More than 40% of stroke survivors are found with cognitive impairment (poststroke cognitive impairment [PSCI]) sometime after the event.1 Almost two thirds of these patients are affected by mild cognitive impairment (MCI).2 A meta-analysis showed that 10% of patients had dementia before first stroke, 10% developed dementia soon after first stroke, and more than a third had dementia after recurrent stroke.3 Ideally, cognitive evaluation of patients with stroke should start early after the event, but this may be difficult. In fact, a cognitive evaluation is not a part of the routine assessment of patients with acute stroke in most centers, and items assessing cognitive functions are poorly represented in the most widely used acute stroke scales.

The Montreal Cognitive Assessment (MoCA) is a brief screening instrument originally designed to identify MCI in elderly patients attending a memory clinic.4 MoCA is a 1-page, 30-point test, administrable in ≈10 minutes, which evaluates different domains: visuospatial abilities, executive functions, short-term memory recall, attention, concentration, working memory, language, and orientation to time and space (Figure).5 A shortened version of MoCA has been proposed as a first assessment of patients with vascular cognitive impairment by a consensus conference.6 When compared with another widely used cognitive screening test, the Mini Mental State Examination (MMSE), one of the possible strengths of MoCA in the vascular patient setting is the assessment of executive functions and the presence of more demanding visual construction tasks.7 The consensus conference proposal was generally directed to not otherwise specified vascular cognitive impairment patients; however, MoCA has recently been used by various groups in the research stroke setting (online-only Data Supplement). However, the use of MoCA in usual stroke practice is not frequent.8

In this article, we reviewed the literature on the use of MoCA in patients with stroke. We dealt separately with articles in which the test was administered in the acute/subacute (the first 4 weeks after stroke) or in the chronic phase after stroke (any time after the first 4 weeks). The aim of this review is to spotlight the diffusion, the main results, the indications, and limitations of the use of MoCA in the stroke setting. This work could serve to implement the use of MoCA in the stroke setting and establish a first level of knowledge about the advantages and limitations of this test. Suggestions and research lines for future studies aimed at better establishing the role of MoCA in this setting may derive from this review.

Article Search Strategy and Selection Criteria
Articles were identified through PubMed searches using the terms: Montreal Cognitive Assessment, MoCA, stroke, hemorrhage, poststroke, poststroke, vascular cognitive impairment, from any date to December 31, 2013. Only articles in which MoCA was cited in title or abstract and written in English were reviewed in detail. Further references were obtained from the reference lists of the articles identified through the search. The final reference list was generated on the basis of relevance to the topic of this review.

Use of MoCA in the Acute/Subacute Poststroke Phase
It is likely that patients with PSCI might be already identified soon after stroke by a neuropsychological evaluation, thus outlining a factor possibly relevant in prognostic, therapeutic, and rehabilitation terms. However, several conditions may influence the applicability and reliability of a cognitive evaluation early after stroke, when extensive testing does not seem routinely feasible on a large scale. A brief, easy-to-use, test such as MoCA could be useful in this context.

Considering the MoCA applicability in the acute stroke setting, we showed that the test administration was feasible in patients with mild-to-moderate stroke, and that MoCA was fully applicable in 73% of all patients admitted to our stroke unit with either ischemic or hemorrhagic strokes.9 The independent determinants of its applicability were left-side lesion location, stroke severity, and premorbid functional status.9 Other studies using MoCA in the acute/subacute phase had various exclusion criteria: previous stroke/transient ischemic...
attack,8,10–13 hemorrhages,10,14 severe stroke,15 major physiological disability,14,16–18 significant aphasia,8,10,11,13,16–18 inability to participate in rehabilitation activities,8 prestroke cognitive impairment,15–17 acute delirium,17 and major psychiatric disorder.10,11,14,16–19 These exclusion criteria led to apply MoCA mostly in mild-to-moderate patients with stroke, usually with first-ever ischemic stroke, without other major disorders or severe aphasia. The fact that patients with severe neurological status or aphasia cannot be tested with MoCA is not necessarily a major limitation of this tool because these patients are already candidates for specific rehabilitation programs or long-term care strategies.9

Some studies compared MoCA performances in patients with acute/subacute stroke with those on other
psychocognitive assessment tools and discharge functional outcome. When compared with the MMSE, MoCA had more frequently altered items,\textsuperscript{8,10,11,16,18} less ceiling effect,\textsuperscript{1,16} but a similar correlation with discharge motor outcome\textsuperscript{4} and with an extensive neuropsychological evaluation.\textsuperscript{11} In 1 study, no correlation was found between MoCA performances and apathy or depression within 2 weeks of stroke onset.\textsuperscript{9} MoCA also identified more patients with cognitive abnormalities than the MindStreams, a 45-minute computerized neuropsychological assessment battery that examines a wide range of cognitive domains.\textsuperscript{15}

To establish the prognostic value of MoCA, 3 studies compared MoCA performances in the acute/subacute poststroke period with those on extensive neuropsychological batteries at midterm follow-up.\textsuperscript{12,17,20} These studies showed that baseline MoCA can predict the development of PSCI at 3, 6, and 12 months with an accuracy of $\geq 90\%$. In our study, MoCA baseline score was an independent determinant of PSCI with an odds ratio 1.4 for each test point lost.\textsuperscript{20} MoCA score was also associated with poor functional status measured with the modified Rankin Scale at 3 to 6 months in patients with ischemic stroke or transient ischemic attack\textsuperscript{14} and at 12 months in patients with subarachnoid hemorrhage.\textsuperscript{13}

### Use of MoCA in the Chronic Poststroke Phase

The presence of poststroke cognitive impairment 3 months after the event is associated with death or disability at 3 and 4 years (odds ratio, 2.0 and 2.2, respectively) and greater institutionalization rates.\textsuperscript{21} Hence, repeating a cognitive evaluation in the midterm follow-up of stroke is crucial for identifying those patients that would need more care and, possibly, specific interventions. After the subacute poststroke phase, patients are supposedly more stable, and it is possible that some spontaneous cognitive recovery has already occurred. Again, a comprehensive neuropsychological battery, the gold standard for the diagnosis of cognitive impairment, might not be feasible in the routine practice because it is time-consuming and require trained personnel, and hence a short and reliable test would be worthwhile to use in this phase.

