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Comparison of the Short Test of Mental Status and the Montreal Cognitive Assessment Across the Cognitive Spectrum

Ryan A. Townley, MD; Jeremy A. Syrjanen, MS; Hugo Botha, MB, ChB; Walter K. Kremers, PhD; Jeremiah A. Aakre, MPH; Julie A. Fields, PhD, LP; Mary M. Machulda, PhD, LP; Jonathan Graff-Radford, MD; Rodolfo Savica, MD, PhD; David T. Jones, MD; David S. Knopman, MD; Ronald C. Petersen, PhD, MD; and Bradley F. Boeve, MD

Abstract

Objective: To compare the Short Test of Mental Status (STMS) with the Montreal Cognitive Assessment (MoCA) for predicting and detecting mild cognitive impairment (MCI).

Participants and Methods: Participants from the community-based Mayo Clinic Study of Aging (MCSA) (November 24, 2010, through May 19, 2012) and an academic referral Alzheimer's Disease Research Center (ADRC) (March 16, 2015, through September 5, 2018) were analyzed. All participants were evaluated using a standardized neuropsychological battery, and a multidisciplinary consensus diagnosis was assigned. The MCSA and ADRC samples included 313 and 106 stable cognitively normal (CN) participants, 72 and 8 CN participants at baseline who developed incident MCI or dementia, 114 and 96 participants with prevalent MCI, and 25 and 132 participants with dementia, respectively.

Results: There were no statistically significant differences between the 2 tests in 6 of 7 diagnostic comparisons across academic referral and community populations. The STMS had a better area under the curve (0.90; 95% CI, 0.87-0.93) for differentiating prevalent MCI from CN participants in the MCSA cohort compared with the MoCA cohort (0.85; 95% CI, 0.81-0.89; P=.01). In addition, 53% of the stable CN participants (222 of 419) scored less than 26 on the MoCA, with specificity of 47% for diagnosing prevalent MCI.

Conclusion: We provide evidence that the STMS performs similarly to the MoCA in a variety of settings and neurodegenerative syndromes. These results suggest that the current recommended MoCA cutoff score may be overly sensitive, consistent with previous studies. We also provide a conversion table for comparing the 2 cognitive tests.

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From the Department of Neurology (R.A.T., H.B., J.G.-R., R.S., D.T.J., D.S.K., R.C.P., B.F.B.), Department of Health Sciences Research (J.A.S., W.K.K., J.A.A.), and Department of Psychology and Psychiatry (J.A.F., M.M.M.), Mayo Clinic, Rochester, MN.

Bedside cognitive tests performed by primary care and neurology providers are an important screening tool for mild cognitive impairment (MCI) and dementia. Mild cognitive impairment represents an intermediate clinical stage between stable normal aging and dementia.[1] Cognitive tests that incorporate brevity and high sensitivity and specificity are required in primary care clinical practice. Early and accurate detection of cognitive changes is essential for appropriate referral for more detailed neurocognitive testing and specialist evaluation. Early diagnosis and support helps families plan strategies to minimize the effect and burden of dementia[2] and will be of increasing importance as disease-modifying therapies become a reality. However, specialist referral systems, as well as participants, can be overburdened if

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screening tests are overly sensitive or lack specificity for detecting neurodegenerative diseases.

A variety of tests are being used in clinics across the world, but few have been validated in community settings.[3] Most of the existing tools are biased toward detection of amnestic-predominant cognitive impairment, with less emphasis on other cognitive domains frequently involved in frontotemporal lobar dementia (FTLD) or dementia with Lewy bodies (DLB).[4] The Mini-Mental State Examination (MMSE) is widely used and can be administered relatively quickly, but MMSE scores are not useful for diagnosing MCI,[5,6] and its licensing fee has made this measure less attractive for clinical use.[7,8] The Montreal Cognitive Assessment (MoCA) was created specifically to improve the diagnosis of MCI and has reported improved sensitivity in head-to-head studies with the MMSE in a variety of cognitive impairment settings.[5,9-11] The proposed cutoff score of 26 has been considered too sensitive in some studies, limiting the specificity of an abnormal score.[12,13]

