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The MoCA and MMSE as Screeners for Cognitive Impairment in a Heart Failure Population: A Study with Comprehensive Neuropsychological Testing

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Abstract

Objective—To examine the ability of the Mini Mental Status Examination (MMSE) and Montreal Cognitive Assessment (MoCA) to detect cognitive impairment in persons with heart failure (HF).

Background—Although the MMSE and MoCA are commonly used screeners in HF, no research team has validated their performance against neuropsychological testing.

Methods—Participants were 106 patients with HF (49.1% male, 68.13±9.82 years) who completed the MoCA, MMSE, and a full neuropsychological battery. Sensitivity and specificity were examined. Discriminant function analyses tested whether the screeners correctly detected cognitive impairment.

Results—A MoCA score <25 and MMSE score of <28 yielded optimal sensitivity/specificity (.64/.66 and .70/.66, respectively). The MoCA correctly classified 65% of patients, Wilk's lambda=.91, $\chi^2(1)=9.89$, $p<.01$, and the MMSE correctly classified 68%, Wilk's lambda=.87, $\chi^2(1)=14.26$, $p<.001$.

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Conclusions—In HF, both the MoCA and MMSE are useful in identifying the majority of patients with and without cognitive impairment. Both tests misclassified approximately one-third of patients, so continued monitoring and evaluation of patients is needed in conjunction with screening.

Keywords

heart failure; screening; cognitive impairment; MMSE; MoCA

Introduction

Millions of individuals in the United States have been diagnosed with heart failure (HF) [1]. In addition to the extensive somatic symptoms of HF, such as shortness of breath, fatigue, and edema [2], neurocognitive symptoms are also highly prevalent [3-7]. Observable deficits across multiple cognitive domains, including attention, executive function, and memory, have been detected in up to 80% of persons with HF [5], with higher rates typically reported among older and inpatient samples compared to community-dwelling samples [3-7]. Persons with HF are also nearly twice as likely to develop neurodegenerative diseases, such as Alzheimer's [8]. Although HF is associated with impaired physical function [2] and increased risk for mortality [1], cognitive deficits in HF contribute to inadequate self-care [9], greater disability [10], and increased mortality [11] over and above the medical burden of HF alone. These poorer outcomes certainly support a need for adequate cognitive screening in persons with HF. However, practice guidelines for this population do not yet require cognitive screening [12], and identification of and consensus regarding a sensitive, specific cognitive screener in HF has proven difficult [12].

The most commonly used cognitive screener for the HF population is the Mini Mental Status Examination (MMSE) [12,13], but evidence of its poor sensitivity has led to use of other potential cognitive screening tools [12]. Alternative screening measures include the clock drawing test [14], the Short Portable Mental Status Questionnaire (SPMSQ) [15], and the Montreal Cognitive Assessment (MoCA) [16]. The MoCA, in particular, is garnering evidence as the only screener that demonstrates high sensitivity (83.5-100%) [12,17-19] in detecting the multiple cognitive deficits associated with HF. Indeed, a consistent pattern of cognitive impairment emerges in persons with HF, that has historically been referred to as vascular cognitive impairment (VCI) by Vogels and colleagues [20,21] and is characterized by deficits in attention, executive function, and less often memory. In contrast to the MoCA, many of the other screeners (e.g., MMSE or SPMSQ) either do not assess or are insensitive to impairments in certain cognitive domains (e.g., executive function). Although the MoCA outperforms many other cognitive screeners [17,19], it has been criticized for poor specificity [18] in detecting mild cognitive impairment and, thus, having limited use as a screener in populations with low bases rates of cognitive impairment [18]. In a HF population, however, this concern is less problematic because the base rates of cognitive impairment are quite high, especially in hospitalized samples [5]. Despite the apparent strengths of the MoCA, a critical gap in the literature remains. Specifically, although the MoCA has been shown to be superior to other screeners, no one has compared its ability to predict cognitive impairment in a sample of persons with HF as validated by a

comprehensive neuropsychological battery. Indeed, cognitive screeners are so rarely compared to gold standard neuropsychological tests that a 2014 editorial has stated that:

“It is imperative that cognitive screening measures administered to HF patients be psychometrically evaluated...[by including] two or three screening questionnaires and a neuropsychological battery of tests...” (p. 236) [22].

