Is the Montreal Cognitive Assessment Superior to the Mini-Mental State Examination to Detect Poststroke Cognitive Impairment? A Study With Neuropsychological Evaluation

Olivier Godefroy, MD, PhD; Andreas Fickl, MD; Martine Roussel, PhD; Caroline Auribault; Jean Marc Bugnicourt, MD; Chantal Lamy, MD; Sandrine Canaple, MD; Gil Petitnicolas, MD

Background and Purpose—A screening test is required to improve the diagnosis of poststroke cognitive impairment. The Montreal Cognitive Assessment (MoCA), a newly designed screening test, has been found to be more sensitive than Mini-Mental State Examination (MMSE), but its clinical value has not been established by means of a comprehensive neuropsychological battery. This study was designed to assess the value of MoCA and MMSE to detect poststroke cognitive impairment determined by a neuropsychological battery.

Methods—Both screening tests and a neuropsychological battery were administered during the acute phase in 95 patients referred for recent infarct or hemorrhage. Raw MMSE and MoCA scores were used with published cutoffs and new cutoff scores for MMSE and MoCA were also computed after adjustment for age and education.

Results—Using raw scores, MoCA was more frequently impaired ($P=0.0001$) than MMSE. MoCA showed good sensitivity (sensitivity, 0.94) but moderate specificity (specificity, 0.42; positive predictive value, 0.77; negative predictive value, 0.76), whereas an inverse profile was observed for MMSE (sensitivity, 0.66; specificity, 0.97; positive predictive value, 0.98; negative predictive value, 0.58). Adjusted scores with new cutoffs (MMSE$_{adj} \leq 24$, MoCA$_{adj} \leq 20$) provided good sensitivity and very good specificity for both tests (MMSE$_{adj}$: sensitivity, 0.7, specificity, 0.97, positive predictive value, 0.98, negative predictive value, 0.61; MoCA$_{adj}$: sensitivity, 0.67, specificity, 0.9, positive predictive value, 0.93, negative predictive value, 0.57). On receiver operating characteristic curve analysis, areas under the curve of all scores were >0.88.

Conclusions—The previously reported high sensitivity of MoCA is associated with low specificity. Both screening tests are moderately sensitive to acute poststroke cognitive impairment. This study provides indications for the diagnosis of poststroke cognitive impairment. (Stroke. 2011;42:1712-1716.)

Key Words: Alzheimer disease ▪ dementia ▪ higher nervous activity ▪ psychomotor performance ▪ stroke ▪ vascular

Poststroke cognitive impairment is frequent, carries a poor prognosis, and remains underdiagnosed. It is observed in 40% to 70% of patients and the severity of this impairment meets the criteria of dementia in half of cases.$^{1,2}$ A screening test is therefore required to improve the diagnosis of poststroke cognitive impairment. The widely used Mini-Mental State Examination (MMSE)$^3$ has a low sensitivity for vascular cognitive impairment.$^{4-6}$ The National Institute of Neurological Disorders and Stroke–Canadian Stroke Network harmonization standard has proposed the use of the Montreal Cognitive Assessment (MoCA).$^7$ This newly designed screening test incorporates subtests assessing executive functions and psychomotor speed$^8$ that are frequently impaired in vascular cognitive impairment.$^{1,2}$ Two recent studies have shown that MoCA is more sensitive than MMSE to detect poststroke cognitive impairment.$^9,10$ This result was expected in view of the poor sensitivity of the MMSE. However, no study has compared the value of these screening tests with the gold standard, that is, a comprehensive neuropsychological battery.

The objective of this study was to assess the discriminant validity of the MoCA and MMSE to detect poststroke cognitive impairment determined by a neuropsychological battery.

Patients

All patients referred to the Acute Stroke Unit of Soissons Hospital and Amiens University Hospital for a recent (<3 months, 95)
weeks) stroke (cerebral infarct or hemorrhage) between November 2008 and March 2009 were considered. The exclusion criteria were severe general and neurological (National Institutes of Health Stroke Scale 1a >1; National Institutes of Health Stroke Scale 1b >1; National Institutes of Health Stroke Scale 9 >2) conditions precluding neuropsychological testing, illiteracy, mental retardation, mother tongue other than French, schizophrenia and psychosis, previous severe traumatic brain injury, and absence of informed consent. Associated neurological diseases, previous stroke, and general conditions (alcoholism, severe cardiac, renal, respiratory and hepatic failure) that may interfere with cognition were recorded but were not exclusion criteria.

