Accuracy and Reliability of Stroke Diagnosis in the Pediatric Emergency Department

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Background and Purpose—Access to acute stroke interventions in the emergency department (ED) relies on correct clinical diagnosis. Our aims were to determine the accuracy and reliability of pediatric ED physician diagnosis of childhood stroke and other conditions presenting with brain attack symptoms.

Methods—Prospective study of consecutive children aged 1 month to 18 years presenting to the ED from June 2009 to December 2010 with focal neurological deficits. Accuracy (sensitivity, specificity, and receiver operator characteristic curves [ROCs]) and interrater agreement (κ) were determined, between ED physician diagnoses, as recorded in the electronic hospital administrative software system, and final neurological diagnosis, after completion of diagnostic work-up.

Results—Two-hundred eighty-seven children with 301 consecutive presentations were recruited. The most common final brain attack diagnoses included migraine in 84 children, first seizure in 48, Bell’s palsy in 29, stroke in 21, and conversion disorders in 18 children. Sensitivity of ED physician stroke diagnosis was 62%, and specificity was 98% (ROC, 0.8). Interrater agreement for ED physician and final stroke diagnosis was substantial (κ=0.61). ED physician diagnostic accuracy and reliability was highest for Bell’s palsy (ROC=0.98; κ=0.96), and lowest for central nervous system demyelination (ROC=0.5; κ=−0.01) and cerebellitis (ROC=0.50; κ=0.50).

Conclusions—ED physician diagnostic accuracy and reliability varies considerably across disorders presenting with brain attack symptoms. Clinical recognition tools are required to assist pediatric ED physicians with diagnosis of stroke and other serious neurological disorders.

Key Words: brain attack ■ cerebrovascular diseases ■ child ■ emergency service, hospital ■ stroke

See related article, p 1132.

Sensitivity of ED physician diagnosis of stroke in adults ranges from 86% to 99%1-4 and positive predictive value, before completion of investigations, ranges from 51% to 81%.5-10 Interrater reliability of clinical assessment, to differentiate stroke from mimics in adults, is good for vascular risk factors, time of onset, focal symptoms, and signs of stroke.11

Previous studies have confirmed significant diagnostic delays for pediatric stroke, well beyond those reported in adults.12-16 In-hospital factors play a more important role than prehospital factors, representing an important difference to adults.14-16 Patient factors including younger age at event,12,14,16 milder14 or shorter duration13 symptoms, normal conscious state,16 presentation after hours,16 and ischemic stroke subtype16 are associated with longer delays, but the influence of emergency department (ED) physician–related factors on time to diagnosis is poorly understood. Poor documentation of suspected stroke among pediatric physicians15 suggests that limited awareness of childhood stroke, and neurological symptoms relevant for stroke, are contributing factors to delayed stroke diagnosis in the ED.

The aims of the study were to determine the accuracy and reliability of pediatric ED physician diagnosis of stroke and other conditions in children presenting with brain attack symptoms.

Methods

This was a prospective, observational study of consecutive children aged 1 month to 18 years presenting to the ED with brain attacks from June 2009 to December 2010. Brain attack was defined as acute onset focal brain dysfunction. To be eligible for the study, at least one of the following symptoms needed to be present: weakness, sensory disturbance, speech disturbance, visual disturbance, altered conscious state, unexplained collapse, first febrile or afebrile seizure with associated symptoms, headache with other symptoms, dizziness, or unsteadiness. Children needed to have persistent neurological symptoms for at least one of the following symptoms needed to be present: weakness, sensory disturbance, speech disturbance, visual disturbance, altered conscious state, unexplained collapse, first febrile or afebrile seizure with associated symptoms, headache with other symptoms, dizziness, or unsteadiness. Children needed to have persistent neurological symptoms (headache and subjective visual or sensory disturbance) on presentation to ED or the presence of objective abnormal neurological signs on examination by the ED physician. Exclusion criteria included known epilepsy, shunted hydrocephalus, witnessed head trauma, and isolated headache without associated neurological symptoms. The cause was determined after review of clinical data, neuroimaging, and other investigations.
The triage nurse used a brain attack screening tool to identify children with neurological symptoms relevant for stroke, who were then followed up by a research assistant during their ED stay, and data were directly entered to the case report form. The patient discharge list in the ED triage system was reviewed daily for children who presented on the previous day outside recruitment hours and data were retrospectively entered to the case report form. The ED physician was not notified by the triage nurse that the brain attack screen was positive, and because this was an observational study, children were investigated and treated, as per normal ED physician practice.