The feasibility of the application of MoCA in patients with stroke at a 3-month follow-up was evaluated by Cumming et al.\textsuperscript{22} The test was completed by 87% of patients with mild stroke (baseline National Institutes of Health Stroke Scale, 0–7), 79% of those with moderate stroke (National Institutes of Health Stroke Scale, 8–15), and 67% of those with severe stroke (National Institutes of Health Stroke Scale, >16).\textsuperscript{22} Sixty-five percent of patients examined were classified as affected by PSCI; the items most frequently impaired were those with attention and executive demands and word recall.\textsuperscript{22}

Many studies compared MoCA with other single cognitive tests or neuropsychological batteries to estimate its accuracy in detecting PSCI in the chronic poststroke phase. When MoCA was compared with MMSE, a larger number of patients with stroke or transient ischemic attack was found with scores under the range of normality.\textsuperscript{23,24} Similar results were reported in out-patients affected by cerebrovascular diseases.\textsuperscript{25} Nevertheless, the MoCA recall task, that is considered harder than the one of the MMSE, showed a floor effect in differentiating patients with more severe impaired recall.\textsuperscript{26} MoCA was also compared with the Addenbrooke’s Cognitive Examination-Revised, another short test that includes frontal executive and attention tasks, for the ability in detecting MCI.\textsuperscript{27} MoCA and Addenbrooke’s Cognitive Examination-Revised had good sensitivity and specificity, suggesting that both tests were useful in detecting cognitive impairment in patients with stable cerebrovascular disease.

When MoCA was compared with neuropsychological batteries in patients with stroke caused by small-vessel diseases, it showed a significant relationship with an extensive battery and a good accuracy in detecting cognitive impairment when optimal cut-off values were found.\textsuperscript{27,28} The same results were detected in another Asian sample of patients with small-vessel disease (not all of them with stroke).\textsuperscript{28}

Two studies compared MoCA and MMSE 3 to 6 months after aneurysmal subarachnoid hemorrhage.\textsuperscript{29,30} MoCA was more sensitive than MMSE in detecting PSCI in patients who had returned to work, and, unlike MMSE, correlated with performances on a comprehensive neuropsychological battery and with the functional outcome (Glasgow Outcome Scale).\textsuperscript{29} Wong et al\textsuperscript{10} examined the ability of MoCA and MMSE to differentiate favorable functional outcome (modified Rankin Scale, 0–2) and Instrumental Activities in Daily Living score in patients with postaneurysmal subarachnoid hemorrhage and found similar accuracy for both tests at their optimal cut-off values.

Considering the possible influence of cognitive performances on stroke motor outcome and rehabilitation, Hwang et al\textsuperscript{31} found a significant correlation between MoCA score and some postural control and gait performances tests in patients with hemiparetic stroke. MoCA was also a predictor of maximal exercise effort on a graded exercise test in patients with stroke.\textsuperscript{32}

### Methodological Issue: The Choice of the Normality Cut-Off Score for MoCA in Patients With Stroke

The choice of the normality cut-off score for MoCA in patients with stroke is a crucial issue. Godefroy et al\textsuperscript{11} using published norms, found that 82% of their patients with acute stroke had a score below the normality. When the cut-off was adjusted for education and age, the proportion of patients decreased to 48%.\textsuperscript{31} Similarly, Lees et al\textsuperscript{33} using the original cut-off of 26, diagnosed cognitive impairments in 86% of acute stroke unit patients; the proportion decreased to 49% if the cut-off was decreased to 20.

Most studies found that the cut-off of 26, suggested by Nasreddine et al\textsuperscript{7} to detect MCI in a memory clinic, is inadequate for the stroke setting. The optimal values for normality range from 19 to 22 in studies in which MoCA was administered in the acute stroke phase,\textsuperscript{11,12,17,20} and from 20 to 27 in studies in which the test was administered in the chronic phase.\textsuperscript{24,27,28,30,34–36} Once performances were compared with those on extensive batteries at follow-up.

Moreover, the proposed addition of 1 point to North America patients with <12 years of education\textsuperscript{9} could not be adequate to patients with different social background,\textsuperscript{17} as
shown in some Asian and European studies, some of these studies found a threshold of 6 years of education for adding 1 point to MoCA total score.28,36

Another methodological problem when selecting the optimal cut-off score for MoCA normality is the choice of the thresholds to define cognitive impairment in the gold standard.34,38 Using the standard threshold of >1 SD below the mean in ≥2 domains in the gold standard battery, MoCA showed higher sensitivity than MMSE using a cut-off value of 24.34 When a more conservative threshold (≥2 SD in ≥2 domains) was used, this superiority in sensitivity was lost, and MMSE showed a slightly greater accuracy than MoCA.34 Pendlebury et al38 investigated the sensitivity, specificity, accuracy, and optimal cut-off values of MoCA and MMSE in detecting MCI based on different thresholds on cognitive tests (≥1, ≥1.5, and ≥2 SD below norms); they also differentiated between the Petersen’s original (subjective memory complain required) and modified MCI criteria (without subjective memory complain).38 MoCA seemed superior to MMSE in detecting MCI with modified criteria, whereas MMSE was better in detecting patients with MCI and subjective memory complains.38 These findings corroborate the supposed superiority of MoCA in the vascular setting, where the nonamnestic single-domain is supposedly prevalent.38 This study showed that the differences between MoCA and MMSE found in other studies almost disappeared when requirement for MCI was more stringent.38