Ninety-five patients were included (infarct: n = 88; hemorrhage: n = 7). Patient characteristics, assessed by a previously reported method,11 corresponded to those usually observed in a stroke unit except for the relatively young age and the mild severity of the neurological deficit and disability (Table 1). According to Trial of ORG 10172 in Acute Stroke Treatment (TOAST) criteria,12 65 infarcts (middle cerebral artery territory: n = 65; posterior cerebral artery territory: n = 4; anterior cerebral artery territory: n = 1; posterior fossa: n = 18) were due to atherosclerosis in 18 cases, cardioembolism in 18 cases, small vessel disease in 11 cases, cerebral artery dissection in 5 cases, and multiple or undetermined causes in 36 cases. Hemorrhages (lobar: n = 3; deep: n = 4) were due to hypertension (n = 3), amyloid angiopathy (n = 1), cavernoma (n = 1), and undetermined cause (n = 2). Screening of prestroke dementia used 4 items of the Instrumental Activities of Daily Living scale (ability to use the telephone, independence for transportation, self-administration of medication, ability to handle finances) and cutoff scores validated in the Personnes Agees QUID (PAQUID) study.13 An impairment of prestroke autonomy highly suggestive of dementia was observed in 15 (15.7%) patients. Among them, dementia (Alzheimer disease: n = 3; vascular dementia: n = 2) was previously diagnosed in 5 patients only.

All patients were assessed by MMSE and MoCA. Comprehensive neuropsychological assessment was performed in patients with MMSE score ≥ 23 out of 30, because a lower score was always associated with cognitive impairment in previous studies14,15 and in the present study (the neuropsychological battery performed in the first 15 patients with MMSE <23 was impaired in every case).

Methods

MoCA and MMSE were performed in a counterbalanced order (49 of 95 patients were assessed using the MMSE first) with a mean poststroke interval of 6.6 ± 3.5 days. The comprehensive neuropsychological battery was performed with a mean poststroke interval of 24.1 ± 6.4 days. It assessed depression,16 anxiety,17 general intellectual efficiency (Mattis Dementia Rating Scale18), and 5 cognitive domains: (1) language using the Shortened Token test19 and Confrontation naming20; (2) visuospatial abilities using the Albert cancellation test21 and copy of Complex Figure2; (3) working (forward and backward digit span22) and long-term memory using a French adaptation of the Grober and Buschke procedure24 previously validated in patients with stroke25; (4) action speed26 using the Digit Symbol substitution subtest23 and time to complete the part A of Trail Making test27 and time to complete the naming subtest of the Stroop test26; and (5) executive functions using a French adaptation29 of the Trail Making test, categorical (animals) and literal (letter “P”) verbal fluencies, and Stroop test. The impairment of a domain was defined by the deficit of at least 1 test except for action speed (≥ 2 impaired performances on Part A of the Trail Making test, naming