ED diagnosis was assigned by the ED physician at the time of ED discharge into the Hospital Administration Software electronic system. This entry was a single diagnosis or complaint forced entry ED physicians have to document at the end of the ED encounter, and is based on International Classification of Diseases-Tenth revision coding. Final diagnosis was assigned by the study neurologist (M.M.) after review of patient records, neuroimaging, and other investigations. A research assistant called parents of children with migraine and Bell’s palsy ≥6 weeks after presentation to the ED to ensure that there were no new developments after discharge, which may have resulted in a change of diagnosis. These groups were chosen because they comprised 2 of the most common diagnoses and because children were less likely to be admitted than other diagnostic categories. A final diagnosis of first febrile or afebrile seizure was made after exclusion of other conditions presenting with a symptom of seizures, such as stroke or encephalitis.

Statistical analyses were performed using STATA 13 (StataCorp, TX). Cohen κ coefficient was used to assess interrater agreement between ED physician and final diagnostic categories. κ statistic of <0.0 represents poor agreement, 0 to 0.2 slight, 0.21 to 0.40 fair, 0.41 to 0.6 good agreement, 0.61 to 0.8 substantial, and 0.81 to 1.00 almost perfect agreement. Emergency physician stroke diagnosis was compared with the final diagnosis to determine sensitivity, specificity, and positive and negative predictive values. Receiver operator characteristic curves (ROCs) were determined to provide summary measures of test accuracy. An ROC of 0.9 to 1.0 was classified as excellent, 0.8 to 0.9 as good, 0.7 to 0.8 as fair, 0.6 to 0.7 as poor, and 0.5 to 0.6 as failure. Diagnostic odds ratios with 95% confidence intervals were also calculated, as a prevalence-free measure of diagnostic accuracy. The study received institutional ethics approval as a clinical audit (HREC30194A).

Results

Two-hundred eighty-seven children (median age, 9.8 years; interquartile range, 5.0–13.7 years), with 301 consecutive presentations met inclusion criteria and were recruited to the study. Migraine was the most common documented ED physician diagnosis in 23% of children, followed by seizures in 16% of children. The 5 most common final diagnoses were migraine in 28%, first seizures in 15%, Bell’s palsy in 10%, ischemic or hemorrhagic stroke in 7%, and conversion disorders in 6% of children (Table 1). There was no change in the final diagnosis, for the subgroups of children with migraine and Bell’s palsy ≥6 weeks after discharge from the ED.

The ED physician documented a suspected diagnosis of stroke in 20 children (7%), and diagnosis was confirmed in 13. Final diagnoses in the 7 children misdiagnosed as stroke included migraine in 3, seizures in 2, central nervous system infection in 1, and conversion disorder in 1 case. Stroke was not considered by the ED physician in 8 children, in whom diagnosis was confirmed on subsequent evaluation. ED diagnoses in these children included seizures in 4, tumor in 1, encephalopathy in 1, and other neurological disorders in 2 cases (Table 2). Accuracy of stroke diagnosis was good (ROC=0.8) and reliability was substantial (κ=0.61) (Table 1). Children correctly diagnosed as stroke by the ED physicians were younger than children with a missed diagnosis of stroke by the ED physician (median age [interquartile range], 7.1 [4.4–9.3] for true strokes versus 11.6 [6.9–17.8] for missed strokes).

Diagnostic accuracy was highest for Bell’s palsy (ROC=0.82) and lowest for cerebellitis and brain demyelination (ROC=0.5 for both; Table 1). Interrater agreement for ED physician diagnosis and final diagnosis was almost perfect for Bell’s palsy (κ=0.96) and poor for brain demyelination (κ=–0.01).