**Shorter and Telephone Versions of MoCA**

Shorter versions of MoCA have been developed to minimize the administration time further. A telephone version of MoCA (total score, 22; cut-off, 19) and its shorter version (total score, 12; verbal fluency, recall and orientation, cut-off, 11) were developed by Pendlebury et al.39 Both versions had good accuracy in detecting MCI but performed worse than the original MoCA.39

According to the National Institute of Neurological Disorders and Stroke-Canadian Stroke Network (NINDS-CSN) statements, a 5-minute protocol based on MoCA items should include the 5-word immediate and delayed memory test, the 6-item orientation task, and the 1-letter phonemic fluency test (letter F).7 Two studies tested this proposal in samples of patients with cerebrovascular disease40,41 and found that the MoCA subitems that more strongly correlated with MoCA total score were delayed recall, clock-drawing, and abstraction with an arbitrary cut-off of 7 of 10 in one study,40 and verbal fluency, cube copy, trial making test, delayed recall, and abstraction with a calculated cut-off of 7 of 10 in another.41

**MoCA as an Outcome Cognitive Measure**

MoCA is mainly considered a screening tool, but it has also been used as a cognitive outcome measure in some studies. Cumming et al25 found a significant correlation between 2 computerized attention cognitive tests administered in the acute phase of stroke and the performances on MoCA 3 months later. Marzolini et al43 measured the effect of a 6-month exercise program on cognitive performances measured with MoCA; they demonstrated a significantly improved MoCA score, and a 44.5% reduction in patients with poststroke meeting the MoCA threshold for MCI.43

**Conclusions**

From the studies we reviewed, the use of MoCA as a brief cognitive tool in both the acute/subacute and chronic post-stroke periods seems overall feasible. Used in the acute period, MoCA has a good predictive value for the development of PSCI in the follow-up. Shorter versions of MoCA are available to make the application of MoCA even faster without significantly decreasing its sensitivity and specificity. In the chronic, midterm poststroke period, MoCA is related to physical performances and to functional outcome, has a good correlation with other short cognitive tests, and shows high sensitivity and specificity in predicting PSCI in both ischemic and hemorrhagic strokes.

Some issues, however, remain open as pointed out by a recent review on the MoCA characteristics and methodological limitations of its use in patients with vascular cognitive impairment.44 For example, the cut-off and the correction for education need to be redefined for the stroke setting and the different ethnic and educational groups. Because in the acute/subacute stroke period a brief screening test should individuate those patients who may need further assessment, the cut-off should be selected to minimize the false-negative rate and the likelihood of a negative test.45

The evaluation of cognition in patients with stroke is important and the use of a brief cognitive test may facilitate this assessment since the early phases. In this regard, it should be noted that available data do not sustain a clear superiority of MoCA in respect to other tools. However, MoCA presents some advantages, such as shortness, easiness of use, availability in different languages, and the free access (Table). The Table also reports the disadvantages of MoCA use in the stroke population. Besides, the already made comments about norms and cut-off, it should be pointed out that domains that are often impaired after stroke, such as intellectual functioning,

### Table. Advantages and Limitations/Disadvantages of the Use of Montreal Cognitive Assessment in Patients With Stroke

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Limitations and Disadvantages</th>
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<tbody>
<tr>
<td>Easy-to-use</td>
<td>Lack of standardized norms</td>
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<td>Brevity</td>
<td>Lack of consensus on the cut-off to define cognitive impairment in the stroke setting</td>
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<td>Correlation with cognitive outcome</td>
<td>Not administrable in severely aphasic patients</td>
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<tr>
<td>Correlation with functional outcome</td>
<td>No assessment of intellectual functioning, speed of information processing, and nonverbal memory</td>
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<tr>
<td>Telephone and shorter versions availability</td>
<td>...</td>
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<tr>
<td>Availability in different languages</td>
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<td>Free of charge</td>
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speed of information processing, and nonverbal memory, are not assessed by this test.

In consideration of all the points above discussed, a multicentric, hopefully international, study enrolling an appropriate number of patients with stroke seems warranted. Such a study should test patients with stroke and MoCA and other brief cognitive tests in the acute phase and then follow them up to define the diagnosis of cognitive impairment (either mild or severe) and explore the predictive values of MoCA according to different cut-offs, controlling for age, sex, and education. This study could also explore definitively whether MoCA is superior, equivalent, or even inferior to other brief cognitive tools.

Acknowledgments

We thank all our patients who took part in our studies on the cognitive consequences of stroke. We acknowledge the work done in this regard by Anna Poggesi, MD, PhD, Emilia Salvadori, PhD, and Marco Pasi, MD.

Disclosures

Dr Pantoni is on the Editorial boards of Acta Neurologica Scandinavica, Cerebrovascular Diseases, and Stroke (Editor of the Vascular Cognitive Impairment section). Dr Chiti reports no conflicts.

References


Key Words: cognition ◼ mild cognitive impairment ◼ neuropsychological tests ◼ stroke
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Guido Chiti and Leonardo Pantoni

