Multicenter Validation of an MMSE-MoCA Conversion Table

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BACKGROUND: Accumulating evidence points to the superiority of the MoCA over the MMSE as a cognitive screening tool. To facilitate the transition from the MMSE to the MoCA in clinical and research settings, authors have developed MMSE-MoCA conversion tables. However, it is unknown whether a conversion table generated from Alzheimer's disease (AD) patients would apply to patients with other dementia subtypes like vascular dementia or frontotemporal dementia. Furthermore, the reliability and accuracy of MMSE-MoCA conversion tables has not been properly evaluated.

METHOD: We retrospectively examined the MMSE-MoCA relationship in a large multicenter sample gathered from 3 Memory Clinics in Quebec, Canada (1492 patients). We produced an MMSE-MoCA conversion table using the equi-percentile method with log-linear smoothing. We then cross-validated our conversion table with the ADNI dataset (1202 patients) and evaluated its accuracy for future predictions.

RESULTS: The MMSE-MoCA conversion table is consistent with previously published tables and has an intra-class correlation of 0.633 with the ADNI sample. However, we found that the MMSE-MoCA relationship is significantly modified by diagnosis ($P < .01$), with dementia subtypes associated with a dysexecutive syndrome showing a trend towards higher MMSE than other dementia syndromes for a given MoCA score. The large width of 95% confidence interval (CI) for a new prediction suggests questionable reliability for clinical use.

CONCLUSION: In this study, we validated a conversion table between MMSE and MoCA using a large multicenter sample. Our results suggest caution in interpreting the tables in heterogeneous clinical populations, as the MMSE-MoCA relationship may be different across dementia subtypes. **J Am Geriatr Soc 65:1067–1072, 2017.**

Key words: Cognitive screening; MMSE; MoCA; Conversion

On the verge of an Alzheimer's disease (AD) epidemic,[1] it is becoming increasingly important to develop and validate cost-effective tools to improve dementia screening in the aging population. Even with the emergence of sophisticated imaging technologies and biomarkers, brief cognitive screening tests remain a core component of dementia diagnosis, as they are quick and useful tools to assess overall cognition. The Mini-Mental State Examination (MMSE)[2] is currently the most widely applied test for dementia screening, being validated by over 100 studies.[3] However, the MMSE has a very poor sensitivity for the early stages of AD—especially in young or highly educated patients—missing up to 50% of AD diagnoses.[3–5] The MMSE was in fact initially designed to assess psychiatric disorders and not AD in the ambulatory setting. Moreover, the MMSE is under copyright restrictions and is no longer freely available, potentially limiting its routine use in clinical and research settings.[6,7] As a result, the Montreal Cognitive Assessment (MoCA)[8] is increasingly used in the dementia field. The MoCA was specifically designed to improve the diagnosis of AD at the mild cognitive impairment (MCI) stage, and hence has better sensitivity in this population.[8–13]

Transiting from the MMSE to the MoCA is, however, complicated by the fact that the MMSE has established itself over the years as a standard measure of cognition, both in research and in the clinic. Since the MoCA is

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globally a more difficult test, scores have never been regarded as being equivalent. A reliable conversion algorithm between both screening tests to ensure continuity in various settings would facilitate smooth transition from MMSE to MoCA. Previous authors have attempted to provide an MMSE-MoCA conversion table over the last years.[10,14–18] These studies were however generally small-sampled—especially in the lower MoCA scores—and did not appropriately reflect the clinical heterogeneity encountered in memory clinics. Moreover, none assessed whether MMSE-MoCA associations was different according to dementia subtype. One cannot assume that the conversion table will be a one-size-fits-all; indeed, cognitive domains are differently weighted in MMSE and MoCA scores, and the relation may differ between predominantly dysexecutive syndromes (e.g., vascular dementia) vs. predominantly amnestic syndromes (e.g., AD). Furthermore, as clinicians, if we are to use a conversion table to predict an MMSE score based on a MoCA score, the main question that has to be answered is: how likely will my prediction be wrong?

Therefore, the current study attempted to validate an MMSE-MoCA conversion table in a large multicenter cohort encompassing a wide variety of dementia subtypes. We also cross-validated our results with data from the Alzheimer's Disease Neuroimaging Initiative (ADNI), a multicenter observational study whose data is publicly available to the scientific community.