| Table 1. Population Characteristics According to the Presence of Cognitive Impairment |
|-----------------|-----------------|-----------------|-----------------|
| Age             | Overall         | No Cognitive Impairment | Cognitive Impairment | P    |
| Years           | 68.2 ± 13.7     | 71.5 ± 13         | 61.5 ± 14         | 0.001|
| Sex             | Male/female     | 60/35            | 23/8             | 21/13 | 0.2  |
| Education level | Primary/secondary/high school | 55/24/16     | 12/14/5          | 21/8/8 | 0.12 |
| Hypertension    | Present: no. (%) | 60 (63%)         | 19 (61%)         | 41 (64%) | 0.9  |
| Diabetes mellitus | Present: no. (%) | 16 (17%)         | 3 (10%)          | 13 (20%) | 0.3  |
| Hypercholesterolemia | Present: no. (%) | 36 (38%)         | 9 (29%)          | 27 (42%) | 0.3  |
| Atrial fibrillation | Present: no. (%) | 9 (9.5%)          | 1 (3.2%)         | 8 (12.5) | 0.3  |
| Previous coronary event | Present: no. (%) | 12 (13%)          | 5 (16%)          | 7 (11%)  | 0.7  |
| Tobacco consumption | Present: no. (%) | 42 (44%)          | 17 (55%)         | 25 (39%) | 0.2  |
| Alcohol consumption | Present: no. (%) | 13 (14%)          | 3 (10%)          | 10 (15.6%) | 0.6  |
| Previous stroke | Infarct/transient ischemic attack | 7/2            | 1/1              | 6/1     | 0.5  |
| Stroke type     | Infarct/hemorrhage | 88/7             | 30/1             | 58/6    | 0.5  |
| Stroke side     | Left/right/bilateral | 39/44/12         | 10/13/8          | 29*/31/4 | 0.03 |
| NIHSS Admission |                   | 4.7 ± 5          | 2.2 ± 2.9        | 5.9 ± 5.3  | 0.0001 |
| NIHSS Inclusion |                   | 2.7 ± 3.2        | 1.6 ± 2.4        | 3.3 ± 3.4  | 0.02  |
| NIHSS Barthel Index (100) | 79.2 ± 25.1       | 87.1 ± 20        | 75.3 ± 27        | 0.02  |
| Modified Rankin Scale | 0/1/2/3/4–5 | 23/27/16/8/21 | 13/9/5/1/3 | 0/0/39/7/18 | 0.0001 |
| MMSE            | (30)            | 22.5 ± 6.5       | 27.7 ± 1.8       | 20.1 ± 6.5  | 0.0001 |
| MoCA            | (30)            | 18.7 ± 7         | 24.6 ± 2.9       | 15.9 ± 6.6  | 0.0001 |
| Goldberg scale  | 2.2 ± 2.5       | 1.9 ± 2.4        | 2.5 ± 2.5        | 0.3      |
| MADRS           | 5.6 ± 4.9       | 3.7 ± 3.4        | 7.1 ± 5.5        | 0.003   |

NIHSS indicates National Institutes of Health Stroke score; MMSE, Mini-Mental State Examination; MoCA, Montreal Cognitive Assessment; MADRS, Montgomery and Asberg Depression Rating Scale.

The methods of cognitive impairment are defined by the deficit of at least 1 test 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 Trail Making test Part B, categorial and literal verbal fluencies, strategic memory process on the Grober-Buschke test). A significant deficit on the battery was defined by the impairment of at least 2 cognitive domains, a criterion that corresponded to the 5% level. Patients were categorized as cognitively impaired when MMSE score was <23 or when the comprehensive battery was impaired.

Statistics
Cognitive impairment on the MMSE and MoCA was first determined using raw scores and published cutoff scores. Because published cutoff scores may be suboptimal in patients with stroke, additional analyses were performed to refine cutoff scores for both tests. Receiver operator characteristic and areas under the curve (95% CI) were generated to examine the ability of the MMSE and MoCA to discriminate between impaired versus normal cognitive status. The area under the curve, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated. Optimal cutoff points were determined using the maximum value of the Youden index (calculated by sensitivity + specificity − 1). Primary analysis used raw scores of MMSE (MMSEraw) and MoCA (MoCAraw). To control for the effect of confounding factors (age and education) on raw scores, secondary analysis used scores of MMSE (MMSEadj) and MoCA (MoCAadj) adjusted for age and education. The effect of age and education on MMSE and MoCA scores was determined in a separate control group (n = 72; age, 62.4 ± 13.6 years; sex, 21 male/51 female; education level: primary school: n = 27; secondary school: n = 29; high school: n = 16) using linear regression analyses (dependent variables: MMSE and MoCA tests; independent variables: age and education level). New cutoff scores were determined at the 5% level in controls according to a previously reported method.15 Raw scores of patients were adjusted for age and education (MMSEadj, MoCAadj) using coefficients of linear regression.

Finally, a stepwise logistic regression analysis was used to determine which of the impaired screening tests (MMSEraw, MoCAraw, MMSEadj, MoCAadj) predicted the impaired cognitive status (dependent variable: MMSE and MoCA tests; independent variable: age and education level). Analyses were performed using SPSS and probability values <0.05 were considered significant.

Results
The MMSE score was <23 in 40 patients. In patients with MMSE score ≥23, the comprehensive battery was impaired in 24 (44%). The deficit concerned predominantly executive functions (46%) and long-term memory (26%); language: 17.9%; visuoconstructive abilities: 26.5%; action speed: 8.8%). Thus, including the 40 patients with MMSE <23, 64 of 95 (67%) patients were categorized as cognitively impaired. Mild depression was observed in 35% of patients. The presence of cognitive impairment (Table 1) was associated with age, more severe neurological deficit, higher depression scores, left-sided stroke, and poor outcome. All patients with impairment of prestroke autonomy (n = 15; P = 0.01) and previous dementia (n = 5; P = 0.1) were found to have cognitive impairment.

