Validating a Pragmatic Approach to Cognitive Screening in Stroke Prevention Clinics Using the Montreal Cognitive Assessment

Richard H. Swartz, MD, PhD; Megan L. Cayley, BA; Krista L. Lanctôt, PhD; Brian J. Murray, MD; Eric E. Smith, MD, MPH; Demetrios J. Sahlas, MSc, MD; Nathan Herrmann, MD; Ashley Cohen, MStats; Kevin E. Thorpe, MMath

Background and Purpose—The Montreal Cognitive Assessment (MoCA) is used commonly to identify cognitive impairment (CI), but there are multiple published cut points for normal and abnormal. We seek to validate a pragmatic approach to screening for moderate–severe CI, by classifying patients into high-, intermediate-, and low-risk categories.

Methods—A total of 390 participants attending an academic Stroke Prevention Clinic completed the MoCA and more detailed neuropsychological testing. Between April 23, 2012 and April 30, 2014, all consecutive new referrals to the regional Stroke Prevention Clinic who were English-speaking, not severely aphasic, and could see and write well enough to complete neuropsychological testing were assessed for inclusion, and consenting patients were enrolled. CI was defined as ≥2 SDs below normal for age and education on at least 2 cognitive subtests. A single cut point for CI was compared with 2 cut points (high sensitivity and high specificity) generated using receiver operator characteristic and area under the curve analyses. The intermediate-risk group contained those scoring between the 2 cut points.

Results—Thirty-four percent of participants had a symptomatic or silent stroke, 34% were seen for possible or probable transient ischemic attack, and 32% were diagnosed with other vascular or nonvascular conditions. Using a single cut point, sensitivity and specificity were optimal with MoCA ≤22, (sensitivity=60.4%, specificity=89.9%, area under the curve=0.801, positive predictive value=48.5%, negative predictive value=93.5%, positive likelihood ratio=6, and negative likelihood ratio=0.4). Using 2 cut points, sensitivity was optimal with MoCA ≥28 (sensitivity=96.2%, positive predictive value =97.6%, and negative likelihood ratio=1.27), and specificity was optimal with MoCA ≤22 (specificity=89.9%, positive predictive value=48.5%, and positive likelihood ratio=6).

Conclusions—Stratifying participants into 3 categories facilitates the identification of a homogenous group at low risk for CI, as well as 2 other groups with intermediate and higher risk. This approach could facilitate clinical care pathways and patient selection for research. (Stroke. 2016;47:807-813. DOI: 10.1161/STROKEAHA.115.011036.)

Key Words: cognition ■ neuropsychological test ■ ROC curve ■ sensitivity and specificity ■ stroke

A fter a stroke, cognitive impairment (CI) is prevalent. Ten percent of patients with stroke meet criteria for dementia before a first stroke, 10% more have dementia after a first stroke and more than one third have dementia after recurrent strokes.1 More general CI, not necessarily meeting criteria for dementia, is even more common affecting >65% of patients with a clinical stroke.2 The most common symptoms of CI include difficulties with executive function, attention, and planning, as well as memory, language, and visuospatial functioning. Patients with poststroke CI are more likely to be functionally impaired,1 have a lower quality of life,4 have higher stroke recurrence,5 and higher mortality.6