The Short Test of Mental Status (STMS) was developed and validated as a bedside tool that emphasizes brevity and reasonable sensitivity and specificity.[14,15] We previously reported that the STMS was more sensitive and specific in detecting early cognitive deficits than was the MMSE.[6] In the present study, we aimed to compare the MoCA and the STMS for detection of MCI, Alzheimer disease (AD), and other forms of dementia in both a community and an academic referral center setting. Owing to subtest differences, we predicted that the MoCA would have better sensitivity and specificity for nonamnestic MCI, DLB, and FTLD compared with the STMS. We also aimed to explore potential sensitivity issues with the currently proposed MoCA cutoff score. The final objective was to establish a conversion table for the 2 tests.

PARTICIPANTS AND METHODS

Study Population

These projects were approved by the Mayo Foundation Institutional Review Board. Study participants were recruited prospectively through the Mayo Clinic Study of Aging (MCSA) and the Mayo Clinic Alzheimer's Disease Research Center (ADRC) using a standardized protocol.[16,17] With the help of the Rochester Epidemiology Project, MCSA participants were randomly selected

TABLE 1. Demographic Characteristics of the MCSA and ADRC Groups

Characteristic	Stable CN	Incident MCI	Prevalent MCI	Dementia
MCSA participants (n=524)				
Participants (No.)	313	72	114	25
Women (No. [%])	159 (51)	36 (50)	57 (50)	13 (52)
Age at baseline (y), mean ± SD	81.7 ± 5.0	84.1 ± 4.8	84.0 ± 5.2	87.1 ± 4.9
Education (y), mean ± SD	14.2 ± 2.9	14.2 ± 2.7	13.8 ± 3.1	13.9 ± 3.0
Baseline STMS score, mean ± SD	34.7 ± 2.3	33.1 ± 2.5	29.8 ± 3.4	23.3 ± 6.8
Baseline MoCA score, mean ± SD	24.5 ± 2.5	23.0 ± 2.8	20.5 ± 2.9	14.5 ± 5.6
CDR Sum of Boxes score, mean ± SD	0.05 ± 0.2	0.19 ± 0.4	1.16 ± 1.3	5.8 ± 4.0
ADRC participants (n=342)				
Participants (No.)	106	8	96	132
Women (No. [%])	50 (47)	3 (38)	24 (25)	60 (46)
Age at baseline (y), mean ± SD	63.1 ± 12.9	71.1 ± 8.5	70.3 ± 8.5	69.3 ± 11.0
Education (y), mean ± SD[a]	15.9 ± 2.4	14.1 ± 1.7	16.3 ± 3.0	15.3 ± 2.8
Baseline STMS score, mean ± SD	36.8 ± 1.4	34.1 ± 2.9	33.3 ± 3.2	24.2 ± 7.7
Baseline MoCA score, mean ± SD	27.1 ± 2.1	24.5 ± 3.2	22.6 ± 3.3	14.0 ± 5.9
CDR Sum of Boxes score , mean ± SD[a]	0.04 ± 0.2	0.13 ± 0.4	1.40 ± 1.1	5.0 ± 2.9

[a]Four observations are missing for CDR Sum of Boxes in the ADRC group and 3 observations are missing for education in the ADRC group.

ADRC = Alzheimer's Disease Research Center; CDR = Clinical Dementia Rating; CN = cognitively normal; MCI = mild cognitive impairment; MSCA = Mayo Clinic Study of Aging; MoCA = Montreal Cognitive Assessment; STMS = Short Test of Mental Status.