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Studies on the use of MoCA in stroke patients
<table>
<thead>
<tr>
<th>Authors, year</th>
<th>Setting</th>
<th>Patients</th>
<th>Aims</th>
<th>Methods</th>
<th>Main Results</th>
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<tbody>
<tr>
<td>Popovic et al. 2007¹</td>
<td>Acute ischemic stroke/TIA</td>
<td>110 pts. and 45 controls</td>
<td>To evaluate and compare usefulness of MoCA and MMSE in detection of cognitive decline in patients with Stroke/TIA and subjects with cerebrovascular risk factors</td>
<td>MMSE and MoCA on admission, at 3 and 6 months.</td>
<td>A decrement in cognitive performance was more evident in both groups when MoCA (cut-off 26) was used instead of MMSE (cut-off 25).</td>
</tr>
<tr>
<td>Dong et al. 2010²</td>
<td>Acute ischemic stroke/TIA</td>
<td>100 pts.</td>
<td>To compare MoCA and MMSE in the early detection of vascular MCI patients.</td>
<td>MoCA and MMSE within the 14th day from the index event. 3 groups: no cognitive impairment (MMSE&gt;24 and MoCA&gt;21), MCI (MMSE&gt;24 and MoCA&lt;/=21) and moderate/severe cognitive impairment (MMSE&lt;/=24).</td>
<td>MoCA scores were normally distributed and with a wide dispersion, MMSE scores were skewed towards the higher scores. More patients were identified with cognitive impairment by the MoCA (n=59) compared to MMSE (n=43). Unlike MMSE, both the mean MoCA score and several MoCA subtest scores could significantly differentiate across all three groups.</td>
</tr>
<tr>
<td>Godefroy et al. 2011³</td>
<td>Acute/sub acute stroke</td>
<td>95 pts.</td>
<td>To assess the value of MoCA and MMSE to detect PSCI assessed by a neuropsychological battery</td>
<td>MoCA and MMSE within 3 weeks from the event (mean 6.6±3.5 days). Neuropsychological battery 24.1±6.4 days later if the MMSE value was &gt;= 23.</td>
<td>AUCs of both MoCA and MMSE were very similar suggesting that both tests had a similar ability to detect PSCI. The cut-off scores determined adjusting for age and education were 25 for MMSE and 21 for MoCA. With these new values, MoCA was not more sensitive than MMSE for screening for cognitive deficits.</td>
</tr>
<tr>
<td>Toglia et al. 2011⁴</td>
<td>Acute stroke</td>
<td>72 pts.</td>
<td>To compare MoCA and MMSE global and subscores in classifying PSCI and explore the relationship between admission and discharge functional status and improvement.</td>
<td>NIHSS, MMSE and the MoCA within 48 hours of admission. Functional outcome measured by the motor subscale of Functional Independence Measure (mFIM).</td>
<td>MoCA (cut-off 26) classified a greater number of stroke patients as cognitively impaired (89%) than the MMSE (47% with cut-off 25; 63% with cut-off 27). MoCA had also higher internal reliability, less ceiling effect, and at least as strong as the MMSE relationship to rehabilitation functional outcome and improvement.</td>
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<td>Authors, year</td>
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<tr>
<td>Dong et al. 2012&lt;sup&gt;5&lt;/sup&gt;</td>
<td>Acute ischemic stroke/TIA</td>
<td>300 pts.</td>
<td>To determine the prognostic value and optimal cut-offs of MoCA and MMSE administered in mild stroke patients in the acute phase for the detection of significant cognitive impairment at 3-6 months.</td>
<td>MoCA and MMSE within 14 days after index stroke, followed by a formal neuropsychological evaluation of seven cognitive domains 3-6 months later.</td>
<td>ROC AUCs were similar between the MoCA and MMSE scores and age- and education-adjusted scores to detect moderate-severe cognitive impairment 3-6 months after the index event. Optimal cut-off points were MoCA 22 and MMSE 26. Using these cut-offs, there was no difference between both screening tests in predicting cognitive impairment in a specific domain, as determined by formal neuropsychological testing at 3-6 months.</td>
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<tr>
<td>Blackburn et al. 2013&lt;sup&gt;6&lt;/sup&gt;</td>
<td>Acute stroke/TIA</td>
<td>50 pts.</td>
<td>To assess if the MoCA could be used in the acute stroke setting.</td>
<td>MoCA and MMSE within 14 days from the event.</td>
<td>The MoCA could be completed in &lt;10 min in 90% of cases. 70% of pts. were impaired on the MOCA (cut-off 26) versus 30% on the MMSE (cut-off 27) or 12% on the MMSE (cut-off 24). The MoCA picked up substantially more cognitive abnormalities than MMSE, demonstrating deficits in executive function, attention and delayed recall.</td>
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<tr>
<td>Pasi et al. 2013&lt;sup&gt;7&lt;/sup&gt;</td>
<td>Acute stroke</td>
<td>137 pts.</td>
<td>To evaluate the feasibility and applicability of the MoCA in the acute stroke setting and investigate the clinical, functional and neuroimaging factors that could influence its applicability</td>
<td>MoCA, NIHSS and GCS between the 5th and the 9th day from stroke. An interview with the caregiver/informant to evaluate ADL, IADL and IQ-code before the index event.</td>
<td>MoCA administration was feasible and entirely applicable to 82.5% of all stroke pts. Lesion location, stroke severity, and pre-morbid functional status were the major determinants of its applicability. Performances on MoCA were mainly influenced by the level of education, NIHSS scores, and pre-morbid functional status. MoCA administration revealed some degrees of cognitive deficit even in patients with mild stroke.</td>
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<tr>
<td>Shopin et al. 2013&lt;sup&gt;8&lt;/sup&gt;</td>
<td>Acute ischemic stroke/TIA</td>
<td>316 ischemic stroke pts. and 138 TIA pts.</td>
<td>To compare a computerized battery of neuropsychological tests for memory, attention and executive functions with the MoCA in detecting mild-to-moderate PSCI.</td>
<td>Not demented stroke/TIA pts. were tested within 3 days of their first ever ischemic stroke/TIA.</td>
<td>Although there was a high concordance between the two methods, each identified cases not detected by the other. MoCA identified substantially more cognitive abnormalities after both TIA and stroke that the computerized test, demonstrating deficits in executive function, attention and delayed recall.</td>