Accordingly, the purpose of the current study is to compare the ability of both the MoCA and MMSE to screen for cognitive impairment in a sample of outpatients with HF – as validated by a comprehensive neuropsychological battery that assessed multiple cognitive domains, including attention, executive function, memory, and visuospatial ability.

Methods

Participants

Participants were 106 outpatients enrolled in the ongoing parent study: Heart Failure Adherence, Behavior, and Cognition (Heart ABC) Study [23]. For the Heart ABC study, inclusion criteria were: (1) Aged 50-85 years at enrollment, (2) Documented systolic HF diagnosis within 36 months of study enrollment (defined as an ejection fraction (EF) 40%), (2) physician-documented New York Heart Association (NYHA) class II or III 3 months duration at time of study enrollment. The age range of 50-85 years was used to minimize the number of participants with dementia and to maximize the number of participants with some cognitive impairment. Exclusion criteria were: (3) Cardiac surgery within last 3 months, (4) History of diagnosed neurological disorder or injury (e.g., Alzheimer's disease or seizures), (5) History of moderate or severe head injury, (6) Past or current history of psychotic disorders, bipolar disorder, learning disorder, developmental disability, renal failure requiring dialysis, or untreated sleep apnea, (7) Current substance abuse within the past 5 years, and (8) Current use of home tele-health monitoring program for HF. For the current study, we selected a subsample of participants who had complete data for the MoCA, the MMSE, and the full neuropsychological battery, yielding a final sample of 106 participants (see Table 1).

Measures

Montreal Cognitive Assessment (MoCA) and Mini-Mental Status Examination (MMSE)—The original form of the MoCA (Version 7.1) was used as a screening test for cognitive impairment [16]. The MoCA assesses short-term memory recall, visuospatial abilities, executive function, verbal abstraction, attention, concentration, working memory, language, and orientation. The MMSE was also used as a cognitive screener and assesses orientation, learning and recall of words, and copy of a simple geometric figure. Scores on both screeners range from 0 to 30 points, with a lower score reflecting greater cognitive impairment, and have been validated in non-HF samples [24-26]. The standard cut-offs vary across populations, but a recent review of screening measures in the HF population suggests a cut-off of <26 on the MoCA and <24 on the MMSE as indicative of cognitive impairment [12].

Neuropsychological Test Battery—Cognitive functioning was also measured using a comprehensive neuropsychological test battery, the gold standard for detecting cognitive impairment. The battery was comprised of tests with strong psychometric properties and assessed the following four cognitive domains:

1. *Attention*: The ability to attend to and process information was measured by the Trail Making Test A [27], Stroop Word and Color subtests [28] and Letter-Number Sequencing (LNS) [29]. For Trail Making Test A, patients connect 25 numbers in ascending order and are timed. For the Stroop tests, participants are asked to read lists of colored words. For LNS, patients are asked to repeat a series of letters and numbers in a specific order.
2. *Executive function*: The ability to reason, plan, problem-solve, and inhibit was assessed using the Trail Making Test B [27], the Stroop Color Word subtest [28], and the Frontal Assessment Battery [30]. For Trail Making Test B, patients connect 25 alternating numbers and letters in ascending order and are timed. For Stroop Color Word, participants identify the ink color (e.g., red ink) of a written list of color words (e.g., “blue”). The FAB is comprised of six subtests, including conceptualization, mental flexibility, motor programming, sensitivity to interference, inhibitory control, and environmental autonomy.
3. *Memory*: The ability to retain and recall verbal information was measured using the Rey Auditory Verbal Learning Test Learning Over Time, Short Delay, Long Delay, and True Hits scores [31]. Participants are read a 15-item word list for five trials and are asked to repeat as many words as they can remember for each trial. After Trial 5, participants are presented an interference list. Participants are then asked to recall words from the original list. Participants are also asked to recall words from the original list 20 minutes later.
4. *Visuospatial Ability*: The ability to perceive and manipulate visual and spatial representations was assessed using the Rey Complex Figure Copy Task [32]. In this test, patients are shown a complex line drawing and asked to reproduce a copy of it to the best of their ability.