Analysis Using Published Norms
The MMSEraw was impaired (43 of 95 [45%]) less frequently (Sign test: P = 0.0001) than the MoCAraw (78 of 95 [82%]). All patients with impaired MMSEraw also had impaired MoCAraw. The MMSE was moderately sensitive (sensitivity, 0.66) to cognitive impairment but had a very good specificity (specificity, 0.97; PPV, 0.98; NPV, 0.58). An inverse profile was observed for the MoCA with a good sensitivity (sensi-

| Table 2. Adjusted Scores of Mini-Mental State Examination and Montreal Cognitive Assessment* |
|----------------------------------|------------------|------------------|
| **Mini-Mental State Examination** | **Montreal Cognitive Assessment** |
| Age                              |                  |
| ≥45 y                            | ...              | −1               |
| 46–74 y                          | ...              | +0               |
| ≥75 y                            | ...              | +1               |
| Education level†                 |                  |
| Primary school                   | +1               | +1               |
| Secondary school                 | +0               | +0               |
| High school                      | −1               | −1               |
| Cutoff score                     | ≤24              | ≤20              |

MMSE indicates Mini-Mental State Examination; MoCA, Montreal Cognitive Assessment.
*For example, adjusted scores of MMSE (MMSEraw: 25) and MoCA (MoCAraw: 20) is the following for a 75-y-old patient with a high school education: MMSEadj: 25 − 1 = 24; MoCAadj: 20 + 1 − 1 = 20 (both correspond to impaired performance).
†Primary school corresponds to <9 y of school, secondary school, to 9 to 11 y of school, and high school, to 12 y or more with high school diploma (baccalauréate).
	diagnosis. Receiver Operator Characteristic Curve Analysis
The areas under the curve of all scores were >0.88 (MMSEraw: 0.884; 95% CI, 0.819 to 0.948; MoCAraw: 0.887; 95% CI, 0.832 to 0.956; MMSEadj: 0.883; 95% CI, 0.818 to 0.949; MoCAadj: 0.894; 95% CI, 0.832 to 0.956) suggesting that both tests had good ability to discriminate between impaired and nonimpaired cognitive status. The sensitivity, specificity, PPV, and NPV of raw and adjusted scores of MMSE and MoCA for detection of cognitive impairment are provided in Table 3. Cutoff points determined using the Youden index (Table 3) provided suboptimal sensitivity (<0.8) for all screening tests (MMSEraw, MoCAraw, MMSEadj, MoCAadj) for diagnostic purposes. Cutoffs yielding a sensitivity ≥0.98 were the following: MMSEraw ≥29, MoCAraw ≥27, MMSEadj ≥29, and MoCAadj ≥26.

Finally, stepwise logistic regression selected impairment on MMSEadj to predict cognitive impairment on neuropsychological battery (OR, 71; 95% CL, 5.5 to 558; P = 0.0001). Because these results might have been influenced by the frequency of prestroke dementia, all analyses were repeated...
Discussion

This study performed in patients with acute stroke supports the high sensitivity of MoCA but reveals its low specificity compared with the gold standard, a comprehensive neuropsychological battery. Using published cutoff scores, the frequency of impaired MoCA (82%) was similar to that observed in previous studies at 6 months poststroke (84%9 and 70%10). The areas under the curve of both MoCA and MMSE were very similar suggesting that both tests have a similar ability to detect poststroke cognitive impairment. The good sensitivity of the MoCA observed in the present and previous studies9,10 is therefore mainly due to the choice of cutoff scores, favoring sensitivity at the cost of specificity. Determination of cutoff scores will be improved by refinement of MoCA norms, which is therefore mandatory.