Discussion

Pediatric ED physicians play a critical role in the clinical differentiation of stroke from other neurological disorders. Correct diagnosis influences decisions about the most appropriate investigations, initial management to stabilize the patient and, in children with serious neurological disorders, implementation of immediate interventions to limit brain injury. Differentiating stroke from mimics is important to increase access to hyperacute therapies and avoid inappropriate treatment of other conditions. We set out to determine the accuracy and reliability of pediatric ED physician diagnosis of childhood stroke, and other conditions presenting with brain attack symptoms relevant for stroke. There was considerable variability across disorders presenting with brain attack symptoms, with accuracy and reliability being for highest Bell’s palsy and lowest for brain demyelination and cerebellitis. Accuracy and reliability of stroke diagnosis while good was lower than other benign conditions.

In adults, accuracy of stroke diagnosis improves as the patient proceeds along the process of care. The positive predictive value of stroke diagnosis by an emergency physician or neurologist ranges from 51% to 81% before completion of investigation, and from 82% to 95% after completion of investigations. Diagnostic errors are more likely in adults if there are inaccuracies in the clinical history, absence of vascular risk factors, milder stroke symptoms, younger age, and longer time from symptom onset to presentation. The positive predictive value of pediatric stroke diagnosis was 65% in our study, which may not be directly comparable to adult studies because pediatric ED physicians were not required to enter a provisional diagnosis before completion of investigation.

The 62% sensitivity of stroke diagnosis in our study is lower than the 77% to 99% rates reported in adults. A Japanese study of >600 adults presenting with neurological symptoms found that 10% of patients who were discharged with a nonstroke diagnosis at initial presentation to hospital were subsequently confirmed to have stroke on representation. Evaluation by non-neurologists, absence of altered consciousness or paralysis, and presence of sensory disturbance were independently associated with misdiagnosis on multivariate analysis. The lower sensitivity of pediatric ED physician diagnosis of childhood stroke is consistent with multiple adult studies that have demonstrated higher rates of stroke misdiagnosis in younger adults, particularly in cases with posterior circulation events. The high specificity and diagnostics odds...
In 1 study from the United Kingdom, 98 adults (including 74 patients with a final diagnosis of stroke) were assessed by medical student–physician and physician–physician pairs of examiners, blinded to the clinical record and results of investigations. Interrater reliability for clinical assessment was good for vascular risk factors and time of onset, good or better for focal symptoms, and good or better for signs of stroke, as opposed to its clinical mimics. Observer experience was associated with higher interrater reliability for physician–physician pairing than for student–physician pairing, across all aspects of clinical assessment; the greatest difference was noted for the neurological examination. Diagnostic confidence was higher for physicians than for students, particularly for the neurological examination. These findings are relevant to the pediatric ED and emphasize the importance of adequate training of ED physicians in performing neurological examinations.

This study has limitations. ED physician diagnosis was based on forced single entry in the ED Hospital Administration Software electronic system, which may not truly reflect the differential diagnoses considered at the time by the ED physician. The influence of investigations or specialist opinions could not be determined because the ED physician was not required to enter a specific clinical diagnosis into the case report form before commencement of investigations or in consultation with specialty units. It is not unusual, however, for ED physicians to simply document presenting symptoms and signs before requesting investigations, without entering differential diagnoses.

Table 1. Accuracy and Reliability of Brain Attack Diagnosis in the Pediatric Emergency Department