Cognitive screening in patients with stroke is endorsed by Best Practice Recommendations,7 and rapid cognitive assessments are widely used in clinic settings to understand patient function and tailor appropriate therapy. The Montreal Cognitive...
Assessment (MoCA) is a common screen for CI that can be administered in 10 minutes, includes the assessment of multiple cognitive domains, and it is recommended by the National Institute of Neurological Disorders and Stroke–Canadian Stroke Network (NINDS-CSN) for use in stroke prevention clinics (SPCs). There is considerable variability in the diagnostic characteristics of the MoCA within the population with stroke (Table 1 in the online-only Data Supplement); most commonly, a cut point of ≥26 is considered normal, whereas ≤25 is considered impaired. This dichotomization stems from the statistical approach to receiver-operating curves, but contradicts clinical thought processes in which screening questions are used throughout a clinical encounter to decide serious concern, no concern, or possible concern and guide further questioning or appropriate actions. The MoCA has been shown to be more sensitive to vascular CI than other quick screens (eg, the Folstein Mini-Mental State Examination), but less specific. However, this reflects the use of a single cut point. In both clinical practice and research, the MoCA is often used as a surrogate for CI. However, it is best considered a screening assessment, not a diagnostic test. Indeed, full clinical assessment of CI includes an understanding of change over time or from baseline, as well as assessment of the impact on daily functioning. Despite the fact that all screens are imperfect, the MoCA is clinically convenient, and often used to define CI. For example, a recent article used MoCA <20 as a surrogate for significant impairment, 20 to 24 to indicate mild impairment, and ≥25 as a surrogate for no impairment. This approach may overestimate the accuracy of a screening test. A given MoCA score or range of scores may better reflect likelihood of impairment rather than severity. Indeed, a low MoCA does not necessarily correspond to greater cognitive severity—most validation studies have used MoCA to predict dichotomous outcomes (impaired or not) based on varying standards (differing cut points from 1 SD on a single test to 2 SDs on multiple domains across variable “gold standard” batteries), selection criteria, sample sizes, and timeframes. Indeed, population normative data suggest that many people functioning normally in the community score <26. A single cut point on the MoCA does not accurately diagnose across the range of cultures, ages, educations, and individual variables encountered in clinical or research environments. An alternative method of screening that corresponds closer to clinical thought processes would include groups at low risk (highly sensitive result), intermediate risk, and high risk (highly specific result). Radiologists have long recognized this approach and have used receiver operator characteristic (ROC) curves to facilitate comparison across the range of diagnostic certainty (eg, definitely normal, probably normal, equivocal, probably abnormal, and almost certainly abnormal). Statistical approaches to 3-class classification problems have been developed and expanded beyond to multiple class classification problems. This approach has been used to support clinical decision making, for example, in screening patients presenting with chest pain, or in differentiating normal aging from CI and dementia. We seek to validate a pragmatic, clinically useful method using ROC and area under the curve analysis of the MoCA to identify patients at low, intermediate and high likelihood of having CI.

Methods

Procedure

This study was approved by our Academic Center Research Ethics Board. Between April 23, 2012 and April 30, 2014, all consecutive new referrals to the regional SPC, including those discharged from hospital with a diagnosis of stroke or transient ischemic attack (TIA), and referrals from emergency departments, family physicians, and other subspecialty clinics, who were English-speaking, not severely aphasic, and could see and write well enough to complete neuropsychological testing were assessed for inclusion. During this period, 2277 new referrals were identified. Of these, 420 patients were unable to be approached in clinic (eg, simultaneous clinics and research team not available). Also from the 2277 patients, 353 were identified as non-English speaking, aphasic, possessing motor/sight impairments, or whose illness would interfere with neuropsychological testing, and thus were not approached. After these exclusions, a total of 1504 patients were approached for inclusion, of whom 390 participants volunteered for the study. All participants gave informed consent to participate in the study at the time of their initial clinic visit. After informed consent was obtained, the MoCA and a neuropsychological test battery (NTP) were administered by trained research staff. All patients attending a regional outpatient SPC were assessed for inclusion. Those who declined screening with the MoCA, and those who were missed were excluded. Patient-related exclusion criteria included: inability to complete the MoCA or neuropsychological testing because of severe aphasia, severe motor or visual impairments, or language barriers. Basic demographic information (age, sex, education, and first language) was also collected at the time of the initial clinic visit.

Assessments

The MoCA was used with permission from the publishing author, and it is a 30-point test that measures multiple cognitive domains, including attention, executive function, memory, language, visuospatial skills, abstraction, calculation, and orientation.

The NTP was based on the NINDS-CSN harmonization standards, and included the Controlled Oral Word Association Test, Digit Symbol Coding, and Trails Making A and B assessments. All scores were normalized for age, sex, and education using data or z scores from each respective test manual. Moderate–severe impairment was defined as ≥2 SDs from the mean score on ≥2 subtests of the battery.

