Validation and Refinement of the ABCD2 Score
A Population-Based Analysis

Amy Fothergill, MS, MPH; Teresa J.H. Christianson, BSc; Robert D. Brown, Jr, MD, MPH; Alejandro A. Rabinstein, MD

Background and Purpose—Transient ischemic attacks are a frequent diagnosis in the emergency department setting, yet expert opinion as to the proper follow-up and need for hospitalization differs widely. Recently, an effort has been made to risk-stratify patients presenting with transient ischemic attacks through scoring systems such as the ABCD and ABCD2 scales. The aim of our study was to independently validate these scores using a population-based cohort.

Methods—Using the data from the Rochester Stroke and Transient Ischemic Attack Registry and resources of the Rochester Epidemiology Project, medical records of all residents of Rochester, Minn, with a diagnosis of incident transient ischemic attack from 1985 through 1994 were examined ($N = 284$). Patients were scored on the ABCD and ABCD2 scales and new scores were created by adding hyperglycemia and a history of hypertension. The end points of stroke and death were collected previously and were verified through the Rochester Epidemiology Project data.

Results—Although our study did find that scores $>4$ had a statistically significant predictive value for future stroke, a substantial proportion of strokes within 7 days (9 of 36 cases [25%]) occurred in patients with low or intermediate risk scores ($\leq 4$) on the ABCD2 scale. Including history of hypertension and hyperglycemia on presentation increased the sensitivity of the score to identify patients who had a stroke within 7 days.

Conclusions—Reliance on the ABCD and ABCD2 scores misses some patients who will have a stroke within 7 days of a transient ischemic attack. Adding hyperglycemia and a history of hypertension to the predictive model could be useful, but the value of these additions need to be evaluated further.

Key Words: prediction ■ risk ■ score ■ stroke ■ TIA

Transient ischemic attacks (TIAs) are common in acute care settings. Most recent data suggest that nearly 240000 TIAs occur each year in the United States.¹ The risk of stroke after a TIA is 2% to 4% at 48 hours, nearly 6% at 7 days, and 10% to 15% at 90 days.¹⁻⁴ However, the management of patients with TIA varies across institutions, with some advocating hospitalization and others outpatient evaluation and management. Consequently, there has been much interest in identifying clinical prognostic indicators that can be used to estimate stroke risk after a TIA. Such prognostic indicators can be combined in models to yield a score, which may then place a patient in a certain risk subset.

One such model, the ABCD score, has been proposed as a useful clinical tool for risk stratification after TIA.⁵ This model combines 4 clinical variables—age, blood pressure, clinical features, and duration of systems—into a 6-point scale. A modification refining the predictive value of the scoring system by including a history of diabetes (ABCD2) was subsequently published⁶ (Table 1). Emergency evaluation and hospital admission for patients with a score of $\geq 4$ on these scales has been recommended. However, independent validation of these scoring systems before their widespread implementation is necessary.

Although other researchers have examined the validity of the ABCD/ABCD2 scores in different groups of patients,⁶⁻¹³ thus far, no studies have independently validated the score in a comprehensive population-based cohort different from those used for the original description. Refinement of the score by including results of imaging studies has been proposed,¹¹ but less attention has been focused on additional simple clinical variables. We performed this study to assess the value of the ABCD2 score in a population-based cohort, the TIA and Stroke Registry of the Rochester Epidemiology Project. We also examined the impact of including other clinical variables on the prognostic yield of the ABCD2 score in an exploratory analysis.

**Methods**
The Rochester Epidemiology Project Medical Record Linkage System provides resources to identify nearly all new cases of stroke and TIA in our community.¹⁴¹⁵ Virtually all medical care in the community of Rochester is supplied by Mayo Clinic and its 2 hospitals or at Olmsted Medical Group, a smaller medical center. All
medical diagnoses made for a patient inscribed as a resident of Rochester, Minn, are entered on a master document in the patient’s medical record, which is then incorporated into a central computer index. The index has been expanded to include medical practices in nearby communities such as the University of Minnesota and the Veterans Administration Hospital in Minneapolis. The medical record includes all inpatient and outpatient data, emergency room visits, nursing home care, and autopsy or death certificate information. By the early 1990s, Rochester, Minn, had a population of approximately 70 000 with a strong predominance of whites (96%).

All incident TIA s occurring during 1985 through 1994 in these residents of Rochester, Minn, have previously been identified and entered into the Rochester Stroke and TIA Registry.16 TIA was defined as an episode of focal neurological symptoms with abrupt onset and rapid resolution lasting <24 hours and thought to be due to altered circulation to a limited region of the brain.16 The method of ascertaining TIA s in the Rochester population using the medical record linkage system and resources of the Rochester Epidemiology Project has been previously described.16,17 A previous comparison of this method of ascertainment with a cohort study in the same population indicated that the retrospective assessment led to nearly complete ascertainment for TIA.18 For this analysis, patients with amaurosis fugax were not included. The medical records for those with TIA s were reviewed.

Data for the ABCD and ABCD2 scores were collected as well as blood sugar on presentation and time from onset of symptoms to presentation in the emergency department. Duration of symptoms was determined using the last time the patient was known to be well. Multiple additional clinical variables collected as part of the Rochester Epidemiology Project were analyzed to determine if they could contribute to produce a more sensitive predictive model, including history of hypertension, history of myocardial infarction, coronary artery disease, atrial fibrillation, and smoking. History of hypertension was defined by blood pressure >140/90 mm Hg on at least 2 measurements or use of antihypertensive therapy.19 Blood sugar level was tabulated using the first measurement obtained in the emergency department.

Patients who were not evaluated within 3 days of symptoms were excluded because the maximal risk of stroke after a TIA occurs during the first 48 hours.1–4 Patients received a clinical symptom score of 2 (unilateral weakness) only if there was a reliable description of loss of muscle strength or weakness on physical examination documented in the medical records; in keeping with the original ABCD scoring criteria, reports of “clumsiness” and “heaviness” were not scored. When a patient presented with a history of multiple symptomatic episodes, the patient was given the highest possible score.

The end points of stroke and death were collected previously and were verified through the Rochester Epidemiology Project data. For this study, follow-up was truncated to restrict events to within 1 year from the index event. Patients were censored at death or loss to follow-up.
hood of stroke over the first week (hazard ratio [HR], 3.90; 95% CI, 1.36 to 11.2 for ABCD score 5 to 6 and HR, 3.42; 95% CI, 1.19 to 9.80 for ABCD2 scores 5 to 7; Table 2). However, 25% of all strokes within 7 days (9 of 36 patients), 27% of strokes within 30 days (11 of 41 patients), and 31% of strokes within 1 year (20 of 64 patients) occurred in patients with ABCD2 scores.

Additional variables were then added to the scoring system to analyze if they could help identify patients with TIA with low scores who had strokes (false-negatives; Table 2). Adding history of hypertension to the ABCD score (AB2CD) resulted in a HR of 8.48 (95% CI, 1.15 to 62.4) for events within 7 days when comparing scores with scores of 0 to 3. However, 14% of the strokes within 7 days still occurred in patients with scores. Adding history of hypertension to the ABCD2 score (AB2CD2) resulted in a HR of 7.58 (95% CI, 1.03, 55.7) for events within 7 days in patients with scores. However, the AB2CD2 did not reduce the percentage of strokes that occurred in patients with scores. Hyperglycemia on presentation (operationally defined as a blood glucose level of ≥120 mg/dL) was then added to create the AB2CD3 score. Forty-eight patients (17%) had blood glucose levels on presentation between 120 and 150 mg/dL. In this scoring classification, no events occurred in the low-risk (0 to 3) reference category and thus a HR could not be calculated.

Of the 4 patients who had a stroke within 7 days and were classified as low risk (0 to 3) by the ABCD score, all 4 were also classified as low risk by the ABCD2 score. The AB2CD and AB2CD2 scores could only be calculated for 3 of those 4 and resulted in one patient remaining in the low-risk category and 2 patients moving to the intermediate-risk category. Because of insufficient data, the AB2CD3 score could only be calculated for 2 of the 4 patients and identified both as intermediate risk.

When we compared the predictive accuracy of the various scores using c-index statistics, the ABCD2 score had the highest c-index for stroke prediction at 7, 30, and 365 days; c-indices were 0.654, 0.653, and 0.635, respectively.

**Discussion**

The ideal tool to stratify the risk of stroke after TIA would be one that identifies all patients who will have a stroke within
the first few days after the TIA while secondarily having a relatively low false-positive rate. Thus, sensitivity and negative predictive value should be the most important attributes of such tool. With these considerations in mind, the AB2CD3 score provided the best risk stratification in our population because it identified more patients who had early strokes than the scores with fewer criteria, albeit at the expense of a somewhat higher false-positive rate.

In our study, 4 patients classified as low risk by the ABCD2 score had a stroke within 7 days of the TIA (5.9% of all patients in the ABCD2 low-risk category). This rate is higher than those reported in previous series (Table 3). Differences in overall 7-day stroke rates, indicative of the type and degree of stroke risk of the population under analysis, may explain the variations across studies. The ABCD2 score had the highest value on c-index statistics indicating that its prognostic performance is the most balanced. However, based on our finding that 25% of patients having strokes within 7 days had a low/medium risk ABCD2 score (0 to 4; including 11% with ABCD2 scores 0 to 3), we feel that it may be premature to use the ABCD2 score alone to define patients at low risk for a stroke in the near future.

In terms of simplicity and ease of use, the AB2CD3 score would not be significantly more burdensome to implement than the ABCD or ABCD2 scores. History of hypertension and serum blood glucose levels are easy and quick to obtain, even in an emergency setting. The addition of these 2 variables increased the sensitivity of the score for patients who had strokes within 7 days and had been categorized as low risk with simpler scores. Yet, these patients were moved to the intermediate- (not high) risk category with the AB2CD3 score. Hence, the use of clinical variables alone may not be optimal for the prediction of stroke after TIA.

Our finding that hyperglycemia and history of hypertension appeared to add sensitivity to the prediction model is in agreement with previous studies showing that these factors increase the risk of stroke after TIA. Impaired glucose tolerance, as defined by elevated nonfasting glucose level, has been associated with greater stroke risk in diabetics and nondiabetics with TIA or minor ischemic stroke.20 Hypertension is a strong risk factor for TIA and stroke and it has been reported to predict a higher risk of stroke within 1 year in patients with TIA.2

Imaging findings can provide invaluable information for the risk assessment of patients with TIA. Findings on CT scan can improve risk stratification,11 but MRI scan with diffusion-weighted imaging offers much greater sensitivity for the diagnosis of acute ischemia.21–23 In fact, there is growing consensus that absence of acute infarction on brain imaging should be considered as part of the definition of TIA.24 Presence of areas of restricted diffusion on MRI indicating acute ischemia is associated with much greater short-term risk of recurrent ischemic events.25–28 ABCD scores correlated well with diffusion-weighted imaging results in one study29 but failed to predict diffusion-weighted imaging lesions in another.8 It is also possible that patients could be further risk-stratified based on carotid ultrasound and electrocardiographic results—studies often available in the emergency setting—but these data were not available for the current cohort.

### Table 3. Comparison of 7-Day Stroke Risks Across Studies Assessing the ABCD/ABCD2 Scores

<table>
<thead>
<tr>
<th>Study</th>
<th>Population, n</th>
<th>Low Risk (Score 0–3), n (%)</th>
<th>7-Day Stroke in Population, n (%)</th>
<th>7-Day Stroke in Low-Risk Patients, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johnston et al</td>
<td>1707</td>
<td>450 (26.4)*</td>
<td>103 (6)</td>
<td>6 (1.3)</td>
</tr>
<tr>
<td>California ED derivation group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Johnston et al</td>
<td>203</td>
<td>70 (34.5)*</td>
<td>17 (9)</td>
<td>1 (1.4)</td>
</tr>
<tr>
<td>Oxford population-based group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Johnston et al</td>
<td>1069</td>
<td>259 (24.2)*</td>
<td>71 (7)</td>
<td>8 (3.1)</td>
</tr>
<tr>
<td>California ED validation group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Johnston et al</td>
<td>962</td>
<td>426 (44.3)*</td>
<td>29 (3)</td>
<td>2 (0.5)</td>
</tr>
<tr>
<td>Oxford clinic validation group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Johnston et al</td>
<td>543</td>
<td>261 (48.1)*</td>
<td>29 (5)</td>
<td>2 (0.8)</td>
</tr>
<tr>
<td>Oxford clinic validation group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tsivgoulis et al13</td>
<td>226</td>
<td>97 (42.9)†</td>
<td>18 (8)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Bray et al6</td>
<td>102</td>
<td>NA†</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Sciolla et al11</td>
<td>274</td>
<td>76 (27.7)†</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Our study</td>
<td>284</td>
<td>68 (23.9)*</td>
<td>36 (12.7)</td>
<td>4 (5.9)</td>
</tr>
</tbody>
</table>

*ABCD2. †ABCD. ED indicates emergency department; NA, not available.
The major strength of our study lies in its population-based design. However, we also acknowledge limitations. More extensive scores could not be calculated for all patients due to the retrospective nature of the study. Missing information impeded categorization of some of the patients who had stroke within 7 days of the TIA when testing the scores with additional variables. This limitation impaired our ability to validate these scores more definitely. Therefore, the results of our attempt to refine the predictive value of the scores should be regarded as hypothesis-generating observations.

Our 7-day stroke rate was relatively high compared with other recent series assessing more contemporary populations. Greater awareness and vigilance of TIA symptoms and more aggressive urgent treatment of risk factors and initiation of antiplatelet therapy in recent years may explain this difference.30,31 However, this difference should not have negatively affected the predictive value of the ABCD2 score in our study. In fact, a TIA population at higher risk of stroke like the one analyzed in this study should serve to highlight the value of the predictive score, because less strokes may have been prevented by early intervention in high-risk patients.

We conclude that the ABCD2 score is useful, but it may fail to identify patients with TIA who will have a stroke within the next week. Therefore, predictive tools including additional clinical risk factors (such as history of hypertension and hyperglycemia at the time of presentation with TIA) and, ideally, information from imaging studies (such as MRI scan of the brain and carotid ultrasound) should be evaluated in future research with the goal of optimizing diagnostic sensitivity.

Disclosures

None.

References

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