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>ED Physician Diagnosis, n (%)*</th>
<th>Final Diagnosis, n (%)†</th>
<th>κ</th>
<th>Sensitivity, %</th>
<th>Specificity, %</th>
<th>ROC</th>
<th>DOR</th>
<th>95% CI</th>
<th>PPV, %</th>
<th>NPV, % †</th>
</tr>
</thead>
<tbody>
<tr>
<td>Migraine</td>
<td>68 (23)</td>
<td>84 (28)</td>
<td>0.68</td>
<td>69</td>
<td>95</td>
<td>0.82</td>
<td>46.2</td>
<td>21.2–100.2</td>
<td>85</td>
<td>89</td>
</tr>
<tr>
<td>Febrile/afebrile seizure</td>
<td>48 (16)</td>
<td>46 (15)</td>
<td>0.79</td>
<td>85</td>
<td>97</td>
<td>0.91</td>
<td>152.2</td>
<td>54.3–426.9</td>
<td>81</td>
<td>97</td>
</tr>
<tr>
<td>Bell’s palsy‡</td>
<td>29 (10)</td>
<td>29 (10)</td>
<td>0.96</td>
<td>97</td>
<td>99.6</td>
<td>0.98</td>
<td>7588.0</td>
<td>558.7–</td>
<td>97</td>
<td>99.6</td>
</tr>
<tr>
<td>Stroke</td>
<td>20 (7)</td>
<td>21 (7)</td>
<td>0.61</td>
<td>62</td>
<td>98</td>
<td>0.80</td>
<td>63.4‡</td>
<td>20.4–197.9</td>
<td>65</td>
<td>97</td>
</tr>
<tr>
<td>Conversion disorder‡</td>
<td>5 (2)</td>
<td>18 (6)</td>
<td>0.33</td>
<td>22</td>
<td>99.6</td>
<td>0.61</td>
<td>80.7</td>
<td>11.08–</td>
<td>80</td>
<td>95</td>
</tr>
<tr>
<td>Syncope</td>
<td>13 (4)</td>
<td>14 (5)</td>
<td>0.73</td>
<td>77</td>
<td>99</td>
<td>0.88</td>
<td>236.7</td>
<td>49.2–1114.3</td>
<td>71</td>
<td>99</td>
</tr>
<tr>
<td>Headache NOS</td>
<td>26 (9)</td>
<td>12 (4)</td>
<td>0.28</td>
<td>50</td>
<td>93</td>
<td>0.72</td>
<td>13.5</td>
<td>4.2–43.6</td>
<td>23</td>
<td>98</td>
</tr>
<tr>
<td>Other encephalopathy</td>
<td>11 (4)</td>
<td>10 (3)</td>
<td>0.36</td>
<td>40</td>
<td>98</td>
<td>0.69</td>
<td>27.1</td>
<td>6.7–112.0</td>
<td>36</td>
<td>98</td>
</tr>
<tr>
<td>Cerebritis†</td>
<td>0 (0)</td>
<td>7 (3)</td>
<td>0.0</td>
<td>0</td>
<td>100</td>
<td>0.50</td>
<td>…</td>
<td>…</td>
<td>0</td>
<td>98</td>
</tr>
<tr>
<td>Brain demyelination†</td>
<td>1 (0.3)</td>
<td>6 (2)</td>
<td>−0.01</td>
<td>0</td>
<td>99.7</td>
<td>0.50</td>
<td>…</td>
<td>…</td>
<td>0</td>
<td>98</td>
</tr>
<tr>
<td>Peripheral nerve‡</td>
<td>7 (2)</td>
<td>5 (2)</td>
<td>0.66</td>
<td>80</td>
<td>99</td>
<td>0.89</td>
<td>390.7</td>
<td>41.7–</td>
<td>57</td>
<td>99.7</td>
</tr>
<tr>
<td>CNS infection</td>
<td>4 (1)</td>
<td>4 (1)</td>
<td>0.24</td>
<td>25</td>
<td>99</td>
<td>0.62</td>
<td>32.7</td>
<td>0–322.8</td>
<td>25</td>
<td>99</td>
</tr>
<tr>
<td>Drug intoxication†</td>
<td>2 (0.7)</td>
<td>4 (1)</td>
<td>0.66</td>
<td>50</td>
<td>100</td>
<td>0.75</td>
<td>…</td>
<td>…</td>
<td>100</td>
<td>99.3</td>
</tr>
<tr>
<td>CNS tumor‡</td>
<td>5 (2)</td>
<td>3 (1)</td>
<td>0.24</td>
<td>33</td>
<td>99</td>
<td>0.66</td>
<td>5.25</td>
<td>2.79–9.87</td>
<td>20</td>
<td>99</td>
</tr>
<tr>
<td>Cord demyelination†</td>
<td>1 (0.3)</td>
<td>2 (0.7)</td>
<td>0.67</td>
<td>50</td>
<td>100</td>
<td>0.75</td>
<td>…</td>
<td>…</td>
<td>100</td>
<td>99.7</td>
</tr>
</tbody>
</table>