One limitation of the study concerned the recommended cutoff scores of the MoCA, which has to be refined in a large sample representative of the general population. This was addressed by the determination of adjusted scores according to age and education. Cutoff scores were refined by controlling for the effect of confounding factors (age and education) on raw scores. These new cutoff scores improved the sensitivity of MMSE (at the cost of specificity) and the specificity of MoCA (at the cost of sensitivity). The impairment on MMSE determined using new cutoff scores was the best predictor of cognitive impairment. Thus, the main finding of this study is that MoCA is not more sensitive than MMSE for screening of cognitive deficit provided adjusted cutoff scores are used. This result was unexpected, because MoCA incorporates more subtests sensitive to executive functions and psychomotor speed, which are frequently impaired in patients with stroke. This could be due to the high frequency of instrumental deficits (ie, language and visuoconstructive domains) at the acute stage, because MMSE is more sensitive to instrumental deficits. The MoCA may therefore be more sensitive for screening of vascular cognitive impairment in patients examined after the acute stage of stroke. However, a recent study in patients with Parkinson disease showed...
similar results.\textsuperscript{31} Both screening tests were found to have similar discriminant validity and the main limitation of the MMSE was the presence of a ceiling effect.

This study was performed in 95 patients representative of the population of stroke units. For that purpose, the study enrolled patients from both university and general hospitals. In the same vein, both cerebral infarct and hemorrhage were evaluated and we did not exclude patients with associated neurological diseases, including dementia. In addition, the contribution of prestroke dementia was ruled out by additional analyses performed after exclusion of these patients (see online supplement). We assessed prestroke dementia using 4 items of the Instrumental Activities of Daily Living scale and cutoff scores validated in the PAQUID study.\textsuperscript{13} It provided a frequency of prestroke dementia close to our previous study using the Informant Questionnaire on Cognitive Decline in the Elderly.\textsuperscript{32} The only difference concerned the decreasing proportion of undiagnosed dementia.

This study provides indications regarding the diagnosis of poststroke cognitive impairment in routine practice. First, a raw MMSE score <23 in literate patients <80 years indicates cognitive impairment. Thus, a comprehensive battery is not mandatory for the diagnosis of cognitive impairment, although it may be useful for the characterization of cognitive pattern. Second, for screening purposes, the objective is to avoid false-negative results (ie, patients with true cognitive deficit but normal screening test); a comprehensive battery may be performed in patients with MMSE\textsubscript{adj} ≤29 or when the MoCA is used in patients with MoCA\textsubscript{adj} ≤26. Under these conditions, a comprehensive battery would be performed in half of patients with stroke and would be impaired in half of these patients.

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Disclosures

None.

References


22. Rey A. \textit{Test de Copie d’une Figure Complexe}. Paris: Éditions du centre de psychologie appliquée; 1959.


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SUPPLEMENTAL MATERIAL

Additional analyses in the 80 patients without prestroke impairment of autonomy

*Analysis using published norms* The MMSE_{raw} was impaired (28/80) less frequently (Sign test: p=0.0001) than the MoCA_{raw} (63/80). All patients with impaired MMSE_{raw} also had impaired MoCA_{raw}. The MMSE was moderately sensitive (sensitivity: 0.55) to cognitive impairment but had a very good specificity (specificity: 0.97; PPV: 0.96; NPV: 0.58). An inverse profile was observed for the MoCA with a good sensitivity (sensitivity: 0.92) and moderate specificity (specificity: 0.42; PPV: 0.71; NPV: 0.76).

*Analysis using adjusted scores* Adjusted scores using the cutoffs determined in controls provided very different results: MMSE_{adj} (31/80) was impaired with the same frequency as MoCA_{adj} (31/80), although in different patients: 5 had impairment of MMSE_{adj}, 5 had impairment of MoCA_{adj} and 26 had a combined deficit on both tests. The sensitivity and specificity of the two tests were very similar (MMSE_{adj}: sensitivity=0.61, specificity=0.97, PPV=0.97, NPV=0.61; MoCA_{adj}: sensitivity=0.57, specificity=0.9, PPV=0.9, NPV=0.57).

*ROC curve analysis* The AUC of all scores were >0.85 (MMSE_{raw}: 0.884; 95CI: 0.77-0.93; MoCA_{raw}: 0.853; 95CI: 0.77-0.93; MMSE_{adj}: 0.848; 95CI: 0.77-0.93; MoCA_{adj}: 0.862; 95CI: 0.78-0.94).

Finally stepwise logistic regression selected impairment on MMSE_{adj} to predict cognitive impairment on neuropsychological battery (OR=47, 95CI=6-377; p=0.0001).