TABLE 2. AUC Values for the STMS and the MoCA Across Diagnostic Groups

Variable	AUC (95% CI)		*P* value
	STMS	MoCA	
MCSA CN vs prevalent MCI	0.90 (0.87-0.93)	0.85 (0.81-0.89)	.01
MCSA CN vs incident MCI	0.71 (0.65-0.77)	0.70 (0.64-0.77)	.83
MCSA CN vs dementia[a]	0.97 (0.94-1.0)	0.97 (0.94-1.0)	.52
MCSA MCI vs dementia[a]	0.81 (0.70-0.91)	0.81 (0.71-0.92)	.74
ADRC CN vs prevalent MCI	0.87 (0.83-0.92)	0.90 (0.85-0.94)	.29
ADRC CN vs dementia	0.99 (0.98-1.0)	0.99 (0.99-1.0)	.10
ADRC MCI vs dementia	0.88 (0.84-0.92)	0.91 (0.87-0.95)	.11

[a]Due to minimal event frequency, the MCSA CN vs dementia and MCSA MCI vs dementia comparison models were not adjusted for age, sex, and educational level.

ADRC = Alzheimer's Disease Research Center; AUC = area under the curve; CN = cognitively normal; MCI = mild cognitive impairment; MCSA = Mayo Clinic Study of Aging; MoCA = Montreal Cognitive Assessment; STMS = Short Test of Mental Status.

from a community population of Olmsted County, Minnesota, from November 24, 2010, through May 19, 2012.[18-20] Participants from the Mayo Clinic ADRC (March 16, 2015, through September 5, 2018) represent a nonrandom sample that is geographically and clinically diverse. Each participant was evaluated by an experienced clinician who obtained a history and performed a neurologic examination, which included the STMS (see the article by Tang-Wai et al[6] for a detailed breakdown table of the STMS). Corroborating information was obtained through family members by a nurse or study coordinator, and a Clinical Dementia Rating scale was documented. Participants completed a MoCA and a comprehensive neuropsychological battery as part of the Uniform Data Set designed by the National Alzheimer's Coordinating Center.[21]

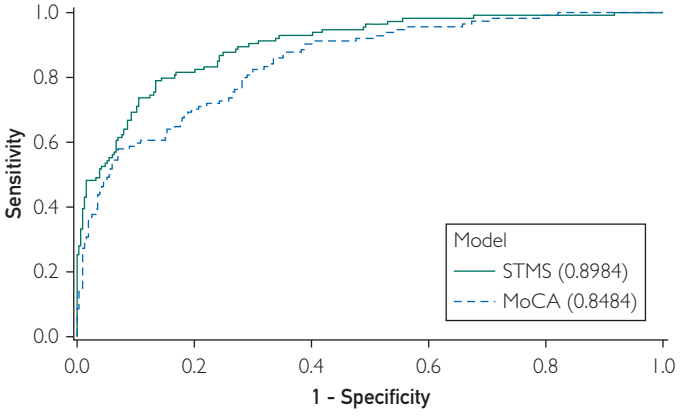

FIGURE 1. Receiver operating characteristic curves for differentiating prevalent mild cognitive impairment from cognitively normal participants on the Short Test of Mental Status (STMS) vs Montreal Cognitive Assessment (MoCA) in the community cohort Mayo Clinic Study of Aging. The area under the curve was 0.90 (95% CI, 0.87-0.93) vs 0.85 (95% CI, 0.81-0.89), respectively (*P*=.01, not corrected for multiple comparisons).

Consensus Process

A consensus meeting was held weekly with study coordinators, physicians, and neuropsychologists to assign a consensus diagnosis of cognitively normal (CN), MCI (amnestic or nonamnestic), or dementia (along with the suspected cause of dementia). A diagnosis of MCI was made if the patient endorsed a cognitive complaint, maintained essentially normal activities of daily living, but had objectively abnormal scores (generally <1.5 standard deviations below the mean) in 1 or more domains of cognitive testing. An AD dementia diagnosis was based on previous National Institute on Aging—Alzheimer's Association criteria.[22] Diagnoses of DLB and FTLD were based on the most recent consensus criteria.[23,24] The STMS scores were factored into the clinician's diagnostic impression, but these were balanced in the consensus meeting by incorporating information provided by family members, as well as standard neuropsychological test performance.