Other neurological causes comprised 39 ED physician diagnoses (13%) and 18 final diagnoses (6%). Other non-neurological causes comprised 20 ED physician diagnoses (7%) and 18 final diagnoses (6%). Accuracy and reliability was not determined because these categories consisted of several conditions. CI indicates confidence interval; CNS, central nervous system; DOR, diagnostic odds ratio; ED, emergency department; κ, kappa coefficient; NOS, not otherwise specified; NPV, negative predictive value; PPV, positive predictive value; and ROC, receiver operator characteristic curve.

*The observed prevalence is reflected by the final diagnosis.
†DOR and 95% confidence intervals were not computable for these disorders because no children were diagnosed with cerebritis by the ED physician, there were no false-negative ED physician diagnoses of drug intoxication, and no false-positive ED physician diagnoses of CNS demyelination.
‡DOR upper 95% CI is infinity.
§The DOR—a prevalence-free measure—is the ratio of the odds of the ED physician correctly diagnosing stroke to the odds of the ED physician diagnosing a mimic as a stroke.

Table 2. Accuracy of ED Physician Stroke Diagnosis

<table>
<thead>
<tr>
<th></th>
<th>Final Stroke</th>
<th>Final Mimic</th>
</tr>
</thead>
<tbody>
<tr>
<td>ED stroke</td>
<td>13</td>
<td>TP 7</td>
</tr>
<tr>
<td>ED mimic</td>
<td>8</td>
<td>FN 280</td>
</tr>
</tbody>
</table>

Sensitivity 62%, specificity 98%, negative predictive value 97%, and positive predictive value 65%, ED indicates emergency department; FN, false-negative; FP, false-positive; TN, true-negative; and TP, true-positive.
differential diagnoses or a specific provisional diagnosis. The end point of a single International Classification of Diseases code may not have provided for the scenario where the ED physician suspected but was unable to confirm a diagnosis of stroke before discharge, because of limited access to confirmatory neuroimaging. Future studies should capture the ED physician’s clinical diagnosis as a more meaningful end point that drives decision making in the ED.

The final diagnosis was determined by a single neurologist, after review of patient records and investigations, rather than by a panel of experts. There was no change, however, in final diagnoses for subgroups of children with migraine and Bell’s palsy (which collectively accounted for 38% of all cases), 6 weeks after discharge. It is possible that the brain attack screen failed to identify children with transient ischemic attacks if their symptoms or signs resolved before arrival at the ED. It is important to not miss this group of children because >10% of cases can subsequently have stroke. Our institution did not have an ED department Code Stroke alert during the study period, and consideration of stroke by the triage nurse or ED physician was not required for inclusion. The findings may, however, provide useful baseline data for future studies assessing the impact of these protocols on accuracy and reliability of ED physician diagnosis. There have been improvements in pediatric systems of acute stroke care since the study was completed in 2010, with the development of consensus recommendations for stroke diagnosis, investigation, and emergency management, focusing on Code Stroke and rapid neuroimaging protocols, which may limit generalizability of the study findings to the current era. The study was also conducted in a tertiary pediatric ED, and therefore the results may not be generalizable to the broader pediatric population. Future studies assessing interrater reliability, and comparing accuracy of pediatric ED physician clinical diagnosis with the “gold standard” neurologist diagnosis, should require the ED physician and neurologist to enter provisional diagnoses before investigations, as has been done in some adult studies.

In summary, ED physician diagnosis of conditions presenting with brain attack symptoms is variable. Overall accuracy and reliability of stroke diagnosis was good, but diagnostic sensitivity was lower than in adults. Clinical recognition tools are therefore required to assist pediatric ED physicians with the diagnosis of stroke and other serious neurological disorders.

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Disclosures

None.

References


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