METHODS

Patient Selection

In the Province of Quebec (Canada), cholinesterase inhibitors reimbursement by health authorities requires an MMSE score between 10 and 26. Since clinicians prefer to use the MoCA for diagnostic purposes, most patients end up undergoing both tests during clinical evaluation. We retrospectively reviewed all cases seen at our academic memory clinic where both MMSE and MoCA were performed on the same day. We contacted our colleagues from other academic memory clinics in Quebec (CB, TF, GL in Sherbrooke; SG and ZN in Montreal) to gather additional cases. We included 1492 patients who had undergone MMSE and MoCA on the same day. Since participating clinics were all tertiary-care academic memory clinics, our sample encompassed a wide range of cognitive disorders, including AD, MCI, vascular dementia, frontotemporal dementia (FTD), primary progressive aphasia, Parkinson's disease dementia, corticobasal syndrome, progressive supranuclear palsy, a wide range of psychiatric disorders, and subjective memory complaints (See Table 1 for patients' characteristics). Following state-of-the-art diagnostic criteria, all diagnoses were made by dementia experts (behavioural neurologists, geriatric psychiatrists, neuropsychiatrists).

To validate our conversion table on other samples, we searched the ADNI database (ADNI 1, 2 and ADNI-GO) for more patients with both MMSE and MoCA scores at the same follow-up visits. Data were downloaded from the October 2015 release (http://adni.loni.ucla.edu). We included 1202 patients who had an MMSE and a MoCA during the same visit. Diagnoses included AD, late- and early-MCI, subjective memory complaints and healthy controls (See Table 2). ADNI is a multi-site, multi-study program funded by a public and private partnership to investigate whether the combination of neuroimaging, biological markers, and clinical and neuropsychological assessments can accurately track progression of AD.[19] Data are publicly available to the scientific community for analyses. Informed consent is collected through the participating ADNI sites. The ADNI-GO and ADNI-2 studies were conducted according to Good Clinical Practice guidelines, US 21CFR Part 50—Protection of Human Subjects, and Part 56— Institutional Review Boards (IRBs)/Research Ethics Boards (REBs), and pursuant to state and federal HIPAA regulations. Also, the study protocols were approved by each site's IRB/REB. At the entry visit into ADNI, cohort subjects received an initial diagnosis according to certain definitions: AD dementia subjects had MMSE scores between 20 and 26 (inclusive), Clinical Dementia Rating Scale (CDR) scores of either 0.5 or 1.0, and all met National Institute of Neurological and Communicative Disorders and Stroke/Alzheimer's Disease and Related Disorders Association (NINDS-ADRA) criteria for probable AD. MCI subjects had a memory complaint, and MMSE scores between 24 and 30, objective memory loss as measured by education-adjusted scores on the Wechsler Memory Scale (WMS) Logical Memory II, CDR score of 0.5, absence of significant levels of impairment in other cognitive domains, essentially preserved activities of daily living, and an absence of dementia. The distribution of MMSE and MoCA scores in the sample is shown in Figure S1.

Table 1. Characteristics of the Sample

Group	N	Age	Gender	Education
ADNI total	1202	73 (7)	652/550	16.2 (2.7)
CN	323	74 (6)	160/163	16.4 (2.6)
SMC	105	72 (6)	43/62	16.8 (2.5)
EMCI	309	71 (7)	171/138	16.0 (2.7)
LMCI	314	73 (7)	189/125	16.1 (2.9)
AD	150	75 (8)	89/61	15.8 (2.6)
Qc total	1492	69 (11)	709/783	11.6 (4.6)
CN/SMC	95	64 (10)	72/23	13.6 (3.8)
MCI	244	72 (9)	119/125	11.1 (4.8)
AD	445	73 (9)	187/258	11.2 (4.6)
Vascular	193	74 (10)	100/93	10.5 (4.5)
Psychiatric	131	62 (11)	56/75	11.9 (4.5)
Others	384	65 (12)	175/209	12.2 (4.5)

Data is mean (SD) for age and education. Gender is male/female.
AD = Alzheimer's disease; CN = cognitively normal; EMCI = early mild cognitive impairment; LMCI = late mild cognitive impairment; MCI = mild cognitive impairment; SMC = subjective memory complaint.