Statistical Analyses

Data analysis consisted of 3 main parts: tables of descriptive statistics, logistic regression models, and equipercentile equating. The tables of descriptive statistics are summarized by diagnosis and are computed separately for the MCSA and ADRC samples. Statistics are presented as frequency (percentage) for categorical variables and as mean ± SD for continuous variables. Logistic regression models were run separately for the MCSA and ADRC samples using the STMS and the MoCA to predict diagnosis (ie, CN vs MCI). Where a sufficient number of events were present, the models were also adjusted for age, sex, and educational level.

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To compare the performance of the STMS and the MoCA in differentiating diagnoses, the area under the curve (AUC) for the models was used. The AUCs were compared using jackknife resampling. The traditional $P \leq .05$ was considered statistically significant. The performance of the MoCA in discriminating diagnoses was further explored by graphically examining the sensitivity and specificity of proposed MoCA cutoff scores. A histogram showing MoCA scores of CN participants was used to explore the potential oversensitivity of the MoCA cutoff score of less than 26. Finally, to create conversion tables between the STMS and the MoCA, equipercentile equating was used. This method allows for conversion of a given percentile score from one test to the score related to the same percentile for the other test. Statistical analyses were completed using SAS software version 9.4 (SAS Institute Inc) and R version 3.4.1 (R Foundation for Statistical Computing).

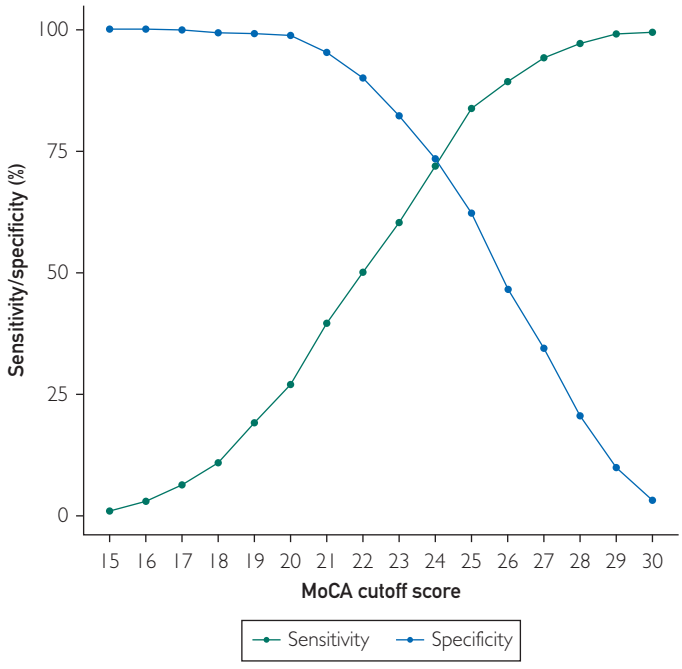

FIGURE 2. Montreal Cognitive Assessment (MoCA) sensitivity/specificity plot for detecting prevalent mild cognitive impairment (MCI). A MoCA cutoff score of 24 provides sensitivity of 72% and specificity of 74% in detecting prevalent MCI.

RESULTS

There were 524 community MCSA participants followed for an average of 3.3 years (range, 0-6.7 years) grouped by diagnosis (Table 1). There were 72 participants categorized as incident MCI (CN at baseline but converted to MCI at follow-up; 1 patient converted from CN to dementia). An additional 342 participants were incorporated from an ADRC setting (Table 1). The ADRC participants were younger (68.9 vs 83.1 years; $P<.001$) and had higher educational levels (16.0 vs 13.0 years; $P<.001$) than the MCSA participants. In the stable CN and prevalent MCI subgroups, those in the ADRC had higher baseline STMS and MoCA scores than those in the MCSA ($P<.001$ for all comparisons). No significant differences were found between baseline cognitive test scores in the incident MCI or dementia subgroups, where there was low statistical power.