Participants

Participants included in the study were either diagnosed with stroke, TIA, or another vascular or nonvascular condition after their initial visit to the SPC. Imaging-based criteria were used to classify stroke: silent infarcts identified for other reasons or a TIA presentation with diffusion-weighted imaging abnormalities were classified as stroke. Patients with both ischemic and hemorrhagic stroke were included. On the basis of this criteria, participants were also categorized as possible or probable TIA, and the remaining participants were categorized as having another vascular (eg, diffuse white matter disease and asymptomatic carotid stenosis) or other nonvascular condition (eg, migraine).

Primary Outcome Measure

The primary outcome measure for this study was the level of agreement between the MoCA and the NTP.

Statistical Analyses

Statistical analyses were conducted in R Version 3.0.3.23 and SPSS Version 22.0. Descriptive statistics to characterize the study population were calculated, and a multiple linear regression analysis was performed to examine the effect of age, sex, education, language, and modified Rankin Scale (mRS) score on MoCA score. Because the
population included both stroke and TIA/mimics, patients were not routinely assessed for stroke severity (eg, using the NIH Stroke Scale [NIHSS]), rather the mRS was used as a general measure of function applicable to all participants. A single, optimized cut point was determined by maximizing the sensitivity and specificity of the ROC curve. A second analysis was conducted, where 2 diagnostic cut points were determined using the ROC curve: first cut point with high sensitivity and a second cut point with high specificity were determined. The same concept applies to the methodology of classifying patients when using 2 cut points as with that of a single, optimized cut point.23,25,26 When a single cut point was chosen, those who scored below the single cut point generated for both high specificity and specificity formed the high-risk group, and those who scored above the cut point formed the low-risk group. When 2 cut points were chosen, those who scored below the cut point generated for high specificity formed the high-risk group and those who scored above the cut point generated for high sensitivity formed the low-risk group. Scores in between the cut points generated for high sensitivity and high specificity distinguished the intermediate-risk group. Positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (+LR), and negative likelihood ratio (−LR) were also calculated in addition to the curves, and diagnostic characteristics of the single cut-point and double cut-point methodologies were compared.

Results

Participant Characteristics

Participant characteristics are summarized in Table 1. Three hundred ninety participants consented to complete the MoCA and subsequent neuropsychological testing, of whom 53% were female. Ages ranged from 17 to 94 years, with a mean age of 62.4±15.4 years. Years of education ranged from 5 to 36 with a mean number of years 15.7±3.8 years. Three hundred thirty-one (85%) participants were English-speaking, and 59 (15%) participants’ second language was English, but they were fluent in English. The median mRS score was 0 (0–1). One hundred thirty-three (34%) study participants with symptomatic or silent imaging-defined stroke (115 ischemic and 18 hemorrhagic), 132 (34%) participants had possible or probable TIA, and the remaining participants (32%) were categorized as other vascular or other nonvascular. The MoCA and NTP were completed on the same day during a scheduled research visit.

Neuropsychological Battery Data

We found 53 (13%) participants met the criteria for moderate–severe CI (≥2 SD on ≥2 subtests), 115 (30%) participants could be classified as mildly impaired (≥1.5 SD on ≥1 subtests), and 222 participants (57%) were found to have no impairment according to the NTP. Patients with stroke were more often impaired on the NTP (18%) compared with other conditions (14%) and with TIA (9%; Table 1).

MoCA Data

The median score attained on the MoCA was 25 of 30 (interquartile range, 23–27). In a multivariate regression model, age, language, and mRS score were independent predictors of MoCA score (overall $R^2=0.153$, $P<0.001$). Older participants ($β=-0.049, P<0.001$), participants whose first language was not English ($β=-1.333, P=0.001$), and those with higher mRS scores ($β=-0.738, P=0.005$) had lower MoCA scores. Sex ($β=0.380, P=0.198$) and number of years of education ($β=0.064, P=0.093$) did not significantly influence MoCA score. Table 2 summarizes the participant’s MoCA scores as they relate to impairment on the NTP. Overall, MoCA scores did not differ significantly between diagnostic groups (Table 1).