Raw scores on the neuropsychological tests were converted to age- and education-adjusted scaled scores ($M = 10$, $SD = 3$) using published normative data for each test [29,30,32-35]. Of note, although these norms were not specific to HF populations, similar norming procedures have been used for other neuropsychological studies of patients with HF, and Bauer et al. [36] have indicated that using age- and education-matched norms from non-HF populations is an acceptable alternative to chronic HF controls. The scaled scores were converted to T-scores to facilitate interpretation ($M = 50$, $SD = 10$). The T-scores of the relevant tests were averaged to create a composite score for each of the four domains. A T-score of 35 or lower is associated with a score 1.5 standard deviations (SD) below the test mean for the normative sample and indicative of cognitive impairment. Impairment of an individual cognitive domain was defined by a deficit (T-score ≤ 35) on one or more tests within that domain. For the primary analyses, multi-domain impairment on the total neuropsychological battery was examined, which was defined as a deficit in two or more of the four domains. We also conducted a supplemental analysis in which we examined single-

domain impairment on the total battery, defined as a deficit on at least one of the four domains.

Demographic Variables—In addition to assessing participants' neuropsychological functioning, we also obtained data on the following demographic and medical variables: age (years), gender (0 = female, 1 = male), race-ethnicity (0 = white, 1 = non-white), education level (1 = no schooling, 2 = 8th grade or less, 3 = 9-11th grade, 4 = high school, 5 = technical or trade school, 6 = some college, 7 = bachelor's degree, 8 = master's degree), and current heart failure severity. Heart failure severity was determined by asking participants' a series of questions about their current symptoms and limitations (e.g., “Do you markedly reduce physical activity due to tiredness, heart fluttering, shortness of breath, anginal pain?”). Based on their responses, patients were assigned to the appropriate NYHA class. Of note, although one of our inclusion criteria was physician-documented NYHA class II or III, we categorized some patients' HF severity as class I or IV based on their current self-reported symptoms and limitations.

Procedure

This current study is part of the larger observational Heart ABC study [23]. All patients were recruited from inpatient and/or outpatient cardiology practices in northeast Ohio and gave their written, informed consent to participate. All procedures were approved by the Institutional Review Boards of Kent State University, Summa Health Systems, Inc., and Case Western Research University. After recruitment and written consent, a research assistant conducted the series of self-report questionnaires and neuropsychological testing.

Data Analyses

Means, standard deviations, and frequencies were calculated to describe the sample. Sensitivity and specificity of different MoCA and MMSE cutoff scores were examined to determine the optimal cutoff to screen for cognitive impairment in the current sample. Sensitivity and specificity of the MoCA and MMSE were examined separately. For the primary analyses, sensitivity was defined as the percentage of patients who had multi-domain cognitive impairment according to the comprehensive neuropsychological battery (impaired on two or more domains) and who scored below each cutoff score on the MoCA or MMSE (true positive rate). Specificity was defined as percentage of patients who had normal cognition (impaired on one or fewer domains) and who scored either above or equal to each cutoff score on the MoCA or MMSE (true negative rate). For the supplemental analyses, all the analyses were repeated using single-domain cognitive impairment (impaired on at least one domain) compared to normal individuals (not impaired on any domains). All data analyses were conducted using IBM SPSS version 20.0.

Following examination of sensitivity and specificity, discriminant function analyses were conducted to determine whether MoCA and MMSE scores could correctly classify impaired and normal patients. Separate discriminant function analyses were conducted for overall performance on the neuropsychological battery (defined as multi-domain impairment or single-domain impairment), as well as impairment on individual domains of attention, executive function, memory, and visuospatial functioning. Prior to analyses, the data were

also examined to ensure the assumptions of discriminant function analyses were met. Data were normally distributed (skewness < 3 and kurtosis < 10). No violations of assumptions were evident.

Results

The sample was predominantly older, white, and had Class II or III self-reported HF severity and a high school education (Table 1). Of the 106 patients, half ($n = 53$) were categorized as multi-domain cognitively impaired based on their performance on the neuropsychological battery (impaired on ≥ 2 domains). With regard to the individual cognitive domains, the following percentages of patients had impairments: 45.3% ($n = 48$) for attention, 23.6% ($n = 25$) for executive function, 20.8% ($n = 22$) for memory, and 79.2% ($n = 84$) for visuospatial function. When using the single-domain impairment definition (impaired on ≥ 1 domain), the majority of participants (90%) were classified as cognitively impaired. Mean composite scores for each cognitive domain are presented in Table 1.