Table 2 summarizes performance between the MoCA and the STMS across both populations and patient subgroups. There were no statistically significant differences between the diagnostic accuracy of the MoCA and the STMS on 6 of 7 contrasts. In the MCSA community population, the STMS was better than the MoCA at differentiating prevalent MCI from CN (AUCs: 0.90 [95% CI, 0.87-0.93] and 0.85 [95% CI, 0.81-0.89], respectively; $P=.01$, not corrected for multiple comparisons) (Figure 1). Comparing CN participants with the incident MCI group in the MCSA, both the STMS and the MoCA performed well, with receiver operating characteristic curves providing AUC values of 0.71 (95% CI, 0.65-0.77) and 0.70 (95% CI, 0.64-0.77), respectively.

Additional subgroups were analyzed to investigate whether subtype of MCI or dementia syndrome performed better with either cognitive test. In the MCSA sample, the 114 participants in the prevalent MCI group were further classified into amnestic MCI (n=89) or nonamnestic MCI (n=25) (Supplemental Table 1, available online at http://www.mayoclinicproceedings.org). In the ADRC

TABLE 3. Test Conversions Using Equipercentile Equating[a]

Converting STMS to MoCA		Converting MoCA to STMS	
STMS	MoCA	MoCA	STMS
38	29	30	38
37	27	29	38
36	26	28	38
35	24	27	37
34	23	26	36
33	22	25	36
32	22	24	35
31	21	23	34
30	20	22	33
29	19	21	31
28	18	20	30
27	17	19	29
26	16	18	28
25	16	17	27
24	15	16	26
23	14	15	24
22	13	14	23
21	12	13	22
20	11	12	21

[a]Combined Mayo Clinic Study of Aging and Alzheimer's Disease Research Center cohort (n=866).

MoCA = Montreal Cognitive Assessment; STMS = Short Test of Mental Status.

dementia group, there were 92 participants with AD, 26 with DLB, and 14 with FTLD (Supplemental Table 2, available online at http://www.mayoclinicproceedings.org). In the MCSA cohort, the STMS provided better discrimination between amnestic MCI and CN compared with the MoCA (AUCs: 0.90 [95% CI, 0.86-0.94] and 0.85 [95% CI, 0.81-0.90], respectively; P=.04). When comparing nonamnestic MCI with CN, the AUC for the STMS was 0.91 (95% CI, 0.87-0.95) compared with 0.84 (95% CI, 0.75-0.92) for the MoCA (P=.07). There was no statistically significant difference between the 2 cognitive tests in differentiating CN from FTLD and DLB in the ADRC subgroups, likely due to low statistical power in the FTLD and DLB subgroups. Of note, the MoCA had a statistically significant AUC compared with the STMS for CN vs AD, but this finding lacks clinical significance (AUCs for MoCA vs STMS: 1.0 [95% CI, 0.99-1.0] vs 0.99 [95% CI, 0.98-1.0]; P=.05) (Supplemental Table 3, available online at http://www.mayoclinicproceedings.org).

We further analyzed sensitivity and specificity cutoff values for each test by combining both patient populations (n=866), which provided a wider range of scores. When combining both patient cohorts, a cutoff score of less than 26 for the MoCA provided sensitivity of 89% and specificity of 47% for diagnosing prevalent MCI. Figure 2 shows that a cutoff score of less than 24 (STMS score equivalent of <35) provided sensitivity of 72% and specificity of 74%. Of the 419 stable CN participants in the cohorts, 222 (53%) scored below the currently used normal cutoff score of less than 26 (Supplemental Figure 1A, available online at http://www.mayoclinicproceedings.org). In the MCSA cohort, a cutoff score of less than 26 for the MoCA provided sensitivity of 96% but specificity of 36%, and a cutoff score of 23 (STMS score equivalent of <34) provided sensitivity of 69% and specificity of 78% (Supplemental Figure 1B, available online at http://www.mayoclinicproceedings.org). In addition, a MoCA cutoff score of less than 20 (STMS score equivalent of <30) provided sensitivity of 82% and specificity of 72% for differentiating prevalent MCI and all-cause dementia across both cohorts (Supplemental Figure 1C, available online at http://www.mayoclinicproceedings.org).

We performed equipercentile equating conversions between the STMS and the MoCA in the combined population samples (Table 3). To analyze whether the subtype of cognitive syndrome influenced the reliability of conversion between the 2 cognitive tests, we combined nonamnestic subgroups (nonamnestic MCI, DLB, and FTLD) and plotted them against amnestic subgroups (amnestic MCI and AD). Figure 3 shows good correlation between the subgroups across the range of scores.

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DISCUSSION

The MoCA has shown superiority over the MMSE in detecting MCI in numerous studies.[5,9-11] The present study is the first to directly compare the MoCA with the STMS. In both patient populations, the STMS and the MoCA performed well in detecting MCI and the 3 most common clinical dementia phenotypes. Both tests were able to predict conversion of CN to MCI, with AUCs of 0.71 (95% CI, 0.65-0.77) for the STMS and 0.70 (95% CI, 0.64-0.77) for the MoCA.

The recommended abnormal cutoff score of less than 26 for the MoCA has proved to be very sensitive for diagnosing participants with MCI.[5] This cutoff score has been criticized in subsequent studies because of the low specificity of an abnormal value, particularly for community-based populations.[13,25-29] Most community-based studies have suggested a lower abnormal cutoff range of 20 to 24 to maintain adequate sensitivity but also yield better specificity. Of the 419 stable CN participants across the present cohorts, 222 (53%) scored lower than the current recommended cutoff score of 26. This finding offers further evidence that the recommended cutoff score is too sensitive.

Overdiagnosis can burden patients and families with diagnostic anxiety while simultaneously burdening referral specialists with CN patients. A MoCA score of less than 24 gave a better balance of sensitivity and specificity among the combined patient cohorts in this study. A comparative cutoff score for the STMS was determined to be less than 35 based on equipercentile equating. Detailed neuropsychological tests use norms that are adjusted for patient demographic characteristics, and 1 cutoff score may not be applicable for all situations. To better adjust the MoCA for educational level, it has been suggested that 1 point be added for a patient with less than 12 years of education. The present population had a mean education of 14.7 years, and this point addition would not apply to most of the participants. Additional *z* scores that correct for age and education may help interpret patient scores to assist in determining level of concern for prompting a specialty referral.

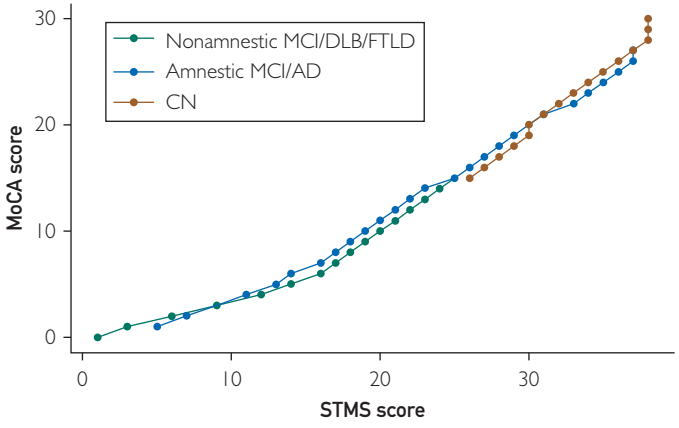

FIGURE 3. Equipercentile equating plot converting Short Test of Mental Status (STMS) scores to Montreal Cognitive Assessment (MoCA) scores compared across cognitive subgroups: nonamnestic (nonamnestic mild cognitive impairment [MCI], dementia with Lewy bodies [DLB], and frontotemporal lobar dementia [FTLD]), amnestic (amnestic MCI and Alzheimer disease [AD]), and cognitively normal (CN).

A previous study suggested that the MoCA trended toward improved accuracy in dysexecutive subgroups (DLB, FTLD, vascular subtypes) compared with the MMSE.[30] The MoCA also incorporates more items for assessing aspects of executive function than does the STMS, and we expected that the MoCA would have better sensitivity and specificity for nonamnestic MCI, DLB, and FTLD compared with the STMS. Each subgroup had small numbers individually, but combining the nonamnestic (n=83) and amnestic (n=259) subgroups did not favor the MoCA statistically.

There are limitations to the generalizability of the present study because participants from both cohorts were native English speakers, were well-educated, and were largely European-American, and so these findings may not apply to less educated groups or populations of diverse race and native language.[29] A potential circularity bias exists in that neurologists had access to STMS and MoCA scores at the time of determining the baseline diagnosis. This bias was partially mitigated by not relying on one factor for diagnosis among the consensus committee. The stable CN group and the incident MCI group were isolated

from this baseline diagnosis bias because their follow-up visit diagnoses were used for classification independent of the baseline scores.

CONCLUSION

Primary care physicians need sensitive bedside tests to detect MCI, but the cutoff scores used must also be specific enough to not overburden patients and a specialist system with CN patients. These data suggest that the current MoCA cutoff score may be overly sensitive. We also provided evidence that the STMS performs as well as the MoCA in a variety of settings and neurodegenerative syndromes and was better at differentiating CN from MCI in a community-based setting.

SUPPLEMENTAL ONLINE MATERIAL

Supplemental material can be found online at http://www.mayoclinicproceedings.org. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.

Abbreviations and Acronyms: **AD** = Alzheimer disease; **ADRC** = Alzheimer's Disease Research Center; **AUC** = area under the curve; **CN** = cognitively normal; **DLB** = dementia with Lewy bodies; **FTLD** = frontotemporal lobar dementia; **MCI** = mild cognitive impairment; **MCSA** = Mayo Clinic Study of Aging; **MMSE** = Mini-Mental State Examination; **MoCA** = Montreal Cognitive Assessment; **STMS** = Short Test of Mental Status

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Potential Competing Interests: Dr Botha has received grant support from the NIH and a travel award from Human Amyloid Imaging. Dr Kremers receives research funding from the NIH, the U.S. Department of Defense, AstraZeneca, Biogen, and Roche. Dr Fields receives funding from the NIH. Dr Knopman serves on a data safety monitoring board for the Dominantly Inherited Alzheimer Network (DIAN) study; is an investigator in clinical trials sponsored by Alzeca, Samus, Biogen, Lilly Pharmaceuticals, and the University of Southern California; and receives research support from the NIH. Dr Petersen serves as a consultant to Hoffman-La Roche, Merck, Genentech, and Biogen; is on the speaker's bureau of GE Healthcare; and receives royalties from the publication of a book entitled *Mild Cognitive Impairment* (Oxford University Press, 2003). Dr Boeve has served as an investigator for clinical trials sponsored by GE Healthcare and Axovant; receives royalties from the publication of a book entitled *Behavioral Neurology of Dementia* (Cambridge Medicine, 2009, 2017); serves on the scientific advisory board of the Tau Consortium, Biogen, and Wave Life Sciences; and receives research support from the NIH, the Mayo Clinic Dorothy and Harry T. Mangurian Jr. Lewy Body Dementia Program, and the Little Family Foundation. The other authors report no competing interests.

Correspondence: Address to Ryan A. Townley, MD, Department of Neurology, Mayo Clinic, 200 First St SW, Rochester, MN 55905 (Townley.Ryan@mayo.edu).

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