Moderate–Severe CI ROC Curve Analysis

Using a single cut point (Figure A), sensitivity and specificity were optimal with MoCA ≤ 22, (sensitivity=60.4%, specificity=89.9%, area under the curve=0.801, PPV=48.5%, NPV=93.5%, +LR=6, and −LR=0.4). Using a single cut point, Table 1.

Table 1. Participant Characteristics

<table>
<thead>
<tr>
<th></th>
<th>All Patients (n=390)</th>
<th>Stroke (n=133)</th>
<th>TIA (n=132)</th>
<th>Other (n=125)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education, y</td>
<td>15.7±7.9</td>
<td>15.8±3.9</td>
<td>15.6±3.9</td>
<td>15.7±3.8</td>
</tr>
<tr>
<td>Age, y</td>
<td>62.4±15.4</td>
<td>59.9±15.1</td>
<td>65.4±14.2</td>
<td>61.9±16.3</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>206 (53%)</td>
<td>55 (41%)</td>
<td>50 (38%)</td>
<td>69 (55%)</td>
</tr>
<tr>
<td>Male</td>
<td>184 (47%)</td>
<td>78 (59%)</td>
<td>82 (62%)</td>
<td>56 (45%)</td>
</tr>
<tr>
<td>Language</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>English</td>
<td>331 (85%)</td>
<td>108 (81%)</td>
<td>117 (89%)</td>
<td>106 (85%)</td>
</tr>
<tr>
<td>ESL, but fluent</td>
<td>59 (15%)</td>
<td>25 (19%)</td>
<td>15 (11%)</td>
<td>19 (15%)</td>
</tr>
<tr>
<td>mRS score, median (IQR)</td>
<td>0 (0–1)</td>
<td>1 (0–2)</td>
<td>0 (0–1)</td>
<td>0 (0–1)</td>
</tr>
<tr>
<td>No. of patients with each score (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0: 211 (54%)</td>
<td>0: 40 (30%)</td>
<td>0: 95 (71%)</td>
<td>0: 76 (61%)</td>
<td></td>
</tr>
<tr>
<td>1: 103 (26%)</td>
<td>1: 44 (33%)</td>
<td>1: 24 (18%)</td>
<td>1: 36 (28%)</td>
<td></td>
</tr>
<tr>
<td>2: 57 (15%)</td>
<td>2: 41 (31%)</td>
<td>2: 8 (6%)</td>
<td>2: 8 (6%)</td>
<td></td>
</tr>
<tr>
<td>3: 14 (4)</td>
<td>3: 8 (6%)</td>
<td>3: 4 (3%)</td>
<td>3: 2 (2%)</td>
<td></td>
</tr>
<tr>
<td>4: 1 (0%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing: 4 (1%)</td>
<td>Missing: 0 (0%)</td>
<td>Missing: 2 (2%)</td>
<td>Missing: 2 (2%)</td>
<td></td>
</tr>
<tr>
<td>MoCA score, median (IQR)</td>
<td>25 (23–27)</td>
<td>25 (23–27)</td>
<td>25 (24–27)</td>
<td>26 (23–28)</td>
</tr>
<tr>
<td>NTP Impairment (2 SD)</td>
<td>53 (14%)</td>
<td>24 (18%)</td>
<td>12 (9%)</td>
<td>17 (14%)</td>
</tr>
</tbody>
</table>

ESL indicates English as second language; IQR, interquartile range; MoCA, Montreal Cognitive Assessment; mRS, modified Rankin Scale; and NTP, neuropsychological test battery.
18.7% of participants scored ≤22, and they were classified as high risk for CI; 81.3% participants scored >22, and these participants were classified as low risk for CI.