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<td>Salvadori et al. 2013&lt;sup&gt;9&lt;/sup&gt;</td>
<td>Acute stroke</td>
<td>80 pts.</td>
<td>To investigate the predictive value of MoCA in the acute phase of stroke in the diagnosis of mid-term PSCI, taking into account other predictors.</td>
<td>MoCA, NIHSS, ADL, IADL and IQ-code administered 5–9 days after a stroke. A comprehensive neuropsychological battery administered at 6-9 months follow-up. Optimal cut-off score for MoCA was derived from ROC analysis</td>
<td>MoCA was a good predictor of PSCI (OR 1.4 for each MoCA point lost), independent of other clinical, neurological and functional characteristics. Leukoaraiosis was the only other significant predictor of PSCI (OR 0.4). A cut-off of 21 was found to have good sensitivity, specificity and predictive values for the development of PSCI.</td>
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<tr>
<td>Yang et al. 2013&lt;sup&gt;10&lt;/sup&gt;</td>
<td>Acute lacunar stroke</td>
<td>75 pts.</td>
<td>To identify risk factors for apathy and depression following a stroke</td>
<td>Pts. were tested with MoCA, MMSE, Hamilton Depression scale, Mattis Dementia Rating Scale (initiation/perseveration subset), Frontal Assessment Battery, and Stroop test within 7 days from the event. MCI was defined as MoCA score &lt;25 but &gt;=14.</td>
<td>33.3% of pts. developed apathy and 16% developed depression. Univariate logistic regression model found an association between MoCA and post-stroke apathy, that was lost in the multivariate logistic regression analysis. No association was found between MoCA and depression.</td>
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<tr>
<td>Lees et al. 2013&lt;sup&gt;11&lt;/sup&gt;</td>
<td>Acute stroke</td>
<td>111 pts.</td>
<td>To describe test accuracy of brief screening tools for diagnosis of cognitive impaired and delirium in acute stroke</td>
<td>Patients were tested with a brief neuropsychological battery, MoCA (used as gold standard for diagnosis of cognitive impairment) and Confusion Assessment Method (used as gold standard for diagnosis of delirium) within 4 days after the event.</td>
<td>Using diagnostic thresholds of MoCA ≤26, &lt;24, and &lt;20 gave proportions of patients with cognitive impairments of 86%, 61%, and 49%, respectively. Using the standard MoCA threshold, the 4A Test had favorable properties for delirium screening and reasonable proprieties as cognitive screen. At lower MoCA thresholds, Clock Drawing Test had favorable sensitivity and specificity.</td>
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<tr>
<td>Dong et al. 2013&lt;sup&gt;12&lt;/sup&gt;</td>
<td>Acute ischemic stroke/TIA</td>
<td>400 pts.</td>
<td>To investigate the prognostic value of MoCA and MMSE, individually and in combination with the NIHSS obtained at baseline, for functional outcome 3-6 months later</td>
<td>NIHSS, mRS, MoCA and MMSE within 14 days from the index event and then at the 3-6 months follow-up with mRS</td>
<td>MMSE, MoCA and NIHSS predicted mRS scores at 3-6 months after stroke (NIHSS as the stronger predictor). 4.3% of the functional outcome after 3-6 months can be predicted early after admission by NIHSS. Baseline MMSE and MoCA can add incremental prediction. However, NIHSS in combination with MMSE and MoCA could only predict for 51% of the functional outcome.</td>
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<tr>
<td>Wong et al. 2013&lt;sup&gt;13&lt;/sup&gt;</td>
<td>Subacute aSAH</td>
<td>108 pts.</td>
<td>To examine the correlation between MoCA score at 2-4 weeks and functional outcomes at 1 year after aSAH and to understand the predictive values of early cognitive impairment</td>
<td>MoCA (cut-off 18) was administered 2-4 weeks after aSAH, and functional outcomes were assessed 1 year after stroke.</td>
<td>After adjusting for age, stroke severity, treatment modality, motor score and mobility in the acute phase, PSCI (cut-off MoCA 18) in the subacute phase correlated with mRS and Instrumental Activities of Daily Living scores at 1 year, but both AUCs were below 0.8, indicating that the predictive positive value and diagnostic accuracy remained low for clinical or research applications.</td>
</tr>
<tr>
<td>Wong et al. 2013&lt;sup&gt;14&lt;/sup&gt;</td>
<td>Subacute aSAH</td>
<td>74 pts.</td>
<td>To assess the diagnostic accuracy of MoCA and MMSE scores in detecting PSCI in the subacute and chronic phase of aSAH</td>
<td>MoCA, MMSE and a neuropsychological battery were administered at 2-4 weeks and 1 year after the event. Cut-off points were derived from the ROC analysis.</td>
<td>MoCA and MMSE were able to differentiate between not cognitive impaired and PSCI patients. At 2-4 weeks, both tests had similar AUCs for both cognitive domain deficit and PSCI. At 1 year, the MoCA achieved significantly higher AUCs than the MMSE for PSCI, although not for single domain deficits. Optimal cut-off values for the MoCA was 19 and for MMSE 25 at 2–4 weeks; at 1 year, MoCA 23 and MMSE 25.</td>
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<td>Wong et al. 2009&lt;sup&gt;15&lt;/sup&gt;</td>
<td>Chronic ischemic stroke due to SVD</td>
<td>40 pts. and 40 matched controls</td>
<td>To evaluate the psychometric properties of the Hong Kong MoCA on patients with stroke due to SVD</td>
<td>MoCA and a neuropsychological battery (MMSE included) at 3 months after discharge. The MoCA score was corrected for subjects with &lt;6 years of education.</td>
<td>The ROC analysis for the MoCA revealed an optimal balance of sensitivity and specificity at cut-off 22, with an AUC of 0.81 in differentiating patients from controls. The MoCA demonstrated good concurrent validity as shown by the significant relationships with formal neuropsychological measures, especially in discriminating vascular MCI patients from non-stroke, cognitively-normal controls.</td>
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<td>Pendlebury et al. 2010&lt;sup&gt;16&lt;/sup&gt;</td>
<td>Chronic stroke/TIA</td>
<td>413 pts.</td>
<td>To evaluate the MoCA on a population affected by cerebrovascular disease</td>