MMSE and MoCA Testing

The MMSE and the MoCA are both brief multidomain cognitive screening tests with a score range of 0–30. MMSE items include orientation, memory, recall, naming objects, attention, following verbal and written commands, writing a sentence, and copying a figure. MoCA items

Table 2. MMSE-MoCA Conversion Table

		95% CI For a New Prediction	
MoCA	**Predicted MMSE**	**Inferior Limit**	**Superior Limit**
MoCA→MMSE			
30	30	28.1	30
29	30	26.8	30
28	29	27.0	30
27	29	26.5	30
26	28	26.4	30
25	28	25.4	30
24	28	25.0	30
23	27	24.0	30
22	27	23.6	30
21	26	22.8	30
20	25	22.2	29.7
19	25	21.7	29.2
18	24	20.5	29.2
17	24	19.6	28.9
16	23	19.4	27.9
15	22	17.9	28.1

		95% CI For a New Prediction	
MMSE	**Predicted MoCA**	**Inferior Limit**	**Superior Limit**
MMSE→MoCA			
30	28	21.8	30
29	26	19.6	30
28	23	17.5	30
27	21	15.4	28.4
26	20	13.3	26.8
25	18	11.5	25.0
24	16	9.1	24.1
23	15	5.4	24.6
22	13	6.3	20.9
21	12	3.1	21.5
20	11	2.3	19.9

include orientation, drawing figures, processing speed, naming objects, memory, recall, attention, vigilance, repetition, verbal fluency, and abstraction (available online at http://www.mocatest.org). The MoCA adds one point for those whose educational level is 12 or fewer years. In this study, we used raw MoCA scores (not corrected for education).

Statistical Analyses

The equipercentile equating method with log-linear smoothing[20] was performed on the MoCA and MMSE to develop a score conversion table between these scales. The analysis was performed using the "equate" library in the SAS 9.2 R statistical program (SAS Institute). To assess the accuracy and validity of the prediction table, we looked at how the observed MMSE/MoCA scores differed from the predicted scores in the Quebec sample. We also calculated 95% confidence interval (CI) for a new prediction and calculated intra-class correlation with the ADNI sample. The superior limit of the 95% CI was blocked at 30/30 to facilitate clinical interpretation. In order to look at potential modifying factors, we split the data according to dementia subtype (AD, vascular, psychiatric, others). We used a linear and quadratic model to statistically compare the different subgroups' curves. All analyses were carried out in SAS version 9.2.

RESULTS

Accuracy and Reliability of the MMSE-Moca Conversion Table

Using the equipercentile method with log-linear smoothing on the Quebec sample, we produced tables for the conversion from MMSE to MoCA, and from MoCA to MMSE (See Table 2). It appears that the MoCA→MMSE conversion is much more accurate than the MMSE→MoCA conversion. Indeed, when predicting MoCA scores from MMSE sores, the observed MMSE score is in a ±1 range of the score predicted from the MoCA less than 50% of cases, with a mean deviation of more than 2 points. Conversely, the MoCA→MMSE conversion table has a better accuracy, especially when the MoCA is in the 23 to 30 range (>70% observed MMSE scores in a ± 1 range of predicted score, mean deviation ≅1 point). When MoCA is <20, the conversion table becomes less accurate, with <50% of observed scores in a ±1 range of the predicted score and a mean deviation of ≅2 points. We also calculated 95% CI for a new prediction (See Table 2). When predicting MMSE from the MoCA in a new patient, the 95% CI spans 6.0 MMSE points on average (4.7 when MoCA ≥20 and 8.8 when MoCA <20). The MMSE→MoCA conversion table is less accurate, with 95% CI of 14 MoCA points on average (12 when MMSE ≥25 and 17 when MMSE <25). Finally, the MMSE-MoCA conversion table showed an intra-class correlation of 0.633 with the ADNI sample.