Sensitivity and Specificity

Sensitivity and specificity for a range of cutoff scores on the MoCA and the MMSE are presented in Tables 2 and 3. Although previous studies indicated optimal sensitivity and specificity using a MoCA cutoff of < 26 as signifying cognitive impairment in cardiovascular disease, we found that a MoCA cutoff score of 25 provided comparable sensitivity and improved specificity (Table 2). In our sample, 49.1% ($n = 52$) of patients scored below 25. Of these patients, 65.4% ($n = 34$) were also considered to have multi-domain impairment on the neuropsychological battery. Using the < 25 cutoff, the positive predictive value was 65% and the negative predictive value was 65%. When we conducted the supplemental sensitivity and specificity analyses using single-domain impairment on the neuropsychological battery as the outcome, results indicated that the optimal cut-off for the MoCA remained 25 with sensitivity decreasing from .64 to .45, and specificity decreasing from .66 to .51. The sensitivity and specificity results for the single-domain impairment analyses yielded poor rates than the multi-domain analyses and thus are not presented (available upon request).

Although many studies use a MMSE cutoff of < 24 to indicate cognitive impairment, our analyses indicated that a cutoff of < 28 yielded better sensitivity and specificity (Table 3). On the MMSE, 42.5% ($n = 45$) of patients scored below 28. Of these patients, 82.2% ($n = 37$) were classified as having multi-domain cognitive impairment on the neuropsychological battery. The positive predictive value was 67% and the negative predictive value was 69% using the < 28 cutoff. Running the supplemental analyses using the single-domain impairment outcome, the optimal cut-off for the MMSE remained 28. Sensitivity decreased from .70 to .52, and specificity decreased from .66 to .45. Again, because the results indicated poorer sensitivity and specificity rates than the multi-domain analyses, they are not presented (available upon request).

Given that the cutoff scores of < 25 for the MoCA and < 28 for the MMSE had better classification accuracy in both the multi-domain and single-domain analyses, we used these cutoff scores for the discriminant function analyses.

The Performance of the MoCA in Detecting Cognitive Impairment

Impairment on the Overall Neuropsychological Battery

Multi-domain Impairment: First, a discriminant analysis for MoCA scores was conducted using the comprehensive neuropsychological battery (see Table 4). MoCA scores significantly differentiated cognitively impaired patients from normal patients. MoCA scores correctly classified 65.1% of patients according to the impaired and normal groups. MoCA scores correctly classified 35 patients (66.0%) as normal, and 34 patients (64.2%) were correctly classified as impaired.

Single-domain Impairment: MoCA scores did not significantly differentiate patients impaired on a single-domain from normal patients, Wilk's $\lambda = 1.0$, $\chi^2(1) = 0.06$, $p = .80$.

Impairment on an Individual Domain

Attention: Discriminant analysis comparing patients impaired and normal on tasks related to attention was also conducted (Table 4). MoCA scores significantly differentiated cognitively impaired and normal patients on tasks related to attention. MoCA scores correctly classified 66.0% of patients according to the impaired and normal groups. Although MoCA scores correctly classified 38 (65.5%) patients as normal on tasks related to attention, 32 (66.7%) were correctly classified as impaired on tasks of attention.

Executive Function: On tasks of executive function, discriminant analysis using the MoCA scores significantly differentiated impaired and normal patients (Table 4). MoCA scores correctly classified 76.40% of patients according to the impaired and normal groups. Although MoCA scores correctly classified 81 (100%) patients as normal on tasks of executive function, no participants were correctly classified as impaired.

Memory and Visuospatial: Discriminant analysis using MoCA scores did not significantly differentiate patients impaired on memory tasks from normal patients (Table 4). Likewise, the MoCA did not adequately classify patients on visuospatial task performance.

The Performance of the MMSE in Detecting Cognitive Impairment

Impairment on Overall Neuropsychological Battery

Multi-domain Impairment: Discriminant analyses were also conducted for MMSE scores (see Table 5). MMSE scores also differentiated cognitively impaired and normal on the comprehensive neuropsychological battery. MMSE scores correctly classified 67.9% of patients. Thirty-five (66%) patients were correctly classified as normal and 37 (69.8%) patients were classified as impaired.

Single-domain Impairment: MMSE scores did not significantly differentiate patients impaired on a single domain from normal patients, Wilk's $\lambda = 1.0$, $\chi^2(1) = 0.03$, $p = .85$.

Impairment on an Individual Domain

Attention: Discriminant analyses indicated that MMSE scores also successfully differentiated cognitively impaired and normal patients with HF on tasks of attention (Table 5). MMSE scores correctly classified 61.3% of patients as impaired on tasks of attention. Thirty-four (58.6%) patients were correctly classified as normal. Thirty-one (64.6%) patients were correctly classified as impaired.

Executive Function: MMSE scores also differentiated cognitively impaired and normal patients on tasks of executive function (Table 5). MMSE scores correctly classified 76.4% of patients on tasks of executive function. Although 81 (100.0%) patients were correctly classified as normal, no patients were correctly classified as impaired.

Memory and Visuospatial: MMSE scores did not significantly differentiate impaired and normal patients on tasks of memory performance or on visuospatial tasks (Table 5).

Discussion

According to the neuropsychological test battery, 50% of patients had multi-domain cognitive impairment, whereas 90% had impairment on at least one domain. The highest rates of impairment were found for the visuospatial and attention domains with lower rates observed for executive function and memory. Our rates of impairment in an outpatient sample are lower than those reported for inpatients (i.e., up to 80%) [3] and higher than those reported among nationally-representative community-dwelling samples (i.e., 15-25%) [3,6].

Using the standard cutoff of <26, the MoCA accurately classified nearly 80% of the individuals who were impaired across multiple domains and failed to screen out 60% individuals who were normal. When an alternative cutoff score (<25) was used, the classification accuracy was improved overall with an adequate sensitivity of 64% and improved specificity of 66%. Discriminant function analyses indicated that the MoCA significantly differentiated patients impaired on multiple domains from those who were normal. In particular, the MoCA successfully detected individuals with normal cognitive function (66% accuracy) as well as those with multi-domain cognitive impairment (64% accuracy). Changing the outcome to single-domain impairment decreased the MoCA's accuracy in detecting impaired (45%) and normal individuals (51%). With regard to specific cognitive domains, the MoCA was better in detecting impairments in attention, with correct classification of 66% of those with normal attention and 67% of those with impaired attention. However, this screener did not accurately classify those with impairments in executive function. One potential explanation for why the MoCA was better at detecting impairments in attention than in executive function (both frontal lobe tasks) is that neuropsychological testing in our sample yielded higher base rates of impairments in attention (45%) compared to executive function (24%) making it easier to detect attentional impairment. The MoCA also failed to discriminate between patients who had normal versus impaired memory or visuospatial performance.

A similar pattern emerged for the MMSE. Specifically, using the <28 cutoff score, the MMSE accurately categorized 70% individuals who had multi-domain impairment and failed to screen out 34% of normal individuals. Discriminant function analyses revealed that the MMSE differentiated multi-domain impaired and normal patients. However, the MMSE more accurately categorized individuals who had normal cognition (66% accuracy) compared to those who were impaired (70% accuracy). As with the MoCA, using single-domain impairment as the outcome decreased the MMSE's detection of impaired patients (52%) and normal patients (45%). Similar to the MoCA, the MMSE was a better detector of attention performance with 69% of normal and 63% of impaired patients correctly identified. The MMSE did not accurately classify those with impairments in executive function or successfully discriminate between patients who had normal or impaired memory or visuospatial performance.

Taken together, our results indicate that the MoCA and MMSE have adequate sensitivity and detect the majority (64-70%) of individuals with multi-domain impairment. Using single-domain impairment as a criterion was not as useful, as the tests detected only 45-52% of persons impaired in one or more domains. With regard to specificity, both tests incorrectly classified 34% of normal individuals as having multi-domain impairment. The results of the discriminant function analyses yielded a comparable pattern for the MoCA and MMSE. Regarding the detection of multi-domain impairment, most normal individuals (66%) were likely be correctly classified as normal when using either the MoCA or the MMSE. Impaired individuals were also likely to be correctly categorized as impaired, with a slightly higher percentage detected by the MMSE (70%) versus the MoCA (64%). When examining single-domain impairment, neither the MoCA nor MMSE were able to accurately discriminate between normal and impaired patients. Both tests were better at detecting impairments in attention compared to all other domains (i.e., executive function, memory, and visuospatial ability).

Practical Implications

The implications of our results for clinical practice are that providers can be confident that the majority of individuals with HF who score at or above the cutoffs on the MoCA or MMSE (25 and 28, respectively) are likely to be normal, as indicated by the adequate sensitivity of these tests and the results of our discriminant function analyses. Similarly, the specificity values for these tests indicate that the majority of individuals who score below these cutoffs are truly impaired and will likely require additional testing and follow-up. Accordingly, providers should know that both the MoCA and MMSE appear to be acceptable screeners for detecting multi-domain cognitive impairment with an adequate degree of confidence; however, it should be noted that approximately 1 in 3 patients will likely be incorrectly classified and continued monitoring and follow-up is warranted after screening. Sensitivity and specificity rates were lower for detection of single-domain impairment and the MoCA and MMSE could not discriminate between normal and impaired patients; thus, single-domain impairment may not be an ideal indicator of true deficits as classification based on a single domain has been shown to be unstable and result in misclassification [37].

Consequently, our results suggest that individuals scoring below the cutoffs on either test may benefit from a referral for more comprehensive neuropsychological testing to follow-up on potential deficits that may impair their HF self-management. Our findings are similar to other studies which have documented that screeners like the MoCA and MMSE have adequate sensitivity in HF [17,19] and other cardiovascular [18] populations although we obtained better specificity rates. Such studies have also pointed out that low specificity is a greater problem in populations in which cognitive impairment has a low base rate [18], which is not true of individuals with HF [3-5]. Importantly, the MoCA and MMSE can be quickly administered to persons with HF in 10-15 minutes and do not require testing kits or special materials that would burden providers. Thus, these tests can quickly alert providers to the need for referral for further testing if warranted, allowing for potential identification of more severe cognitive impairment which could compromise patient adherence or self-management. It is also important to note that cognitive impairment likely has multiple causes in patients with HF, including emotional factors such as depression [38,39]. Thus, if providers also administered a screener for depressive symptom severity (e.g., the Patient Health Questionnaire-9), this information could be used to clarify the potential contributors to cognitive dysfunction and guide treatment recommendations (e.g., prescribing an antidepressant in addition to providing medication reminders).

Limitations

Despite the strengths of this study, which include validation of cognitive impairment using a comprehensive neuropsychological battery as well as assessment of two different cognitive screeners, limitations should be noted. First, our sample size was modest and comprised mostly of older, white outpatients with Class II or III HF, an EF $\geq$ 40%, and at least a high school diploma. Thus, our findings may not generalize to other populations, including younger, non-white individuals, inpatients, or those with Class I or IV HF, preserved EF, and/or lower education levels. Next, we did not use age- and education-matched data from individuals with chronic heart failure in our norming procedure; however, this limitation is mitigated by previous work documenting that age- and education-matched norms from non-HF populations is an acceptable alternative to having chronic HF controls [36]. Lastly, although we used a comprehensive neuropsychological battery assessing several cognitive domains, our assessment of visuospatial ability was comprised of a single test, thereby potentially reducing its validity and reliability. Future studies should address these limitations through the following measures: 1) assessing a more diverse HF population across age, race-ethnicity, education, and HF severity levels, 2) including patients without HF who are matched for age and education, and 3) using multiple measures of visuospatial ability such as the Clock Drawing Test or the Hooper Visual Organization Task, given that we demonstrated that the highest rates of impairment may be in this domain.

Conclusions

In brief conclusion, we found that both the MoCA and MMSE are acceptable screeners for detecting cognitive impairment in individuals with HF as validated through a neuropsychological test battery. Individuals scoring below the cutoffs on either screener may benefit from a referral for more comprehensive neuropsychological testing to follow-up regarding the nature and extent of cognitive deficits. Given the adequate sensitivity of these

tests, individuals scoring above the cutoff scores are likely to be truly cognitive normal and may have no need for additional testing. However, it should be noted that 1 in 3 patients may not be correctly classified, so continued monitoring is warranted to detect potential decline. Despite less than ideal performance of the MoCA and MMSE in screening for cognitive impairment, the high rates of single-domain (21-79%) and multi-domain (50%) impairment in our sample highlight the need for continuing development, evaluation, and use of effective cognitive screening tools for individuals with HF.

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Abbreviations

HF	heart failure
MMSE	Mini Mental Status Examination
MoCA	Montreal Cognitive Assessment
SPMSQ	Short Portable Mental Status Questionnaire
VCI	vascular cognitive impairment
NYHA	New York Heart Association

Table 1
Demographic and Cognitive Characteristics of Participants (*n* = 106)

	<i>M(SD) or n(%)</i>
<i>Demographic and Medical Factors</i>	
Age	68.13(9.8)
Male	54 (49.1)
White	73 (68.9)
Education Level	
8 th Grade or Less	7(6.6)
9-11 th Grade	10(9.4)
High School	31 (29.2)
Technical or Trade School	13(12.3)
Some College	25(23.6)
Bachelor's Degree	11(10.4)
Master's Degree	9(8.5)
Heart Failure Severity (NYHA class)	
Class I	10 (9.4)
Class II	28 (26.4)
Class III	60 (56.6)
Class IV	8 (7.5)
<i>Cognitive Factors</i>	
MoCA	23.18 (3.9)
MMSE	26.78 (2.6)
Attention Domain ^a	43.10 (7.9)
Executive Function Domain ^a	45.00 (8.4)
Memory Domain ^a	48.20 (8.1)
Visuospatial Ability Domain ^a	49.12 (10.9)
Multi-domain impairment ^b	53 (50.0)
Single-domain impairment ^c	95 (89.6)

Note. NYHA = New York Heart Association. MoCA = Montreal Cognitive Assessment. MMSE = Mini-mental Status Exam. Means and standard deviations are presented for continuous variables. Sample size and percentages are presented for categorical variables.

^a Domain composite score created as an average of T-scores of domain-specific tests.

^b Multi-domain impairment defined as individuals impaired on 2 or more cognitive domains.

^c Single-domain impairment defined as individuals impaired on 1 or more cognitive domains.

Table 2
Sensitivity and Specificity of the MoCA for Detecting Neuropsychological Impairment in Heart Failure

MoCA cut-off	Overall Battery		Attention		Executive Function		Memory		Visuospatial Ability	
	Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity	Specificity
<22	.43	.79	.46	.79	.56	.75	.41	.70	.36	.82
<23	.49	.75	.52	.76	.64	.72	.41	.64	.38	.68
<24	.57	.68	.58	.67	.72	.64	.55	.58	.45	.59
<25	.64	.66	.67	.66	.80	.60	.64	.55	.49	.50
<26	.79	.40	.79	.38	.92	.37	.82	.33	.68	.23
<27	.94	.26	.94	.24	.96	.20	.91	.18	.85	.18
<28	.96	.11	.96	.10	.96	.09	.95	.08	.93	.09

Table 3
Sensitivity and Specificity of the MMSE for Detecting Neuropsychological Impairment in Heart Failure

Overall Battery		Attention		Executive Function		Memory		Visuospatial Ability	
MMSE cut-off	Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity
<23	.08	.98	.08	.98	.08	.96	.05	.95	.06
<24	.28	.92	.25	.88	.36	.88	.27	.85	.21
<25	.34	.92	.31	.88	.40	.85	.32	.82	.25
<26	.43	.87	.40	.81	.48	.78	.41	.75	.33
<27	.60	.75	.56	.69	.72	.67	.55	.61	.46
<28	.70	.66	.65	.59	.84	.58	.68	.52	.54
<29	.83	.49	.75	.40	.96	.42	.86	.38	.70
									.45

Table 4

Results of discriminant function analyses conducted for cognitive impairment on the MoCA.

	Eigenvalue	Canonical correlation	Wilk's lambda	χ^2	<i>p</i>
Overall Battery	.10	.30	.91	9.89	.002
Attention	.11	.32	.90	11.22	.001
Executive Function	.13	.34	.88	13.03	.000
Memory	.02	.15	.98	2.33	.127
Visuospatial Ability	.00	.01	1.00	.01	.922

Table 5

Results of discriminant function analyses conducted for cognitive impairment on the MMSE.

	Eigenvalue	Canonical correlation	Wilks' lambda	χ^2	<i>p</i>
Overall Battery	.15	.36	.87	14.26	.000
Attention	.06	.23	.95	5.68	.017
Executive Function	.15	.36	.87	14.12	.000
Memory	.03	.17	.97	2.92	.087
Visuospatial Ability	.00	.07	1.0	0.45	.502