Population-Based Study of ABCD$^2$ Score, Carotid Stenosis, and Atrial Fibrillation for Early Stroke Prediction After Transient Ischemic Attack

The North Dublin TIA Study

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Background and Purpose—Transient ischemic attack (TIA) etiologic data and the ABCD$^2$ score may improve early stroke risk prediction, but studies are required in population-based cohorts. We investigated the external validity of the ABCD$^2$ score, carotid stenosis, and atrial fibrillation for prediction of early recurrent stroke after TIA.

Methods—Patients with TIA in the North Dublin city population (N=294 529) were ascertained by using overlapping hospital and community sources. The relations between individual ABCD$^2$ items, carotid stenosis, atrial fibrillation, and early stroke were examined.

Results—In confirmed TIA cases (n=443), carotid stenosis predicted 90-day stroke (hazard ratio=2.56; 95% CI, 1.27 to 5.15, $P=0.003$). Stroke risk rose with increasing grade of carotid stenosis, ranging from 5.4% (95% CI, 3.3% to 8.7%) with <50% stenosis to 17.2% (95% CI, 9.7% to 29.7%) with severe stenosis/occlusion (hazard ratio=3.3; 95% CI, 1.5 to 7.4, $P=0.002$). In confirmed TIA cases (n=443), the ABCD$^2$ score performed no better than chance for prediction of 90-day stroke ($c$-statistic=0.55; 95% CI, 0.45 to 0.64), largely related to the 24.2% (8/33) of patients who experienced a recurrence and had low ABCD$^2$ scores (0–3). However, in nonspecialist-suspected TIA cases (n=700), the predictive utility improved for stroke at 28 ($c$-statistic=0.61; 95% CI, 0.50 to 0.72) and 90 ($c$-statistic=0.61; 95% CI, 0.52 to 0.71) days.

Conclusions—In a population-based TIA cohort, significant predictive information was provided by carotid stenosis. The ABCD$^2$ score had predictive utility in patients with TIA suspected by nonspecialists. Low scores occurred in several patients with stroke recurrences, suggesting that caution is needed before using the score in isolation. (Stroke. 2010;41:844-850.)

Key Words: transient ischemic attack ■ ABCD$^2$ score ■ carotid stenosis ■ cerebrovascular disorders
were retrospective and some reported very few stroke outcome events.

Most validation studies have been performed in selected, hospital-based cohorts attending specialist neurovascular services. Although providing valuable information, specialist-referred TIA patients are more likely to have speech or motor symptoms, have lower stroke recurrence rates, and are unlikely to fully represent the spectrum of TIA encountered in all healthcare settings. If the score is to be widely used by community-based non-specialists before hospital referral, then population-based validation studies are needed. Ideally, these should include all patients with transient neurologic symptoms in whom the non-specialist physician making triage decisions has a reasonable suspicion of TIA, some of which will eventually be assigned a noncerebrovascular (non-CVD) diagnosis after specialist assessment.

The ABCD² score is also used to guide decisions such as hospital admission in some secondary care settings (such as TIA clinics) in which carotid imaging and ECG information may be available. Although not included in the score, this information may further improve the identification of high-risk patients. In particular, carotid stenosis is associated with early recurrence after ischemic stroke and may also be a risk marker for recurrent stroke after TIA. We hypothesized that carotid stenosis and atrial fibrillation (AF) might predict early stroke recurrence after TIA. We aimed to investigate this hypothesis and to examine the external validity of the ABCD² score in a population-based TIA cohort.

Subjects and Methods

Patient Cohort

The North Dublin TIA Study is a substudy of the North Dublin Population Stroke Study, a population-based, prospective, cohort study of stroke and TIA in 294,529 inhabitants of North Dublin city. The cohort described includes all TIA cases identified from December 2005 until November 2008.

In the first ascertainment year, “hot” and “cold” pursuit strategies in multiple overlapping hospital and community sources were used to determine stroke/TIA incidence. Overall, 94% (180/190) of North Dublin city general practitioners and 95% (17/18) of nursing homes participated. A 5-day minor stroke/TIA clinic was established to facilitate assessment of suspected TIA patients from community sources and emergency departments.