Consistency with Other Published MMSE-Moca Conversion Tables

We retrieved the MoCA→MMSE conversion tables previously published in peer-reviewed articles[10,14–18] and compared them to our Quebec and ADNI tables. The tables are well matched for the higher spectrum of MoCA scores, and slightly diverge in the lower MoCA scores, where sample sizes are small (See Figure S2). Overall, we found a mean difference of 0.8 MMSE points between our conversion table and the average of other published tables.

Is the MMSE-Moca Relationship Consistent Across Dementia Subtypes?

In order to look at potential modifying factor of diagnosis, we split the data in four diagnostic groups (AD, vascular, psychiatric, others). When modelling curves either through a linear or quadratic model, we observed significant differences ($P < .01$) in MMSE-MoCA relationship across diagnosis subgroups. We therefore generated an MMSE-MoCA conversion table that is specific for the main dementia subtypes (AD, vascular, psychiatric, others; See Figure 3). Some diagnostic groups were too small to model through this approach, but did not seem to fit the MMSE-MoCA relationship. For instance, frontotemporal dementia

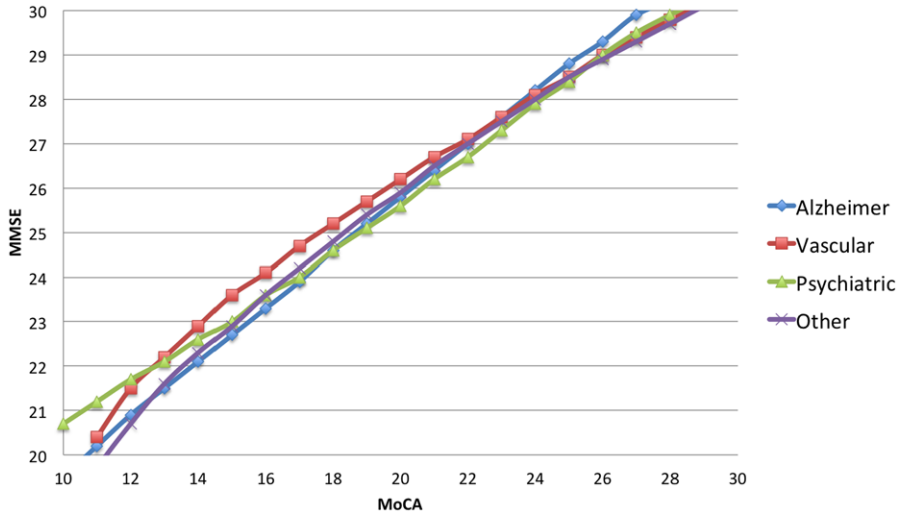

Figure 1. MMSE-MoCA conversion table according to dementia subtype. [Color figure can be viewed at wileyonlinelibrary.com].

(n = 26) was the diagnostic subgroup with the highest mean difference between predicted and actual MMSE score (2.31), with a trend towards a higher MMSE than predicted from the MoCA (equal or higher in 19/26 cases). A similar trend was observed in patients with Parkinson's disease (mean difference 1.95, 17/22 with equal or better MMSE than predicted from MoCA) and normal pressure hydrocephalus (mean difference 1.97, 32/46 with equal or better MMSE than predicted from MoCA). Overall, dementia subtypes associated with a dysexecutive syndrome (vascular dementia, Parkinson's disease, normal pressure hydrocephalus, frontotemporal dementia) showed a trend towards higher MMSE scores than other dementia subtypes (e.g., AD) for a given MoCA score (not significant). This is consistent with our MMSE-MoCA tables stratified by diagnosis (See Figure 3), which shows that the vascular dementia spectrum generally predicts a higher MMSE score than other dementia syndromes for a given MoCA score.