<td>MMSE and MoCA were administered to consecutive patients with stroke or TIA at 6-month or 5-year follow-up.</td>
<td>The MoCA (cut-off 26) picked up substantially more cognitive deficits than the MMSE (cut-off 27) in patients with TIA or stroke. 58% of patients with normal MMSE had abnormal MoCA, and these patients were more dependent on the mRS than those with normal MoCA. While the MoCA differentiated well between different levels of cognitive ability, the MMSE had a clear ceiling effect; &gt;50% the patients with MMSE scores &gt;27 were designated as cognitively impaired using the MoCA.</td>
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<td>MacKenzie et al. 2011&lt;sup&gt;17&lt;/sup&gt;</td>
<td>Stroke prevention clinic (mainly chronic stroke and TIA)</td>
<td>20 pts.</td>
<td>To determine a screening process to identify patients at risk of non-adherence and to evaluate and compare the ability of two screening tools to identify MCI in this population</td>
<td>MMSE was administered at study admission followed by a second screening within two weeks using the MoCA.</td>
<td>Although the majority of the participants scored in the normal range on the MMSE (cut-off 26), MoCA (cut-off 26) showed that 55% of this population had a mild to severe cognitive impairment. MoCA scores were lower and had a wider range than the scores obtained at MMSE.</td>
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<td>Cumming et al. 2011&lt;sup&gt;18&lt;/sup&gt;</td>
<td>Chronic stroke</td>
<td>294 pts.</td>
<td>To test the feasibility of administering MoCA at 3 months follow-up.</td>
<td>MoCA was administered at 3 months after the index stroke (ischemic or hemorrhagic)</td>
<td>The administering of MoCA at 3 months post-stroke was feasible. MoCA was completed by 87% with mild stroke, 79% with moderate stroke and 67% with severe stroke on admission. Mean score was 21.1, and 65% were classified as PSCI (cut-off &lt;26); attentional and executive domains were the most often affected.</td>
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<td>Pendlebury et al. 2012&lt;sup&gt;19&lt;/sup&gt;</td>
<td>Chronic stroke/TIA</td>
<td>100 pts.</td>
<td>To determine the sensitivities and specificities of the MoCA, ACE-R, and MMSE at &gt;=1 year after TIA or stroke for detection of MCI</td>
<td>100 patients tested with ACE-R and the NINDS-CSN Harmonization Standards Neuropsychological Battery in addition to the MMSE, MoCA, Barthel, and mRS at 1- or 5-year follow-up.</td>
<td>Both the MoCA (cut-off 25) and the ACE-R (cut-off 94) had good sensitivity and specificity for MCI defined using the modified Petersen's criteria. The pattern of cognitive deficits in this study is characteristic of VCI (slowed processing speed and visuexecutive deficits). Cognitive profiles were qualitatively similar in patients with TIA and stroke, although more abnormalities were seen after stroke, particularly in memory. It was observed a ceiling effect for the MMSE that only cutoffs of &lt;29 or greater had sensitivities for MCI of &gt;70%.</td>
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<td>Schweizer et al. 2012&lt;sup&gt;20&lt;/sup&gt;</td>
<td>Chronic aSAH</td>
<td>32 pts.</td>
<td>To determine how MoCA and MMSE scores relate to cognitive impairment and return to work in a cohort of aSAH survivors.</td>
<td>Neurocognitive assessment was performed at least 6 months after aSAH with MoCA and MMSE.</td>
<td>Compared to the MMSE (cut-off 27), the MoCA (cut-off 26) was more sensitive to PSCI in a cohort of aSAH survivors with good outcome. This has been related to the inclusion of the executive functions and information processing speed subtests of MoCA. Finally, MoCA, unlike MMSE, correlated with neurocognitive test performance, suggesting that it can be used as a proxy for neurocognitive assessment if the latter is not feasible.</td>
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<td>Pendlebury et al. 2012&lt;sup&gt;21&lt;/sup&gt;</td>
<td>Chronic stroke/TIA</td>
<td>207 stroke pts., 156 TIA pts. and 107 memory research subjects</td>
<td>To compare the performance of the MMSE and MoCA in TIA and stroke patients and a memory research cohort of elderly subjects.</td>
<td>All the patients were tested with MoCA and MMSE at least 6 months after the index event (for the stroke/TIA patients). Only those with a MMSE &gt;=24 were included.</td>
<td>Total MMSE and MoCA scores were lower in patients with CVDs versus a memory research cohort, and this was more apparent with the MoCA than the MMSE. In subjects with normal MMSE scores, rates of low MoCA score were higher in patients with CVDs than in the memory clinic cohort. The MoCA demonstrated more differences than the MMSE in cognitive profile between CVDs and memory groups and also between those with TIA versus stroke.</td>
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<td>Cumming et al. 2012&lt;sup&gt;22&lt;/sup&gt;</td>
<td>Chronic stroke</td>
<td>33 pts.</td>
<td>To test whether acute measures of attention (two computerized cognitive tasks) correlated with attentional function at 3 months post-stroke.</td>
<td>Patients completed 2 computerized cognitive tasks (one tests the speed of processing while the other visual attention) within 2 weeks of stroke. MoCA and a neuropsychological battery were administered at 3 months follow-up.</td>
<td>The multivariate analysis showed that the reaction times of acute stroke patients on simple computerized tasks were related to attentional function assessed at 3 months post-stroke. There was a significant relationship between speed of processing task at baseline and MoCA score at 3 months after the stroke.</td>
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<td>Wong et al. 2012&lt;sup&gt;23&lt;/sup&gt;</td>
<td>Chronic aSAH</td>
<td>90 pts.</td>
<td>To investigate the prevalence and risk factors of PSCI defined by the MMSE and MoCA, and how performances in each test correlated with patient’s functional outcome at 3 months.</td>
<td>3 months assessment with MoCA, MMSE, mRS, Instrumental Activities of Daily Living, Geriatric Depression Scale and short form-36</td>
