

# Transient ischemic attacks: predictability of future ischemic stroke or transient ischemic attack events

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**Abstract:** The short-term risk of an ischemic stroke after a transient ischemic attack (TIA) is estimated to be approximately 3%–10% at 2 days, 5% at 7 days, and 9%–17% at 90 days, depending on active or passive ascertainment of ischemic stroke. Various risk prediction scores are available to identify high-risk patients. We present here a pragmatic review of the literature discussing the main scoring systems. We also provide the sensitivity, specificity, positive predictive value, and negative predictive value for each scoring system. Our review shows that scoring systems including brain imaging and vascular imaging are better at risk prediction than scores that do not include this information.

**Keywords:** ischemic stroke, transient ischemic attack, prediction, systematic review

## Introduction

### Definition and epidemiology

A transient ischemic attack (TIA) has been traditionally defined as an episode of neurologic dysfunction caused by focal cerebral ischemia with complete recovery within 24 hours.<sup>1</sup> Approximately 240,000 TIAs are seen annually in the US, and about one third of TIA patients do not see a physician within 24 hours.<sup>2,3</sup> In 2009, the American Heart Association changed the definition of a TIA from a time-based definition to a tissue-based definition, whereby the presence of restricted diffusion on magnetic resonance imaging (MRI) is now classified as ischemic stroke irrespective of duration of symptoms.<sup>4</sup> It has been estimated that a tissue-based definition of TIA could reduce the annual incidence of TIA in the US by 33% and increase the annual incidence of stroke by 7%.<sup>5</sup>

### TIA and risk of future TIA/ischemic stroke

Short-term risk of ischemic stroke after a TIA is estimated to be ≈3% to 10% at 2 days, 5% at 7 days, and 9% to 17% at 90 days depending on active or passive ascertainment for ischemic strokes.<sup>6,7</sup> Electronic medical records were used for passive ascertainment in the California cohort with a 10% 90-day stroke risk whereas a face-to-face patient encounter was used for active ascertainment in the Oxford cohort with a 14% 90-day stroke risk.<sup>8</sup> The fluctuation in short-term risk of stroke can further be explained by a difference in study methods (timing from TIA event to enrolment in the study, inclusion/exclusion criteria, and methods used for stroke ascertainment), clinical setting (outpatient clinic, emergency department, or inpatient stroke service), intensity of secondary stroke prevention, patient characteristics, and underlying stroke etiology.<sup>7,8</sup>

Early treatment post TIA has been shown to reduce the 90-day risk of ischemic stroke by 80% in a population-based cohort study.<sup>9</sup> Interventions to reduce the

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recurrent stroke risk include antiplatelet therapy (aspirin and/or clopidogrel),<sup>10–13</sup> anticoagulation if indicated, statins,<sup>14</sup> antihypertensives with a goal systolic blood pressure of <130 mmHg, and endarterectomy for  $\geq 50\%$  symptomatic carotid stenosis.<sup>9,15,16</sup> Brain imaging with computed tomography (CT)/MRI should be performed to rule out hemorrhage or tumor before initiation of antiplatelet or anticoagulation therapy. Practice guidelines have advised secondary stroke prevention in the form of lifestyle modification; however, there is no randomized trial proving its efficacy.<sup>17</sup> INSPiRE-TMS (intensified secondary prevention intending a reduction of recurrent events in TIA and minor stroke patients) is a prospective, multicenter, randomized, open intervention trial designed to study the role of intensified secondary prevention after a minor stroke or TIA.<sup>18</sup>

The post TIA stroke risk is different for each individual based on his/her modifiable (high blood pressure, diabetes, abnormal blood lipid profile, smoking status, sedentary lifestyle, and obesity) and nonmodifiable (age, sex) risk factors. Many clinical risk scoring systems, such as the ABCD, ABCD2, ABCD2-I, ABCD3-I, and California rule, have been developed to predict future ischemic stroke events after a TIA. Scoring systems like these not only help in diagnosing TIA but also help to predict future risk of ischemic stroke and in triaging patients in the acute setting for urgent workup during inpatient admission versus outpatient workup. Triage in the emergency room based on prediction scores can help physicians to identify patients who are at high risk of stroke recurrence in the next 48 hours or at high risk for a severe ischemic stroke. This paper aims to review the current literature on predictors of ischemic stroke after a TIA, to determine whether one scoring system is better than another, and to identify the limitations of these clinical scoring systems.