DISCUSSION

In this study, we aimed to validate an MMSE-MoCA conversion table using retrospective data from four academic memory clinics in Quebec. This will allow comparability of cognitive staging data in longitudinal studies of MCI or dementing illnesses, and potentially to impute data in heterogeneous research cohorts (some patients having only MMSE, and others only MoCA scores). Our table is similar to previously published tables and shows good intraclass correlation with the ADNI sample. On the other hand, large 95% CI for new predictions suggest questionable reliability for clinical use. For instance, a MoCA score of 20/30 would predict an MMSE score of 26, with a 95% CI between 22 and 30 (See Table 2)—a width that is clinically very significant. Encouragingly however, the conversion table is more reliable at higher levels of function, that is where clinical and research settings need it the most (MMSE usually being preferred at lower levels of function).[21] Finally, we showed that the MMSE-MoCA relationship might differ according to dementia subtype, which potentially limits its use in heterogeneous clinical populations. Specifically, dementia subtypes associated with a dysexecutive syndrome generally have a higher MMSE than predicted from the MoCA. This might be due to the fact that the MoCA contains more executive tasks than the MMSE, hence dysexecutive patients can get lower scores on MoCA with a relatively preserved MMSE. Authors have suggested that the nature of a cognitive measure (emphasis on certain cognitive domains) impacts its ability to capture clinical deterioration in a given dementia syndrome: for instance, MMSE-matched AD and FTD patients significantly differ in other measures of disease severity such as the Functional Assessment Questionnaire (FAQ), Neuropsychiatric Inventory (NPI), and Clinical Dementia Rating Scales (CDRs).[22,23] Likewise, although the MMSE and MoCA test similar neuropsychological constructs, their differential weighting of cognitive domains should prevent us to convert scores using the same scale in all types of neurocognitive syndromes.

Accumulating evidence suggests that the MoCA is superior to the MMSE for the screening of AD or other dementias at the MCI stage. Among the advantages of the MoCA over the MMSE: a higher ceiling that helps better detecting the early stages of the disease, especially among young and/or educated patients;[11,21,24–26] availability of three equivalent alternate versions to minimize re-test effects;[27] future availability of an online version that will help gathering automatic calculations of processing speed for executive subtests (http://www.mocatest.org/electronic-tests); and its free open-access availability.[6,7] On the other hand, MMSE is generally preferred to the MoCA for cognitive staging visits due to its presumed lower floor effect. Moreover, executive subtests—most notably verbal fluency, but also trail-making and clock drawing—can be discouraging to patients with severe cognitive deficits, hence clinicians instinctively chose easier tests like the MMSE in this population. Nonetheless, multiple studies have shown that the MoCA in fact does not have a significant floor effect even in moderate to advanced stages of dementia.[28–30]

Our study has limitations. First and foremost, we must highlight the scarcity of data for MoCA scores below 20 both in our samples (See Figure 1) and other published

studies. This is explained by the fact that, as mentioned above, the MoCA is mostly used for screening and diagnostic purposes (e.g., in the first visits), whereas the MMSE is generally preferred for cognitive staging in follow-up visits. Further research is needed to evaluate the value of the MoCA for the cognitive staging of patients in follow-up visits. Moreover, the retrospective design of the study implies potential biases. For instance, since there was no *a priori* determined method for the administration order of the tests, there may be a systematic preference for a specific order in some centers (e.g., always starting with the MoCA). In our experience, patients tend to perform better on the first test compared to the second, probably due to decreasing attention over time. This in turn may induce a systematic bias in the MMSE-MoCA relationship. Unfortunately, administration order was not available for most of the data gathered in this effort.

CONCLUSION

As accumulating evidence points to the superiority of the MoCA over the MMSE as a cognitive screening tool, we validated an MMSE-MoCA conversion table to allow comparability of cognitive staging data in longitudinal studies of MCI or dementing illnesses. The MMSE→MoCA conversion table should be used with caution in clinical practice, since it shows questionable reliability and may not apply equally to every dementia subtype.

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Conflict of Interest: Dr. Ziad Nasreddine MD FRCPC is the author of the MoCA. He is also the founder and director of the MoCA Clinic & Institute (Montreal, Canada).

Author Contributions: DB and RJrL elaborated the study concept and design. All authors contributed to data acquisition. DB and RJrL analysed and interpreted the data. DB drafted the initial version of the manuscript. All authors participated to the preparation of the paper and approved the final version of the manuscript.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Figure S1. Distribution of MMSE and MoCA scores in the ADNI and Quebec samples.

Figure S2. Comparison of published MMSE-MoCA conversion tables. AD = Alzheimer's disease; HC = healthy controls; MCI = mild cognitive impairment; PD = Parkinson's disease.

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