<td>MMSE scores were &lt;27 in 40% of pts., whereas MoCA scores were &lt;26 in 73% of the patients. There were no statistically significant differences between the two ROC curves. The optimal cut-off scores were MoCA 20 and MMSE 25. MoCA correlated with functional outcomes in a similar, but not superior, way to MMSE.</td>
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<td>Tang et al. 2013&lt;sup&gt;24&lt;/sup&gt;</td>
<td>Chronic stroke</td>
<td>47 pts.</td>
<td>To examine the determinants associated with achieving maximal exercise effort on a graded exercise test (GXT) among individuals with stroke</td>
<td>NIHSS, MoCA, Chedoke-McMaster Stroke Assessment (CMSA) and two tests for walking ability were used together with the GXT. Patients were dichotomized in 2 groups using the age-predicted maximal heart rate.</td>
<td>The multiregression analysis revealed that CMSA lower limb impairment (OR 2.3) and MoCA (OR 1.3) were significant contributors to the participants' ability to achieve age-related maximal heart rate. Age and NIHSS score remained in the model, but were not significant independent contributors.</td>
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<td>Marzolini et al. 2012</td>
<td>Chronic stroke</td>
<td>41 stroke pts.</td>
<td>To evaluate the effects of a 6-month exercise program of aerobic and resistance training on cognition in patients with motor impairments ≥10 weeks post-stroke</td>
<td>Outcome measures were conducted at baseline and following 6 months of exercise training (90min exercise class once a week) in the same order: CES-Depression scale, MoCA and duel-energy X-ray absorptiometry (DXA) scan.</td>
<td>In patients with residual motor impairment post-stroke, a 6-month combined aerobic and resistance training exercise program resulted in significantly improved MoCA scores and a 44.5% reduction in the proportion of patients meeting threshold criteria for MCI (MoCA cut-off &lt;25). Improvement was characterized by gains in the subdomains of attention/concentration and visuospatial/executive functioning. The cognitive improvement was independently associated with fat-free mass accretion of no affected limbs.</td>
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<td>Hwang et al. 2012</td>
<td>Chronic stroke</td>
<td>47 pts. (25 fallers; 22 not fallers)</td>
<td>To identify the effects of falls experience on cognitive function, postural control, and gait performance in patients with chronic hemiparetic stroke and to evaluate the feasibility of using the MoCA to predict falls in stroke patients.</td>
<td>MoCA, the Berg Balance Scale (BBS), the Dynamic Gait Index (DGI), the Timed Up-and-Go (TUG) Test, the 10 Meter Walk Test (10MWT), and the 6 Minute Walk Test (6MWT) were administered at 25 patients with falls experience (fallers group) and 22 patients without falls experience (non-fallers group) in the previous 6 months.</td>
<td>MoCA was significantly correlated with the 6MWT, BBS, DGI, and the TUG test in the fallers group. In the no faller group, MoCA was significantly correlated with the 10MWT and DGI. This study also showed the feasibility of using the MoCA for predicting the risk of falls in community-dwelling stroke patients.</td>
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<td>Pendlebury et al. 2013²⁷</td>
<td>Chronic stroke/TIA</td>
<td>73 pts.</td>
<td>To compared the telephone MoCA (T-MoCA) and the modified Telephone Interview of Cognitive Status (TICSm) with MoCA and the NINDS-CSN VCI neuropsychological battery in patients with TIA or stroke.</td>
<td>Patients were tested at 1-or 5-year follow-up with MoCA and the NINDS-CSN VCI Harmonization Standards Neuropsychological Battery. At least 1 month after neuropsychological testing, they were tested with T-MoCA (22 points) and TICSm presented in counterbalanced order. The T-MoCA-Short (verbal fluency, recall, and orientation; total 12 points), recommended by NINDS-CSN VCI group, was also considered.</td>
<td>The T-MoCA and the TICSm had similar AUC curves and reasonable sensitivity and specificity for MCI, although the T-MoCA-Short performed less well and face-to-face MoCA was better. Performance was better and more similar for all tests in detecting multiple-domain impairment.</td>
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<td>Mai et al. 2013²⁸</td>
<td>Stroke prevention clinic (almost 50% chronic stroke and TIA)</td>
<td>102 pts.</td>
<td>To evaluate the use of MoCA as screening tool for cognitive impairment in a outpatients clinic</td>
<td>Consecutive patients (Stroke/TIA, chronic subcortical white matter disease, epilepsy, migraine and other) were tested with MoCA and white matter change scales (on CT or MRI scan)</td>
<td>63.7% of patients demonstrates cognitive impairment using MoCA cut-off 26. No correlation between age and MoCA or age and white matter changes or MoCA and white matter changes. The high probability of identify cognitive impairment argues for a brief test screening. The mini-MoCA (clock drawing, delayed recall and abstraction) with a cut-off of 7/10 correlates well with MoCA (cut-off 26), better than brief-5-MoCA of NINDS-CSN, but remains to be validated versus proper neuropsychological testing.</td>
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<td>Cumming et al. 2013</td>
<td>Chronic stroke</td>
<td>60 pts.</td>
<td>To compare performance on MoCA and MMSE with a diagnosis of PSCI derived from a neuropsychological battery.</td>
<td>Patients were tested at 3 months post-stroke follow-up with MoCA and MMSE and then re-tested 1 week later with a comprehensive neuropsychological battery. Patients were divided into 3 groups of severity. Cut-off of both tests were found with AUC of ROC</td>
<td>Using criterion standard of &gt;1 SD in 2 or more domains, MoCA (optimal cut-off 27) exhibited acceptable validity and better AUC than MMSE (optimal cut-off 24) in identifying PSCI, with a good sensitivity even at the mild end of the PSCI spectrum (no ceiling effect). Using &gt;1.5 SD and then &gt;2 SD to detect only more severely cognitively impaired patients, MoCA superiority in sensitivity was lost. MoCA had greater predictive validity for patients with right hemisphere stroke compared with left hemisphere stroke.</td>
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<td>Volonghi et al. 2013</td>