## Literature review

We reviewed all published articles via a comprehensive search conducted using Ovid Medline from 1995 to April 18, 2013, irrespective of any language barrier. The search strategy (controlled vocabulary supplemented with keywords) was designed and conducted by an experienced librarian (AMF) with input from the study team. The search terms used were “transient ischemic attack” AND “stroke” AND “prediction OR predictor OR outcome OR future risk”. “Future risk” related to the risk of recurrent TIA or ischemic stroke. All papers of interest were further screened for relevant references.

## Prediction scores

An ideal score for stroke prediction after TIA is one that is easily available, easy to calculate manually, cost-effective, practical, includes up to five variables, has high predictive value, can accurately categorize patients into meaningful categories, and is validated in various cohorts and settings. Weighing of variables should ideally be done based on the beta coefficient for each variable calculated during logistic regression.<sup>19</sup> Another method is based on the odds ratio (OR) or hazards ratio, which may be less precise than using the beta coefficient, but is simple to use clinically, making it a viable pragmatic option.<sup>20</sup> Weighing of scores in the California score was not based on the hazards ratio or the beta coefficient from the logistic regression. The authors simply allocated an integer of 1 to each risk factor irrespective of the OR or beta intercepts.<sup>21</sup> For the ABCD score, the authors allocated each bivariate risk factor integer values of 0 and 1, and values of 0, 1, and 2 for each trivariate factor.<sup>22</sup> This method of integer allocation is not precise and may not provide the correct prediction due to poor calibration. Subsequent scores followed ABCD scoring and have the same issues with precision and internal validity.

In Table 1, we have compared various prediction scores for post TIA stroke. In Table 2, we have compared data from the derivation cohort of all the above scores in terms of their sensitivity, specificity, positive predictive value, and negative predictive value. When available, follow-up at 3 months was selected for different score comparison. For a stroke prediction model, we want to have the maximum sensitivity and negative predictive value to identify patients who are at a higher risk of stroke after a TIA episode. For the purpose of comparison, we set the cutoff as 90% true positives for dichotomizing the scores when possible.

### California score (2000)

The California score was designed to predict the 90-day stroke risk after an episode of TIA, using stroke risk factors (age, diabetes), clinical features of TIA, and duration of symptoms (Table 1). It was later validated in a study with patients from the UK and the US.<sup>8</sup>

Limitations: in the absence of vascular imaging or cardiac testing, the California score does not help to differentiate various stroke etiologies (ie, large vessel atherosclerosis, cardioembolic, or small vessel disease).

### ABCD score (2005)

The ABCD score was designed to predict post TIA ischemic stroke using stroke risk factors (age, blood pressure), clinical features of TIA, and duration of symptoms (Table 1).<sup>22</sup>

**Table 1** Various post TIA stroke prediction scores

Predictors	California score <sup>21</sup>	ABCD score <sup>22</sup>	ABCD2 score <sup>8</sup>	ABCD-I score <sup>23</sup>	ABCD2-I <sup>44</sup>	ABCD3 <sup>49</sup>	ABCD3-I <sup>34</sup>	ABCD3-V <sup>39</sup>
Age ≥60 years	1 point	1 point	1 point	1 point	1 point	1 point	1 point	1 point
Elevated blood pressure (systolic BP ≥140 mmHg and/or diastolic BP ≥90 mmHg)	NA	1 point	1 point	1 point	1 point	1 point	1 point	1 point
Clinical features								
Unilateral weakness	1 point	2 points	2 points	2 points	2 points	2 points	2 points	2 points
Speech disturbance	1 point	1 point	1 point	1 point	1 point	1 point	1 point	1 point
Symptom duration								
≥60 minutes	NA	2 points	2 points	2 points	2 points	2 points	2 points	2 points
10–59 minutes	NA	1 point	1 point	1 point	1 point	1 point	1 point	1 point
<10 minutes	NA	0 point	0 point	0 point	0 point	0 point	0 point	0 point
>10 minutes	1 point	NA	NA	NA	NA	NA	NA	NA
Diabetes	1 point	NA	1 point	NA	1 point	1 point	1 point	1 point
Dual TIA*	NA	NA	NA	NA	NA	2 points	2 points	2 points
Imaging abnormal	NA	NA	NA	1 point**	3 points***	NA	2 points (DWI)	2 points (DWI)
Normal				0 point	0 point			
Vessel imaging	NA	NA	NA	NA	NA	NA	2 points****	2 points*****
Total possible score	0–5	0–6	0–7	0–7	0–10	0–9	0–13	0–13

**Notes:** When a stated criterion is not met, then a score of 0 is assigned. \*TIA prompting medical attention plus at least another TIA in the preceding 7 days; \*\*CT scan in emergency room showing leukoaraiosis and/or old/new ischemic lesions = 1 point; \*\*\*DWI with any acute infarction or CT head with any infarction (old/new); \*\*\*\*ipsilateral >50% ICA stenosis using CTA/MRA/angio/carotid Doppler, calculated using the NASCET method;<sup>71</sup> \*\*\*\*\*>50% narrowing of the ipsilateral ICA lumen or intracranial vessel lumen on CTA/MRA/carotid Doppler.

**Abbreviations:** angio, digital subtraction angiography; AUC, area under the curve; BP, blood pressure; CT, computed tomography; CTA, computed tomography angiography; DWI, diffusion-weighted imaging sequence of magnetic resonance imaging; ICA, internal carotid artery; MRA, magnetic resonance angiography; NA, not applicable; TIA, transient ischemic attack; NASCET, North American Symptomatic Carotid Endarterectomy Trial.

The ABCD score has been externally validated in various countries, including Italy, Australia, and the US.<sup>8,23,24</sup> To increase its ease of use, the ABCD score was dichotomized into <5 or ≥5 (high risk) with a high sensitivity (100%, 86%) and negative predictive value (100%, 98%) but poor specificity (53%, 54%) and a positive predictive value (8%, 12.5%) for 7-day and 90-day stroke prediction, respectively.<sup>24</sup> In a study of 274 TIA patients, an ABCD score of 4–6 was associated with a four-fold increase in stroke risk and a score of 5–6 was associated with a six-fold increase in stroke risk at 7 days and 30 days.<sup>23</sup>

**Limitations:** in the absence of vascular imaging or cardiac testing, the ABCD score by itself does not help to understand the stroke etiology (large vessel atherosclerosis, cardioembolic, or small vessel disease). Also, a low ABCD score does not rule out the risk of recurrent stroke, as shown in a prospective study where patients with an ABCD score <4 still had a high risk (14%) of clinical cerebral ischemia during 90 days of follow-up.<sup>25</sup>

## ABCD2 score (2007)

The ABCD2 score was created combining diabetes with the ABCD score to predict the 2-day, 7-day, and 90-day risk of stroke after an episode of TIA. Diabetes was an independent predictor of stroke at 30 days after a TIA in a case series

and pooled data from two population-based Oxford groups, justifying its addition to the ABCD score.<sup>8</sup> The ABCD2 score was classified as low stroke risk (score <4), moderate stroke risk (score 4–5), and high stroke risk (score >5, Table 1).<sup>8</sup> It has been extensively validated in multiple cohorts from Canada, People's Republic of China, Greece, Italy, Singapore, and the US.<sup>26–32</sup> Despite the change in TIA definition from a time-based to a tissue-based one, the ABCD2 score is still a good predictor of stroke after a TIA. In a study of more than 4,500 patients, the 7-day recurrent stroke rate was 7.1% in diffusion-weighted imaging (DWI)-positive patients (defined as complete and rapid symptomatic recovery but presence of infarction on MRI) and 0.4% in tissue-negative events (no infarction on MRI but complete clinical recovery).<sup>33</sup> Similar rates in CT-imaged patients were 12.8% and 3.0%, respectively.<sup>33</sup> At 90-day follow-up, tissue-positive events with low ABCD2 scores and tissue-negative events with high ABCD2 scores had a similar stroke risk.<sup>33</sup>

**Limitations:** for stroke prediction, a study of 2,056 patients from Canada found a low (12.5%) specificity but high sensitivity (94.7%) for the ABCD2 score at 7 days or 90 days with a cutoff score of 2.<sup>29</sup> No significant association was seen between a higher ABCD2 score and future stroke risk in a study of 393 TIA patients by Ghandehari et al.<sup>34</sup> Another study of 1,679 TIA patients found that those with a

Table 2 Comparison of various prediction scores according to their derivation cohorts

Predictors	California score <sup>21</sup>	ABCD score <sup>8</sup>	ABCD2 score <sup>8,8</sup>	ABCD-I score <sup>23</sup>	ABCD2-I <sup>44</sup>	ABCD3 <sup>49</sup>	ABCD3-I <sup>49</sup>	ABCD3-V <sup>9</sup>
Cutoff for ≥90% recurrence stroke identification	≥3	≥3	≥3	≥4	≥4	***	***	***
Study design	Cohort study	Cohort study	Cohort study	Cohort study	Cohort study	Cohort study	Cohort study	Cohort study
Location of initial ascertainment	Emergency room	Emergency room	Emergency room	Emergency room	Mixed**	Hospital-based setting	Hospital-based setting	Hospital-based setting
Examiner's specialty to diagnose TIA	Emergency room physician	Emergency room physician	Emergency room physician	Neurologist	Mixed	Stroke specialist	Stroke specialist	Neurologist
Stroke ascertainment	Passive (electronic medical records)	Passive (electronic medical records)	Passive (electronic medical records)	Active (telephone or face-to-face interview)	Mixed	Mixed	Mixed	Active (clinical assessment)
Patients (n)	1,707	1,707	1,707	310	4,574	1,877***	1,877***	1,137
Patients with stroke recurrence, n (%)	178 (10)****	180 (11)	180 (11)	18 (6)	145 (3)	73 (4)	73 (4)	43 (4)
Follow-up period	90 days	90 days	90 days	30 days	7 days	90 days	90 days	90 days
Sensitivity (95% CI)	78.7 (72.0–84.3)	89.4 (83.8–93.4)	92.2 (87.0–95.5)	93.3 (66.0–99.7)	91.0 (84.9–94.9)	***	***	***
Specificity (95% CI)	44.0 (41.5–46.5)	31.1 (28.8–33.5)	28.6 (26.3–30.9)	46.7 (40.6–53.0)	50.6 (49.1–52.1)	***	***	***
Positive predictive value (95% CI)	14.0 (12.0–16.4)	13.3 (11.4–15.3)	13.2 (11.4–15.2)	9.2 (5.3–15.3)	5.7 (4.8–6.7)	***	***	***
Negative predictive value (95% CI)	95.0 (93.0–96.1)	96.2 (94.0–97.6)	96.9 (94.7–98.2)	99.2 (94.5–99.9)	99.4 (99.0–99.7)	***	***	***
C statistic	***	0.65 (0.61–0.69)	0.67 (0.63–0.71)	0.79 (0.69–0.89)	0.80 (0.74–0.86)	0.77 (0.72–0.82)	0.79 (0.66–0.90)	0.63 (0.54–0.73)

**Notes:** \*Although the ABCD score was derived from an Oxford cohort, the California cohort was later used to validate the ABCD; to maintain a uniform comparison in terms of patient setting and follow-up time period, we have included the California cohort in this table; \*\*combination of various studies that had recruited patients from either the emergency room, population based outpatient clinic, or neurovascular unit; \*\*\*not reported; \*\*\*\*missing data.

**Abbreviations:** CI, confidence interval; TIA, transient ischemic attack.

ABCD2 score  $<4$  in the presence of internal carotid artery stenosis, intracranial stenosis, or a source of emboli, remained at high risk of stroke.<sup>35</sup>

Systematic review and meta-analysis showed a better predictive value of ABCD and ABCD2 scores for TIA patients in terms of future stroke prediction at 0–7 days<sup>36</sup> (area under the curve [AUC] 0.71) than at 8–90 days (AUC 0.63).<sup>37</sup> The ABCD2 score is useful as an initial screening tool for use by non-neurologists, but should be used with caution in young patients and in those with other risk factors for recurrent stroke, including atrial fibrillation, carotid stenosis, intracranial stenosis, and a positive DWI lesion on MRI.<sup>35,38</sup>

### ABCD-I score (2008)

Sciolla et al<sup>23</sup> added imaging findings to the ABCD score and formulated a new scoring system, ie, the ABCD-I score (Table 1). The ABCD-I score (OR 2.89, 95% confidence interval [CI] 1.62–5.16) had better predictive power than the ABCD score (OR 2.62, 95% CI 1.44–4.76) for 30-day stroke recurrence.

Limitations: this study was limited due to its small sample size.<sup>23</sup> The ABCD-I score was not found to be useful in a multicenter cohort from Spain, probably due to initiation of early evaluation and preventative treatment by a stroke neurologist, which may have led to a change in the patients' recurrent stroke risk. Another factor which may have led to a lower AUC for the ABCD-I score is the heterogeneity arising from inclusion of 30 Spanish centers and the difference in training of the study neurologists (ie, neurologists versus stroke neurologists).<sup>39</sup>

### ABCD2-I score (2010)

DWI lesions are seen in 28%–40% of patients with a transient neurologic event and are associated with a higher (10.8%) incidence of stroke recurrence at 90 days when compared with patients without DWI lesions (4.3%).<sup>40–44</sup> The incidence of DWI lesions initially increases up to 5 days (lesions occurring after 24 hours may represent silent infarcts) from symptom onset and then decreases (small lesions may resolve by the time of imaging).<sup>45</sup> A systematic review revealed a relationship between DWI lesions and symptom duration  $>60$  minutes, dysphasia, and motor weakness, but not with age, hypertension, or diabetes. DWI lesions were seen more often in patients with atrial fibrillation or carotid stenosis ( $\geq 50\%$ ).<sup>46</sup> After this study, infarction on DWI or CT head was added to the ABCD2 score to formulate the ABCD2-I score, which increased the predictive value of the ABCD2 score for stroke at 7 days (AUC 0.66 with the

ABCD2 score and 0.78 with the ABCD2-I score, three points for infarction) and 90 days (AUC 0.68 with the ABCD2 score and 0.80 with the ABCD2-I score).<sup>44</sup> This score was externally validated in a study of 410 patients with an AUC of 0.77 for one-year risk of stroke.<sup>47</sup>

Limitations: This score may not be generalizable to all centers across the world due to the need for MRI to calculate an individual's risk of future stroke. Availability of MRI is restricted to larger centers and developed nations, thereby limiting its use.

### ABCD3 and ABCD3-I score (2010)

During hospitalization, patients with recurrent TIA have a higher (7%) risk of ischemic stroke than patients with a single TIA (2%).<sup>48</sup> Carotid stenosis was noted to be an independent predictor for 90-day stroke in a population-based study.<sup>38</sup> Identification of recurrent TIA, carotid stenosis, and DWI lesions as independent predictors for 90-day stroke led to the inception of the ABCD3 and ABCD3-I scores. A study of 3,886 patients derived the ABCD3 score (range 0–9 points) by assigning two points for dual transient ischemic attack (ie, an earlier transient ischemic attack within 7 days of the index event). Different weightings were assigned for carotid stenosis, DWI lesions, and dual TIA in this study based on the regression beta coefficients. The authors did not change the weights for the ABCD2 score and used the previously reported weights.<sup>49</sup> The C statistic was 0.80 at 7 days and 0.77 at 90 days. Merwick et al<sup>49</sup> also included stenosis of at least 50% on carotid imaging (two points) and abnormal DWI (two points) in the ABCD3-imaging (ABCD3-I) score. The C statistic for the ABCD3-I score was 0.92 at 7 days and 0.79 at 90 days.<sup>49</sup> The ABCD3-I score has been externally validated in the People's Republic of China and Spain.<sup>50–52</sup>

Limitations: like the ABCD2-I score, the ABCD3-I score may have limited generalizability due to the need for MRI to calculate an individual's risk for future stroke. The ABCD3 and ABCD3-I scores may also be limited due to recall bias, given that some patients may not be able to provide an accurate account of TIA in the previous 7 days.

### ABCD3-V score (2012)

A proximal lesion in the intracranial arteries has been shown to be an independent predictor of recurrent ischemic lesions (stroke or TIA) at 7 days.<sup>53</sup> The ABCD3-V (vasculature) score included all components of the ABCD3-I score with addition of vessel information (two points for at least 50% symptomatic stenosis on carotid or intracranial imaging).<sup>39</sup> In the PROMAPA study, a comparison of various TIA



prediction scores (ABCD, ABCD2, ABCDI, ABCD2-I, ABCD3, California score, Essen stroke risk score, and Stroke Prognosis Instrument II) showed that scores not including vascular imaging or prior TIA (TIA before the TIA episode when the prediction is being done) failed to predict stroke risk after TIA. The ABCD3-V score has not been validated thus far.

Limitations: similar to other imaging-based scores, use of the ABCD3-V would be limited due to its higher cost and need for MRI, carotid imaging, and intracranial vessel imaging. Also, this score has not been externally validated.

## Other variables

### TIA characteristics

TIA may have different underlying mechanisms (large artery atherosclerosis [LAA] 23%–38%, cardioembolism 22%, or small vessel disease 18%).<sup>54,55</sup> Cluster TIAs are more common with LAA (42%) than cardioembolic (17%) or small vessel TIAs (13%). Aphasia or cortical signs are more common in cardioembolic TIA (48%, 56%) than LAA (31%, 36%) or small vessel disease (0%).<sup>55</sup> LAA TIAs are short-lasting as compared with small vessel or cardioembolic TIAs.<sup>55</sup> Small vessel TIAs mainly present with motor weakness (57%), are stereotypical (90%), and have multiple episodes (48%).<sup>54</sup> Small vessel TIAs also have a shorter latency between the last episode or the first episode and the definitive ischemic stroke.<sup>54</sup> A study of 388 TIA patients found large artery atherosclerosis to carry the highest risk of recurrent stroke (20%) followed by cardioembolism (11.5%), undetermined (4.7%), and small vessel disease (1.5%).<sup>55</sup> Interestingly, a study of 1,753 patients found previous TIA to be an independent predictor of a good outcome for patients with nonlacunar strokes. The authors suggested ischemic tolerance as the possible underlying mechanism for better recovery in these patients.<sup>56</sup>

### Atrial fibrillation

Atrial fibrillation is a well known risk factor for cardioembolic stroke; however, so far it has not been found to be an independent predictor for future stroke risk after a TIA.<sup>24,38,41,57,58</sup>

### Ankle-brachial pressure index

Although a decreased ankle-brachial pressure index (ABPI) is not a recognized risk factor for stroke or TIA, we found a few studies that correlated the ABPI value with recurrent ischemic strokes. Weimer et al and later Tsivgoulis et al found an ABPI  $\leq 0.9$  to be an independent predictor of future

stroke or TIA at 30 days (19.2% versus 3.3% for ABPI  $> 0.9$ ; OR 2.67, 95% CI 0.64–11.05) and 17.5 months (6.6% versus 4.6% for ABPI  $> 0.9$ ; OR 1.47, 95% CI 0.76–2.83) in acute ischemic stroke or TIA patients.<sup>59,60</sup>

## C-reactive protein

C-reactive protein is a protein synthesized by the liver, that rises in response to acute inflammation. High-sensitivity C-reactive protein  $> 4.1$  mg/L at the time of a TIA has been linked to future stroke events at one year (hazard ratio 2.81, 95% CI 1.12–7.10);<sup>61</sup> however, a recent nested case control study did not confirm this finding.<sup>62</sup>

## MicroRNAs

MicroRNAs (miRNAs) are a novel class of endogenous, non-coding small RNAs that bind to complementary sequences, resulting in their silencing.<sup>63</sup> miRNAs are involved in different aspects of cardiovascular disease, are mediators of smooth muscle cell phenotypic modulation and vessel remodeling, and can be used to identify the development and progression of atherosclerosis. Animal studies have shown upregulation of miRNAs after ischemic brain injury. It remains to be seen if blood miRNAs may be used as a biomarker in the future for stroke diagnosis in patients with negative neuroimaging, for differentiating stroke subtypes, or for predicting recurrent episodes of TIA or stroke.<sup>64</sup>

## Fluid-attenuated inversion recovery imaging in TIA

In a study of 43 patients with TIA, distal hyperintense vessels on fluid-attenuated inversion recovery MRI sequence were independently associated with large artery severe stenosis or occlusion, seen in 33% patients who had an MRI brain performed within 24 hours of symptom onset.<sup>65</sup>

## Need for carotid imaging

Tholen et al conducted a cost-effectiveness analysis for various noninvasive carotid imaging techniques in patients with a recent TIA or a minor stroke. In low-risk patients, they found duplex ultrasound to be a cost-effective first test, followed by CT angiogram if the patient has symptomatic carotid stenosis on carotid imaging. In a high-risk patient, they found CT angiogram to be the cost-effective initial carotid imaging modality.<sup>66</sup> The ABCD2 score may be used to identify high-risk patients ( $> 5$ ) in the emergency room when making a decision about ordering a carotid ultrasound or CT angiogram. Low-moderate risk patients (ABCD2 score  $\leq 5$ ) may be considered for outpatient

evaluation, because in a study from Spain, outpatient evaluation for low-moderate risk patients reduced the cost by one fifth without any increase in cerebrovascular recurrence rate.<sup>67</sup> Similar findings were also noted in the US and Portugal, with outpatient evaluation being more cost-effective.<sup>68,69</sup> In the absence of availability of ultrasound imaging or limited resources, clinical prediction can be used to identify patients with carotid stenosis. A study of 726 patients reported 97% specificity and 17% sensitivity for any three of the four features (ipsilateral bruit, diabetes mellitus, and previous TIA, no lacunar syndrome); and 99% sensitivity and 22% specificity for one or more of the four features.<sup>70</sup> The decision for carotid imaging should be tailored according to a patient's individual risk, local infrastructure (availability of a same-day TIA clinic), insurance coverage, and patient preferences.

## Conclusion

Multiple studies have investigated prediction scores and their validation. Different scores may produce different results depending on the examiner's specialty (emergency room physician versus neurologist), patient setting (emergency room versus outpatient clinic), and duration of follow-up (7 days versus 90 days). So far, the ABCD2-I and ABCD3-I seem to be the best scoring systems because they have the maximum AUC, include patient imaging and vasculature data, and have been externally validated. The ABCD3-V score further includes intracranial imaging data and its external validation is needed. These prediction scores are clinically useful because they can help to identify at-risk patients who need to be admitted to the hospital versus patients who can be worked up in an outpatient setting to offset the huge costs of inpatient admissions. Future studies are needed to validate the ABCD3-V score and also to understand how these scores will change TIA patient triage in the emergency room.

## Disclosure

None of the authors has any disclosure to make or any conflicts of interest in this work.

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