A “hot pursuit” strategy for TIA identification was used in all 6 acute-care hospitals, with daily checking of admissions; referrals to neurology, geriatric, medical, and vascular services; and visits to specialist wards to ascertain in-hospital events. Nonspecific clinical descriptors (eg, weakness, dizziness) and requests for brain/vascular imaging were reviewed twice weekly. Specialist (geriatric, neurology, vascular, and ophthalmology) clinics were contacted regularly to encourage referral. Our “cold pursuit” strategy included regular contact with general practitioners, nursing homes, pediatric, obstetric, psychiatric, and other relevant specialist hospitals and regular review of pathology and coroners’ records.

After the first year of ascertainment, recruitment of TIA patients was restricted to those sources that had proven most effective in the first year (daily review of emergency department referrals, hospital admissions, referrals to specialist services, and the rapid-access TIA clinic).

Definitions

TIA was defined clinically as an acute loss of focal cerebral or ocular function lasting <24 hours, presumed, after investigation, to be due to embolic or thrombotic vascular disease after in-person assessment by a stroke specialist physician. After stroke specialist assessment, patients referred to hospitals or the TIA clinic with TIA suspected by a non-specialist physician were further categorized as confirmed TIA or non-CVD, regardless of ABCD² score and with blinding to neuroimaging findings. Patients with non-CVD diagnoses most commonly had syndromes such as migraine, focal seizures, or vasovagal syncope.

In cases where multiple TIAs occurred during the study period, the first event was used for the calculation of ABCD² score. The first recorded blood pressure after the TIA (performed by a general practitioner, emergency department, or clinic) was used for ABCD² assignment. In patients who presented with stroke after an earlier TIA for which they had not sought medical attention, blood pressure was scored as the first available after the TIA.

The World Health Organization definition of stroke was used. Recurrent strokes were defined as a new neurologic deficit fitting the standard definition of a stroke, which occurred after a period of neurologic stability or improvement lasting at least 24 hours.

Carotid stenosis was defined according to the TOAST method as narrowing of the cervical internal carotid artery lumen of 50% or greater on carotid duplex ultrasound or angiography, as estimated by the radiologist reporting for clinical management. The degree of carotid stenosis on duplex ultrasonography was calculated with the use of NASCET-based criteria according to joint recommendations for reporting carotid ultrasound.

Standard definitions of other variables (eg, hypertension, diabetes mellitus) were applied. All data were prospectively entered into a standard electronic case report form.

Clinical Management

Patients were referred on the basis of their clinical syndrome regardless of ABCD or ABCD² score. Patients with confirmed TIA at the 5-day clinic were immediately treated according to recommended guidelines with an antiplatelet agent (aspirin, dipyridamole + aspirin, or clopidogrel), an antihypertensive agent (when systolic blood pressure at assessment was >140 mm Hg systolic), and a statin if subsequent fasting LDL cholesterol was >96.7 mg/dL. Warfarin was commenced immediately after the detection of AF if no contraindication existed. Carotid imaging was performed by duplex sonography, usually on the day of the clinic, with admission of patients with severe stenosis (≥70%) for early assessment for endarterectomy. Because the study was observational and no intervention was specified, clinical management of patients treated in other settings was not dictated by a defined protocol but was delivered according to the practice of the treating physician and patient preference.

Follow-Up

Follow-up assessments were performed by trained study staff at 2, 7, 28, and 90 days after TIA onset. Two stroke specialist physicians confirmed all potential recurrences in-person. Institutional ethics board approval was obtained from all collaborating institutions, and participants provided informed consent.

Statistical Analysis

Univariate parametric and nonparametric comparisons of clinical characteristics were performed with χ², Mann-Whitney, and Student t tests, as appropriate. Life-table analysis was performed to determine recurrent stroke rates at 7, 28, and 90 days, with censoring of patients who died and 1 patient with recurrent stroke after carotid endarterectomy. The log-rank test was used for univariate comparisons of event-free survival between groups. Multivariable Cox regression analysis was used for multivariable analysis of recurrent stroke predictors. The discriminative ability of ABCD² score and carotid stenosis was evaluated by receiver-operating curve analysis. Analyses were performed with STATA (version 9). All significance tests were 2-sided.
Clinical Characteristics of Confirmed TIA Patients

Four hundred forty-three patients with stroke specialist–confirmed TIA were identified (Tables 1 and 2). The median time from symptom onset to hospital or TIA clinic evaluation was 1 day. Brain imaging was performed in 85.6% (379/443) and carotid imaging in 93.7% (415/443). ECG and/or cardiac monitoring was performed in 93% (410/443), AF was previously known in another 11, and carotid stenosis was identified in 7 patients. Overall, 96.6% (428/443) had cardiac investigations, prior AF, or carotid stenosis; 57.6% (255/443) were admitted to hospital; and 2% (9/443) did not seek medical attention for the initial TIA but presented with recurrent stroke.

Slightly more than one third (38.2%, 169/443) of patients had low (0–3) ABCD2 scores, 44.9% (199/443) had intermediate scores (4, 5), and 16.9% (75/443) had high (6, 7) scores. Compared with patients with intermediate/high scores, those with low scores were younger (66 vs 73 years, \( P < 0.00001 \)), were less likely to have had previous stroke (18.2% vs 81.8%, \( P = 0.004 \)), and had less frequent unilateral weakness (16.6% vs 83.4%, \( P < 0.00001 \)) and speech disturbance (47.6% vs 52.4%, \( P = 0.02 \)).

Follow-up status was determined for all 443 patients at 90 days, 4 of whom had died. Calculated from TIA onset, recurrent stroke rates were 3.4% (95% CI, 2.1% to 5.6%) at 7 days (n=15), 5.4% (95% CI, 3.7% to 8.0%) at 28 days (n=24), and 7.5% (95% CI, 5.4% to 10.4%) at 90 days (n=33). All 33 recurrences were ischemic strokes. All TIA patients with stroke recurrences had brain imaging performed (55%, 18/33, computed tomography or magnetic resonance imaging alone, 45%, 15/33, both computed tomography and magnetic resonance imaging). Ninety-one per cent (30/33) of strokes occurred in the same arterial territory as the original TIA.

ABCD2 Low-Score Patients With Recurrent Stroke

Low ABCD2 scores were observed in 33% (5/15) of patients with stroke recurrence at 7 days, in 29.2% (7/24) of those at 28 days, and in 24.2% (8/33) of those at 90 days. Three (37.5%) were younger than 60 years. Of the 5 patients with low scores and stroke at 7 days, 2 had sensory TIAs and 3 had posterior circulation events, whereas of the 3 other patients with stroke after 7 days, 2 had amaurosis fugax and 1 had expressive dysphasia. Of these 8 patients, 6 (75%) scored zero on the ABCD2 “clinical syndrome” item. With the exception of antihypertensive medication, which was prescribed less frequently in low-ABCD2 patients (probably owing to a significantly lower prevalence of hypertension in this group), patients with low scores received secondary prevention equivalent to that given patients with intermediate and high scores. After their TIA, 82.8% of patients with low scores received antiplatelet therapy, 63.3% received antihypertensive medication, and 76% received lipid-lowering medication.

Predictive Utility of ABCD2 Score in Confirmed TIA Cases

When each ABCD2 item was analyzed individually, there were no associations with stroke at 7, 28, or 90 days in...
patients with confirmed TIA. On receiver-operating curve analysis, the area under the curve (c-statistic) for 7-day stroke was 0.49 (95% CI, 0.35 to 0.63), 0.55 (95% CI, 0.43 to 0.66) for 28-day stroke, and 0.55 (95% CI, 0.45 to 0.64) for 90-day stroke. When the ABCD² score was trichotomized into low (0–3), intermediate (4, 5), and high (6, 7) categories, a trend toward higher 90-day stroke risk was observed in the intermediate (10.7%) and high (5.3%) groups compared with the low group (4.8%, log-rank P=0.07).

**Carotid Stenosis and Recurrent Stroke in Confirmed TIA Cases**

Overall, 23.8% (99/415) of TIA patients had unilateral carotid stenosis (40.4%, 40/99, with 50% to 69% stenosis, 59.6%, 59/99, with >70% stenosis or occlusion). Carotid endarterectomy was performed in 38.4% (38/99) and stenting in 61.1% (61/99). The median time from physician assessment to endarterectomy was 10 days (interquartile range, 6 to 17). ABCD² score was no different in patients with confirmed TIA. On receiver-operating curve analysis, when increasing degree of carotid stenosis was categorized as an ordinal variable (<50%, 50% to 69%, ≥70%), a c-statistic of 0.63 (95% CI, 0.53 to 0.73) was observed for prediction of 90-day stroke, with c-statistics of 0.55 (95% CI, 0.42 to 0.68) at 7 days and of 0.56 (95% CI, 0.45 to 0.67) at 28 days.

**AF in Confirmed TIA**

AF was present in 25.7% (112/435) of patients, including 17% (28/165) with low ABCD² scores, 26.2% (51/195) with intermediate scores, and 44.0% (33/75) with high scores (P<0.001 for trend). No relation was observed between AF and recurrent stroke at 7, 28, or 90 days.

**Suspected TIA Patients Referred by Non specialist Physicians**

The analysis was repeated in the cohort of patients referred for specialist evaluation by non specialist physicians for suspected TIA, the “intended population” for ABCD² score use. This included the 443 patients in whom TIA was subsequently confirmed by a stroke specialist and an additional 257 patients with a subsequent non-CVD diagnosis (total=700). Almost all patients (95.1%, 666/700) were assessed in person by a study stroke specialist physician and by medical record review for the remainder.

Unilateral weakness was the sole ABCD² item associated with 90-day stroke (log-rank P=0.006) with a trend for association with 28-day stroke (log-rank P=0.08). The pre-
stroke. The HR for stroke associated with previous reports of a 3-fold increased risk of early recurrence after first ischemic stroke associated with carotid stenosis and those who presented with recurrent stroke, further supporting their validity.

We also observed a dose-dependent relation between the severity of carotid disease and risk of stroke after TIA, which has not previously been reported. In contrast to our findings, no difference in stroke risk was observed with increasing degree of carotid stenosis in medically-treated TIA patients in NASCET.11 However, direct comparisons are difficult, as patients included in the NASCET analysis represent a more

### Table 3. Risk of 90-Day Stroke With Carotid Disease in Stroke Specialist–Confirmed TIA

<table>
<thead>
<tr>
<th>Stroke recurrence with ≥50% carotid disease, HR (95% CI)</th>
<th>Specialist-Confirmed TIA</th>
<th>Specialist-Confirmed TIA Carotid Occlusion Excluded</th>
<th>Specialist-Confirmed TIA Contralateral Stenosis Excluded</th>
<th>Specialist-Confirmed TIA, Presentation With Stroke Excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unadjusted</td>
<td>2.57 (1.28–5.20)</td>
<td>0.006</td>
<td>2.09 (0.98–4.5)</td>
<td>0.05</td>
</tr>
<tr>
<td>Adjusted for age, sex</td>
<td>2.65 (1.31–5.39)</td>
<td>0.007</td>
<td>2.16 (1.09–4.6)</td>
<td>0.047</td>
</tr>
<tr>
<td>Stroke recurrence with ≥70% carotid disease, HR (95% CI)</td>
<td>3.3 (1.5–7.4)</td>
<td>0.002</td>
<td>2.9 (1.27–6.71)</td>
<td>0.008</td>
</tr>
<tr>
<td>Adjusted for age, sex</td>
<td>3.23 (1.45–7.21)</td>
<td>0.004</td>
<td>2.86 (1.25–6.55)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

*Log-rank, or log-rank test for trend.

dictive ability of the score improved, with c-statistics for 7-day stroke of 0.56 (95% CI, 0.42 to 0.70), for 28-day stroke of 0.61 (95% CI, 0.50 to 0.72) and for 90-day stroke of 0.61 (95% CI, 0.52 to 0.71). When the score was dichotomized into low (0–3), intermediate (4, 5), and high (6, 7) score categories, a higher 90-day stroke risk was observed in the intermediate (7.8%) and high (4.4%) groups compared with the low group (2.4%; log-rank for trend, P<0.056). The HR for 90-day stroke was 2.9 (95% CI, 1.3 to 6.5) in patients with scores ≥4 (6.9% vs 2.4%, log-rank P=0.006) and for 28-day stroke was 2.25 (95% CI, 0.93 to 5.43, log-rank P=0.06).

In this larger cohort, 77.4% (542/700) had carotid imaging. Imaging was not performed in the remainder because a non-CVD diagnosis (eg, migraine, seizure) was apparent on specialist assessment. Carotid stenosis had moderate sensitivity (84.8%) and high specificity (80.2%) for identification of patients who subsequently developed 90-day stroke (c-statistic=0.62; 95% CI, 0.53 to 0.71).

### Multivariable Analysis

Cox regression modeling was performed with 90-day stroke as the dependent variable and carotid stenosis and dichotomized ABCD² score (0–3, 4–7) as independent variables. In specialist-confirmed TIA (415 included), carotid stenosis (HR=2.55; 95% CI, 1.23 to 5.13, P=0.009) but not ABCD² score (HR=1.9; 95% CI, 0.86 to 4.25, P=0.1) predicted 90-day stroke. However, in nonspecialist-suspected TIA (542 patients included), both carotid stenosis (HR=2.83; 95% CI, 1.4 to 5.7, P=0.004) and ABCD² score (HR=2.21; 95% CI, 0.99 to 4.93, P=0.052) were associated with 90-day stroke.

### Discussion

In a large, prospective, population-based study, we found that imaging evidence of internal carotid artery stenosis independently predicted early stroke after TIA. Although a few reports of increased stroke risk after TIA with carotid stenosis exist from selected patients in clinical trials and hospital registries,24–26,30,31 to our knowledge this is the first report in an unselected population-based cohort reflecting daily clinical practice. Our observed HRs of 2.6 to 3.3 are consistent with previous reports of a 3-fold increased risk of early recurrence after first ischemic stroke associated with carotid stenosis.31 Our results also remained consistent after exclusion of patients with carotid occlusion, contralateral stenosis, and those who presented with recurrent stroke, further supporting their validity.

We also observed a dose-dependent relation between the severity of carotid disease and risk of stroke after TIA, which has not previously been reported. In contrast to our findings, no difference in stroke risk was observed with increasing degree of carotid stenosis in medically-treated TIA patients in NASCET.11 However, direct comparisons are difficult, as patients included in the NASCET analysis represent a more

### Table 4. 90-Day Stroke Recurrence Rates With Carotid Disease in Stroke Specialist–Confirmed TIA

<table>
<thead>
<tr>
<th>Stroke Recurrence Rates, % (95% CI)</th>
<th>Specialist-Confirmed TIA</th>
<th>Specialist-Confirmed TIA Carotid Occlusion Excluded</th>
<th>Specialist-Confirmed TIA Contralateral Stenosis Excluded</th>
<th>Specialist-Confirmed TIA, Presentation With Stroke Excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;50% carotid disease</td>
<td>5.4 (3.3–8.7)</td>
<td>0.002</td>
<td>5.8 (3.5–9.4)</td>
<td>0.01</td>
</tr>
<tr>
<td>50%–69% carotid disease</td>
<td>10 (3.9–24.5)</td>
<td>0.002</td>
<td>6.3 (1.6–22.8)</td>
<td>0.01</td>
</tr>
<tr>
<td>≥70% carotid disease</td>
<td>17.2 (9.7–29.7)</td>
<td>0.002</td>
<td>16.4 (8.9–29.1)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

*Log-rank, or log-rank test for trend.
select group with hemispheric TIA only, and events were recalled at the time of randomization (up to 180 days later) rather than prospectively followed, as in our study.