<td>Chronic stroke/TIA</td>
<td>182 TIA, pts., 216 stroke pts. and 216 acute coronary syndrome pts.</td>
<td>To compare cognitive outcome including cognitive domain profile &gt;1 year after Acute Coronary Syndrome (ACS) versus TIA and minor stroke.</td>
<td>Patients with either ACS or TIA or minor stroke (either ischemic and intracerebral hemorrhage) were tested at 1 year with MMSE and TICSm (telephone interview for cognitive status-modified) and at 5 year follow-up with MMSE (cut-off 24) and MoCA (cut-off 26).</td>
<td>ACS outcomes were comparable to minor stroke and were worse than that after TIA. The cognitive profile of ACS was more similar to that of memory clinic patients. There was a lack of significantly different performance between ACS and TIA/stroke patients on the recall (and repetition) subtest of MoCA, probably because this task is more difficult in MoCA than in MMSE, resulting in floor effect and inability to differentiate between subjects with more impaired recall.</td>
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<td>Bocchi et al. 2013</td>
<td>Chronic ischemic stroke/TIA</td>
<td>386 pts.</td>
<td>To test if MoCA at 3 months is associated with functional outcome (mRS) in addition to the 3 months MMSE, baseline NIHSS and other clinical factors.</td>
<td>MoCA (cut-off 26) and MMSE (cut-off 26) were administered to minor stroke (NIHSS&lt;4) or TIA patients at their 3-month follow-up. Favorable outcome was mRS 0-1. Individual subtest of MoCA were converted using z-score to find the 5 most useful subtest to achieve a short-MoCA.</td>
<td>MoCA detected PSCI in 55% of patients, MMSE did it in 13%. In a multivariate analysis, MoCA &lt;26 was associated with the outcome (OR 3.00), as were remote lacunar stroke and white matter changes of at least moderate severity. Five subtest (5-word recall, word list generation, trail making test, abstract reasoning, and cube copy) formed an optimal short-MoCA with 7/10 or less as good cut-off for VCI.</td>
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<td>Pendlebury et al. 2013&lt;sup&gt;32&lt;/sup&gt;</td>
<td>Chronic stroke/TIA</td>
<td>91 pts.</td>
<td>To determine the effect of differential operational definitions within the Petersen-MCI criteria on rates of MCI and reliability of short tests &gt;=1 year after TIA/Stroke.</td>
<td>MoCA, MMSE and neuropsychological battery were administered at least 1 year after the event. MCI was defined using the Petersen's criteria and subclassified as single or multiple domain, both with original and modified criteria. Different cut-off (&gt;1, &gt;1.5 and &gt;2 SD) on a given test below published norms were compared together with use of single versus multiple test to define domain impairment.</td>
<td>Rates of cognitive impairment ranged from 15% for MCI-original at &gt;2 SD cut-off to 67% MCI-modified at &gt;1 SD cut-off, and the proportion of MCI that was multiple domain varied from 52% versus 20% at 1 versus 2 SD cut-off for MCI-modified. Requirement for subjective memory complaint approximately halved estimates. Diagnostic accuracy was higher, and optimal cut-offs lower, on MMSE and MoCA for multiple-domain versus single-domain MCI, but the MoCA appeared superior for detecting MCI-modified, whereas the MMSE performed well in detecting MCI-original. The use of MCI-modified and MoCA rather than the MMSE appeared more appropriate for studies of VCI. Differences in operational methodology result in 4-fold variation in MCI estimates. Optimal MMSE (from &lt;30 to &lt;26) and MoCA (from &lt;27 to &lt;23) cut-offs were lower, and reliability more similar, when criteria for MCI were more stringent.</td>
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<td>Wu et al. 2013&lt;sup&gt;33&lt;/sup&gt;</td>
<td>Chronic ischemic CVDs</td>
<td>111 not cognitively impaired pts. and 95 VCIND pts.</td>
<td>To assess the effect of education level on MoCA screening for VCIND after ischemic stroke.</td>
<td>Ischemic CVD patients were divided into 2 groups (not cognitively impaired or VCIND) and tested with MoCA. Every group was then divided in three educational levels. 1 point was added if education was &lt;12 years</td>
<td>MoCA was an effective screening tool for evaluating early cognitive impairment in VCIND patients. However, the MoCA naming factor did not differentiate between VCIND and in all three educational groups. In the other groups, other subtests could differentiate between VCIND and not cognitively impaired. This suggested that an increase in the educational level reduced the effectiveness of MoCA screening for some factors. The optimal cut-off value was 23, with a low sensitivity and specificity compared with other studies (65% and 79%), probably due to the different educational levels.</td>
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<td>Tu et al. 2013</td>
<td>Chronic Ischemic CVDs</td>
<td>338 ischemic CVDs pts. and 132 controls</td>
<td>To assess the reliability and validity of the Chinese-MoCA in ischemic CVD patients and explore the optimal cut-off scores for detecting VCIND and VD</td>
<td>Patients underwent a high number of cognitive tests (MoCA and MMSE included) to assess if they were cognitively normal; those who did not pass this phase, were tested with a comprehensive neuropsychological battery. Optimal cut-off scores were explored based on ROC analysis.</td>
<td>MoCA had a good reliability and validity (high correlation with MMSE). 1 point should be added for subjects with &lt;6 years of education. Optimal cut-off scores are 27 (NCI vs. VCI) and 117 (NCI+VCIND vs. VD).</td>
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MoCA = Montreal Cognitive Assessment  
MMSE = Mini-Mental State Examination  
aSAH = aneurysmal SubarAchnoid Hemorrhage  
NIHSS = National Institutes of Health Stroke Scale  
mRS = modified Rankin Scale  
VCI = Vascular Cognitive Impairment  
VCIND = Vascular Cognitive Impairment, No Dementia  
GCS = Glasgow Coma Scale  
PSCI = Post-stroke Cognitive Impairment  
AUC = Area Under the Curve  
ROC = Receiver Operating Characteristic  
pts. = patients  
CVD = CerebroVascular Disease  
ACE-R: Addenbrooke’s Cognitive Examination-Revised
References:


