a stroke, and 2 (2%) children had a TIA (Figure). There were 21 of 30 (70%) ischemic strokes and 9 of 30 (30%) hemorrhagic strokes. Seventeen (14%) had nonstroke neurological emergencies, and 75 (61%) had other stroke mimics. Emergencies included intracranial neoplasm (n=4), meningitis/encephalitis (n=5), traumatic brain injury (n=2), methotrexate toxicity (n=2), epidural abscess (n=1), hydrocephalus (n=1), ketotic hypoglycemia (n=1), and demyelinating disorder (n=1). Other nonemergency stroke mimics are presented in Figure. The most common of these were migraine/headache (n=21, 17%) and focal seizure with Todd paralysis (n=19, 15%).

### Acute Interventions

Of the 30 children with ischemic stroke, 2 (7%) underwent mechanical thrombectomy\(^9\) and 1 (3%) underwent local endovascular thrombolysis.\(^10\) Of the 9 patients with hemorrhagic stroke, 2 (22%) underwent hematoma evacuation, 5 (56%) had external ventricular drain placement, and 1 (11%) had a preexisting ventriculoperitoneal shunt, which was tapped.

### Outcomes

Of stroke cases, 1 child with hemorrhagic stroke died. Three-month outcomes were available for 28 of 29 survivors. Median pediatric stroke outcome measure score\(^8\) was 0.75 (IQR, 0–2.13), indicating mild-to-moderate ongoing neurological deficits with effect on function.

### Discussion

When a pediatric stroke alert was activated from a children’s hospital ED, 1 in 4 children had a final diagnosis of stroke. Another 14% had true neurological emergencies. As anticipated, the most common stroke mimics were migraine and focal seizure with Todd paralysis.\(^1,2\) Even in a tertiary medical center, the median time from ED arrival to pediatric stroke alert activation was 17 minutes. Medical provider delay in considering a stroke is well reported.\(^11,12\) Time to neuroimaging (median, 79 minutes) and stroke diagnosis is much shorter in this study than what has been reported in the medical literature, possibly because of increased awareness and a pediatric stroke protocol. This population should be representative of children presenting to pediatric medical centers where thrombolysis could be given; however, only one ischemic stroke case presented within 4.5 hours of symptom onset.

Imaging times may seem long. Our policy is that if a child has an acute stroke and is a candidate for off-label use of thrombolysis or intervention, then a nonurgent MRI that is in progress may be interrupted after consultation with the radiologist, so that a stroke may be rapidly diagnosed and treated. However, if a child is outside the window for acute stroke intervention or is not a candidate for acute stroke intervention, then a MRI in progress is not interrupted, and there may be a wait for the scanner to be available.

Limitations include that, at our center, stroke alerts may be activated for children with symptoms onset within 48 hours. Some centers would only activate the pediatric stroke team if a child presented within a 4- to 6-hour window for acute stroke intervention. In this retrospective study, times were only documented in the medical record for about half of the patients. Our quality improvement database was sent up to collect data to enhance our pediatric acute stroke program, but improvements to capture times were not implemented until recently.
and children with stroke not recognized in the ED were not captured.

In summary, when a pediatric ED physician activates a stroke alert, 40% of children have stroke, TIA, or another neurological emergency. A system for emergency evaluation of children with stroke-like systems is warranted. Raising awareness of stroke in a children’s medical center can improve the time to stroke diagnosis compared with what is reported in the medical literature. The only interventions that have been shown to improve outcome in adults with ischemic stroke are (1) tissue-type plasminogen activator administration, (2) endovascular thrombectomy, and (3) dedicated stroke centers that provide acute, supportive care. These interventions also may affect the outcomes of children with acute stroke. Thus, early diagnosis of stroke in these young patients is imperative.

Disclosures
None.

References
Pediatric Acute Stroke Protocol Activation in a Children's Hospital Emergency Department
Travis R. Ladner, Jasia Mahdi, Melissa C. Gindville, Angela Gordon, Zena Leah Harris, Kristen Crossman, Sumit Pruthi, Thomas J. Abramo and Lori C. Jordan

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Pediatric Acute Stroke Protocol Activation in a Children’s Hospital Emergency Department
ONLINE SUPPLEMENT

Pediatric stroke program milestones that may have impacted the stroke alert process

EMR=electronic medical record. QA/QI=quality assurance/quality improvement. tPA=tissue plasminogen activator.
Acute Pediatric Stroke MRI protocol:

Axial diffusion weighted sequence (DWI)
Axial single shot T2-weighted sequence
Axial T1-weighted sequence
Axial Gradient recalled echo (GRE) sequence
Axial FLAIR

Total time = Approximately 14-16 minutes (based on scanner strength and patient’s age)

A 3D time of flight (TOF) angiogram of the circle of Willis is added to the above protocol on case-by-case basis. Typically, MRA is added if the MRI shows ischemic or hemorrhagic stroke or if there is strong suspicion for transient ischemic attack. The MRA adds approximately additional 7 minutes to the total scan time.