In our population-based study, the ABCD² score did not perform as well as in earlier studies to identify patients who experienced early stroke after TIA. A major contributor to this finding was the occurrence of low ABCD² scores in several patients with recurrent strokes. In our study, 24% to 33% of patients who experienced early stroke had ABCD² score of 3 or less at the time of their initial TIA, including 5 of 15 who experienced stroke at 7 days. The proportion of patients with stroke recurrence and low scores is greater in our study than in previous reports. Several potential explanations must be considered for this finding. First, our population-based design may have identified TIA events not usually referred to hospital stroke specialist services, such as amaurosis fugax, which may be referred to eye clinics. Second, our detailed ascertainment may have detected a higher proportion of TIA clinical syndromes to which the ABCD² score may be relatively insensitive, supported by the observation that 7 of 8 (88%) patients with low scores and early stroke had sensory, visual, or posterior circulation TIA events. Third, although antihypertensive medication was prescribed less frequently in low-ABCD² patients (probably owing to a lower prevalence of hypertension in this group), no difference in post-TIA antiplatelet or lipid-lowering medication use was found between ABCD² strata, indicating that prescribing patterns are unlikely to explain our findings. Finally, we cannot exclude the possibility that our findings are due partly to chance.

Available data indicate that the ABCD² score is a valid and potentially useful instrument for TIA risk stratification when examined in large patient groups. Indeed, despite the patients with early stroke and low scores in our study, we observed reasonable ABCD² predictive accuracy and a 3-fold increase in stroke risk with intermediate/high scores in patients with TIA suspected by nonspecialists (the main “intended population” for use of the score). However, for clinicians faced with management decisions involving individual patients, we suggest that caution is indicated when deciding whether a patient with a low score may be treated on a nonurgent basis. This may be the case particularly in younger patients with transient focal symptoms and those with visual, sensory, or posterior circulation symptoms, groups in whom the score may have lower predictive utility. Taken together, these clinical subgroups account for at least 25% of all TIA patients identified in population studies. Our caution is supported by a recent population study that also observed a high proportion (25%) of low ABCD² scores among TIA patients with 7-day stroke, whereas 20% of patients with low scores in the SOS-TIA registry had carotid, intracranial, or cardiac sources of embolism requiring urgent evaluation and treatment.

Despite our sample size, the number of outcome events was insufficient to provide statistical power for detailed analysis of stroke predictors at 2 and 7 days. Although single-center studies may provide valuable information, ideally, studies including several thousand patients will be required to validate the score for stroke recurrence at very early time points, to accurately identify TIA subgroups for whom the score may be less useful, and to determine the additional utility of combining information from carotid and brain imaging.

We acknowledge that our study has other limitations. The diagnosis of carotid stenosis was not assigned via a uniform imaging protocol but was made after review of imaging findings by the reporting radiologist involved in clinical management. However, this approach reflects patient care in a “real life” setting and increases the likelihood that our findings may be generalized to routine practice. Finally, too few patients had early brain imaging to allow analysis of the additional predictive value of early ischemia on imaging in our cohort.

Our data suggest that the risk of early stroke is significant in TIA patients with moderate or severe carotid stenosis and those with ABCD² scores >3. Although our findings require confirmation in larger studies, they may be an initial indication that some subgroups of patients with low ABCD² scores may not be safely triaged for nonurgent investigation and treatment, as recommended in some international guidelines. Until further large studies are performed, we believe that a prudent approach is to consider the individual clinical profiles of these patients, and immediately assess and treat those with clinical syndromes strongly suggestive of TIA.

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Disclosures

None.

References


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