Using 2 cut points (Figure B), sensitivity is optimal with MoCA ≥28 (sensitivity=96%, NPV=97.6%, and −LR=1.27), and specificity is optimal with MoCA ≤22 (specificity=89.9%, PPV=48.5%, and +LR=6). Using 2 cut points, 18.7% of participants scored ≤22, and they were classified as high risk for CI; 21.1% participants scored ≥28, and these participants were classified as low risk for CI; 60.3% of participants scored 23 to 27, and they were classified as intermediate risk for CI. Of the 240 participants who score in the intermediate risk range on the MoCA (23–27), 19 (8%) are moderate–severely impaired and 221 (92%) have no moderate–severe impairment.

### Discussion

Using ROC analysis to stratify participants into low-, intermediate-, and high-risk categories is an effective method to categorize clinic patients at risk of CI. This approach provides both excellent sensitivity and specificity for detecting moderate–severe impairment. This approach emphasizes that a given MoCA score is not a diagnosis, but reflects a range of performance on more detailed testing. When compared with the traditional method of ROC analysis, determining a single dichotomous cut point (≤22, sensitivity=60.4%, and specificity=89.9%), the generation of 2 cut points for high sensitivity and specificity (≤28 and ≤22, respectively) improved diagnostic characteristics (sensitivity=96%, specificity=90%, Table 3), but leaves a majority of patients in the intermediate category. Previous validation studies that chose single cut points generally favored optimal sensitivity over specificity, decreasing the accuracy of the screening measure to rule patients in for CI (Table I in the online-only Data Supplement).

Yet the large intermediate group probably explains much of the variability in this range. Comparing the MoCA to various criterion standards, studies report cut points that range from ≤25 to ≤19, with widely varying sensitivities and specificities. Cut points reported may vary based on the criterion standard chosen (reflecting mild, moderate–severe impairment, or dementia); however, even when criterion standards are similar among studies, resulting cut points are not uniform. This variability in cut points stems, in part, from the heterogeneity inherent in screening cognition. Even in normal elderly populations, cognitive performance varies across trials. Patient factors such as age, education, mood, motivation, attention, and level of fatigue may contribute to misidentification of CI. In contrast to an approach using separate cut points for different criterion standards (eg, mild impairment versus severe impairment), the risk-based approach to screening explicitly acknowledges this heterogeneity.

The initial MoCA validation in the MCI/Alzheimer disease population cited a score of ≥26 as a cut point for normal, but subsequent stroke studies have suggested lower cut points. In clinical practice, many healthcare professionals thus define a score of ≤25 as abnormal. Yet 92% of participants scoring 23 to 27 were within 2 SD of normal on multiple neuropsychological test scores, suggesting a single cut point is not optimal for characterizing these participants and may artificially minimize the uncertainty inherent in screening for a complex phenomenon, such as cognition. Choosing 2 optimal cut points is a clinically useful strategy for more accurately classifying these participants.

When choosing 2 diagnostic cut points, the major use lies in examining the PPV and +LR of the specific cut point and the NPV and −LR of the sensitive cut point. Understanding the operating characteristics of a screening test is essential to optimizing its use. If the goal is to identify those likely to be normal (eg, avoid unnecessary referrals or assessments), then the sensitive cut point of ≥28 has value. If the goal is to identify those most likely to have difficulties (eg, for research purposes or to choose who to send for driving evaluations), the more specific cut point of ≤22 would be most useful. Indeed, the NPV is strengthened for the sensitive cut point (NPV=97.6% at a cut point ≥28 versus 93.5% at a cut point ≥23), and the PPV remains constant for the specific cut point (PPV=48.5% at ≤22). The PPV is still relatively modest compared with the

### Table 2. MoCA Score and Impairment on the Neuropsychological Test Battery

<table>
<thead>
<tr>
<th>MoCA Score</th>
<th>Not Impaired (No. of Participants)</th>
<th>Impaired (No. of Participants)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>19</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>20</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>21</td>
<td>5</td>
<td>8</td>
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<tr>
<td>22</td>
<td>13</td>
<td>10</td>
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<tr>
<td>23</td>
<td>29</td>
<td>3</td>
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<tr>
<td>24</td>
<td>38</td>
<td>5</td>
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<tr>
<td>25</td>
<td>59</td>
<td>5</td>
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<tr>
<td>26</td>
<td>45</td>
<td>3</td>
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<tr>
<td>27</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>28</td>
<td>37</td>
<td>0</td>
</tr>
<tr>
<td>29</td>
<td>27</td>
<td>2</td>
</tr>
<tr>
<td>30</td>
<td>18</td>
<td>0</td>
</tr>
</tbody>
</table>

MoCA indicates Montreal Cognitive Assessment.

### Table 3. Single Optimal Cut Point and 2 Optimal Cut Points Diagnostic Characteristic Comparison

<table>
<thead>
<tr>
<th>Diagnostic Characteristic</th>
<th>Single Optimal Cut Point, ≤22</th>
<th>Two Optimal Cut Points Sensitive Cut Point, ≤22 Specific Cut Point, ≥28</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>60.4%</td>
<td>96%</td>
</tr>
<tr>
<td>Specificity</td>
<td>89.9%</td>
<td>90%</td>
</tr>
<tr>
<td>PPV</td>
<td>48.5</td>
<td>48.5</td>
</tr>
<tr>
<td>NPV</td>
<td>93.5</td>
<td>97.6</td>
</tr>
<tr>
<td>+LR</td>
<td>6</td>
<td>5.98</td>
</tr>
<tr>
<td>−LR</td>
<td>0.4</td>
<td>1.27</td>
</tr>
</tbody>
</table>

LR indicates likelihood ratio; NPV, negative predictive value; and PPV, positive predictive value.
NPV, suggesting that the MoCA is more reliable as a screening test to rule out moderate–severe impairment than as a specific test for ruling in the condition.

Clinically, 3 groups of patients emerge: those who are evidently low risk, those at more significant risk, and an intermediate group who warrant further assessment. The low-risk group is the most homogenous group. Only 2 participants (2.4%) who score ≥28 on the MoCA had impairment according to the neuropsychological battery (Table 2). In the high-risk group, 48.5% were impaired. The intermediate-risk group included the largest fraction of our clinic population (61.5%), but only 19 (8%) of them had moderate–severe impairment on more detailed neuropsychological testing. Time and resource limitations may pose a challenge to providing additional investigation of these patients. However, if the goal is to identify as many patients as possible with impairment, omitting the intermediate group would eliminate 19 of 53 (36%) of those with impairment.

Given that any neuropsychological screen, including the MoCA, does not assess effect on function or decline from previous levels of function, they cannot be used in isolation to make a diagnosis of CI or dementia. The duration, triggers or acuity of a patient’s symptoms, comorbidities (eg, depression and obstructive sleep apnea), and baseline cognitive function may all be relevant to determine whether impairment is clinically significant, what type of intervention is warranted, or whether the patient is appropriate for specific research studies. Yet, low scores on the MoCA are often cited in practice to imply CI or dementia. A breakdown of risk as described here can help to emphasize that screening is only one aspect of the diagnostic workup. Pairing screening scores with 1 or 2 clinical questions (eg, “are you having trouble with your memory, thinking or planning?”), or “have you noticed your ability to remember, think or plan are different than they were before?”) or asking similar questions of the caregiver’s perception may be necessary to rule out cognitive decline (low- and intermediate-risk groups without concerns), or to guide targeted assessment and intervention for those with new and functionally significant changes in cognition.

Although this study represents a pragmatic approach, with a large sample size, there are several key limitations. First, our study required volunteers, and thus was not entirely representative of our clinic population. Participants tended to be younger, slightly more mildly affected on mRS, and slightly more educated than our general clinic population by virtue of the study requirements: they had to have sufficient motor, language, and visual function to complete neuropsychological testing. Time and resource limitations may pose a challenge to providing additional investigation of these patients. However, if the goal is to identify as many patients as possible with impairment, omitting the intermediate group would eliminate 19 of 53 (36%) of those with impairment.

Figure. A, Receiver operator characteristic (ROC) curve comparing Montreal Cognitive Assessment (MoCA) to neuropsychological test battery (where impairment is defined as moderate–severe), which displays the point of optimized sensitivity and specificity. B, ROC curve displaying MoCA diagnostic cut points, where a cut point for both high sensitivity and specificity is chosen, which stratifies participants into high-, intermediate- and low-risk categories for moderate–severe cognitive impairment.
greater number of people scoring ≥2 SDs from age-, sex- and education-matched norms on ≥2 tests. Yet, requiring formal neuropsychological evaluation would have further biased the study population toward the most mild who could tolerate volun-
teeing for several hours of assessment and was not feasible for the large numbers of patients required. Finally, our results reflect a large stroke and TIA clinic population but the operat-
ning performance of the 2 cut point model may vary slightly if applied in other populations. This variability will likely be signif-
ically less with the 2 cut point approach given the results already seen in multiple other studies (Table I in the online-
only Data Supplement).

Effective screening to identify patients at low, interme-
diate and high risk for CI has important implications for sec-
ondary prevention, management, and treatment. The ability to
categorize patients as high risk for moderate–severe CI can
facilitate clinical care pathways through prioritization and
expedited assessment and treatment. This may include occu-
tional therapeutic assessments (eg, driving and home safety
evaluations) and referrals to cognitive specialists. It has been
demonstrated that patients benefit from recommendations of
physical exercise. They may also benefit from cognitive
rehabilitation training and pharmacological therapy with
acetylcholinesterase inhibitors.

Conclusions

Stratifying participants into 3 categories using ROC and area
under the curve analyses, rather than 2, facilitates the iden-
tification of a homogenous group at low risk for CI, as well
as groups with intermediate and high risk. This creates use-
ful clinical categories—those of low-level concern who are
unlikely to have CI and thus do not require immediate man-
agement, those of intermediate-level concern with possible
presence of CI, who should be monitored or further assessed,
and those with greater concern for the presence of CI, for
whom management or intervention may be necessary. This
pragmatic approach could facilitate both clinical care path-
ways and patient selection for research.

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Validating a Pragmatic Approach to Cognitive Screening in Stroke Prevention Clinics
Using the Montreal Cognitive Assessment
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Demetrios J. Sahlas, Nathan Herrmann, Ashley Cohen and Kevin E. Thorpe

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## SUPPLEMENTAL MATERIAL

### Supplemental Table I. Sensitivities and specificities according to validated MoCA cut-points

<table>
<thead>
<tr>
<th>Paper</th>
<th>Comparison</th>
<th>Definition of Cognitive Impairment</th>
<th>Cut-point</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lees (2013)¹*</td>
<td>PSCI versus NCI</td>
<td>N/A</td>
<td>≤25†</td>
<td>95</td>
<td>45</td>
</tr>
<tr>
<td>Pendlebury (2012)²</td>
<td>Post-stroke MCI versus NCI</td>
<td>Score 1.5 SD below on at least 1 cognitive domain compared with age and education matched published norms, with no impairment of ADL as measured by the Barthel index, and did not fit criteria of DSM for Dementia</td>
<td>≤22</td>
<td>49</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>≤23</td>
<td>59</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>≤24†</td>
<td>77</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>≤25</td>
<td>87</td>
<td>63</td>
</tr>
<tr>
<td>Cumming (2013)³</td>
<td>PSCI versus NCI</td>
<td>Score 1.0 SD below on in 2 or more cognitive domains compared with age and education matched norms</td>
<td>≤21</td>
<td>77</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>≤22</td>
<td>80</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>≤23†</td>
<td>92</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>≤24</td>
<td>97</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>≤25</td>
<td>100</td>
<td>43</td>
</tr>
<tr>
<td>Cumming (2013)³</td>
<td>PSCI versus NCI</td>
<td>Score 1.5 SD below on in 2 or more cognitive domains compared with age and education matched norms</td>
<td>≤23†</td>
<td>94</td>
<td>54</td>
</tr>
<tr>
<td>Wu (2013)⁴</td>
<td>VCIND versus NCI</td>
<td>Presence of ischemic cerebrovascular lesion on CT scan or MRI, stable condition 24 hours prior to the test, mild cognitive impairment manifested with cognitive disabilities communicated by patients or their family members, cognitive impairment due to a major regional infarction, large area of infarction, multiple infarctions or cerebral infarction within 3 months prior to diagnosis, sudden onset and gradual progression of the lesions with imaging evidence, and a CDR score which did not reach the diagnostic criteria for dementia based on the DSM-IV</td>
<td>≤22†</td>
<td>65</td>
<td>79</td>
</tr>
<tr>
<td>Salvadori</td>
<td>PSCI as MCI or</td>
<td>Presence of an abnormal</td>
<td>≤21†</td>
<td>91</td>
<td>76</td>
</tr>
<tr>
<td>Year</td>
<td>Study</td>
<td>Group</td>
<td>Definition of Impairment</td>
<td>Cut-off Scores</td>
<td></td>
</tr>
<tr>
<td>------</td>
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<td>-------</td>
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<td></td>
</tr>
<tr>
<td>2013</td>
<td>Dong</td>
<td>VCIND (moderate/severe) versus VCIND (mild)</td>
<td>Score of 1.5 SD below (education adjusted) established norms in at least half of the tests in a single domain constituted failure in that domain. Cognitive outcomes were dichotomized as either no/mild (impairment in ≤2 cognitive domains) or moderate/severe (impairment in ≥3 cognitive domains) vascular cognitive impairment. Diagnoses of Dementia were made according to the DSM IV.</td>
<td>≤21† 88 64</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>Dong</td>
<td>VCIND (moderate/severe) versus VCIND (mild)</td>
<td>Cognitive outcomes were dichotomized as either no/mild (impairment in ≤2 cognitive domains) or moderate/severe (impairment in ≥3 cognitive domains) vascular cognitive impairment. Criteria for domain impairment were not described. Diagnoses of Dementia were made according to the DSM IV.</td>
<td>≤19 77 89 ≤20 84 85 ≤21† 90 77 ≤22 92 68 ≤23 95 60</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>Wong</td>
<td>PSCI Including SVD versus NCI</td>
<td>Composite scores for executive and non-executive functions were calculated by averaging the z scores of individual tests in the respective domain. Impairment on the neuropsychological battery was not otherwise defined.</td>
<td>≤21† 73 75</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>Godefroy</td>
<td>PSCI versus NCI</td>
<td>Impairment of at least 2 cognitive domains, where domain</td>
<td>≤19 64 97 ≤20 67 90</td>
<td></td>
</tr>
</tbody>
</table>
(age and education adjusted MoCA score) impairment is defined as deficits in at least 1 test in a domain except for action speed (2 impaired performances on Part A of the Trail Making test, naming subtest of the Stroop test, and Digit Symbol substitution subtest) and executive functions (2 impaired performances within the Stroop interference index, perseveration on Trails Making test Part B, categorical and literal verbal fluencies, strategic memory process on the Grober-Buschke test). Patients were categorized as cognitively impaired when MMSE score was < 23 or when the comprehensive battery was impaired.

<table>
<thead>
<tr>
<th>Godefroy (2011) * (raw MoCA score)</th>
<th>PSCI versus NCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impairment of at least 2 cognitive domains, where domain impairment is defined as deficits in at least 1 test in a domain except for action speed (2 impaired performances on Part A of the Trail Making test, naming subtest of the Stroop test, and Digit Symbol substitution subtest) and executive functions (2 impaired performances within the Stroop interference index, perseveration on Trails Making test Part B, categorical and literal verbal fluencies, strategic memory process on the Grober-Buschke test). Patients were categorized as cognitively impaired when MMSE score was &lt; 23 or when the comprehensive battery was impaired.</td>
<td>≤19†</td>
</tr>
<tr>
<td>≤20</td>
<td>72</td>
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<tr>
<td>≤21</td>
<td>75</td>
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<tr>
<td>≤22</td>
<td>78</td>
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<tr>
<td>≤23</td>
<td>88</td>
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<tr>
<td>≤24</td>
<td>92</td>
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<tr>
<td>≤25</td>
<td>94</td>
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<tr>
<td>≤26</td>
<td>97</td>
</tr>
</tbody>
</table>

*Pooled Data, †Optimal Cut-point chosen

References


