Published in final edited form as:
Stroke. 2014 November ; 45(11): 3337–3342. doi:10.1161/STROKEAHA.114.006309.

Validation of the MoCA versus MMSE against hypertension and hypertensive arteriopathy after TIA or minor stroke

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Abstract

Background and Purpose—Lack of reduced cognitive impairment with blood pressure (BP) lowering in trials may reflect use of the Mini-Mental State Examination (MMSE), which is insensitive to mild cognitive impairment after cerebrovascular events compared to the Montreal Cognitive Assessment (MOCA). We determined relationships between impairment on MMSE vs. MoCA with the major physiological determinant of vascular cognitive impairment: hypertension and hypertensive arteriopathy.

Methods—Cognitive impairment in consecutive patients 6 months after TIA or minor stroke was defined as “significant”, “mild” or “none” (MMSE<23,23-26,≥27; MOCA<20,20-24,≥25) and related to 20 premorbid systolic blood pressure (SBP) readings, home BP (HBPM, 3 measurements, 3 times daily for one month) and hypertensive arteriopathy (creatinine, stroke vs TIA, leukoaraiosis), by ordinal regression.

Results—Of 463 patients, 45% vs 28% had at least mild cognitive impairment on the MOCA vs MMSE (p<0.001). Hypertensive arteriopathy was more strongly associated with cognitive impairment on the MOCA than MMSE (Creatinine:OR=3.99, 95%CI 2.06-7.73 vs 2.16, 1.08-4.33; event:1.53, 1.06-2.19 vs 1.23, 0.81-1.85; leukoaraiosis:2.09, 1.42-3.06 vs 1.34, 0.87-2.07). Premorbid and HBPM SBP were more strongly associated with impairment on vascular subdomains of the MoCA than MMSE (OR/10mmHg: visuo-spatial 1.29 vs 1.05; attention 1.18 vs 1.07; language 1.22 vs 0.91; naming 1.07 vs 0.86).

Conclusions—The stronger relationship between impairment on the MoCA with hypertensive arteriopathy, independent of age, indicates a greater sensitivity for vascular-origin cognitive impairment. Use of MoCA should improve sensitivity for cognitive impairment and treatment effects in future studies.

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Disclosures
None

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Introduction

Vascular cognitive impairment may result from chronic subcortical arteriopathy1 or acute cerebrovascular events, especially on the background of reduced cerebrovascular reserve.2 Hypertension is the strongest risk factor for both acute cerebrovascular events3 and subcortical arteriopathy,4 and is strongly associated with cognitive impairment.5 However, randomised controlled trials (RCTs) of antihypertensive medications6–7 have not demonstrated consistent delays in cognitive decline despite reductions in BP. One explanation is that most studies used the Mini-Mental State Examination (MMSE) to screen for cognitive decline, which is optimised for detecting Alzheimer's-type cognitive impairment with early language and memory dysfunction, but not for early visuo-spatial and executive dysfunction seen in vascular-type impairment.

Recent studies after TIA or minor stroke reported higher rates of cognitive impairment on the Montreal Cognitive Assessment (MOCA) versus MMSE,8–9 due partly to the visuo-spatial / executive components of the MOCA and the greater sensitivity to single-domain cognitive impairment.10–12 However, these studies compared the short tests with a more detailed cognitive battery, and it remains uncertain whether the MOCA is a better marker than the MMSE of underlying cerebrovascular damage or if it will better predict progression to dementia. It is possible that the MOCA is simply a harder test and is not specific for clinically relevant vascular cognitive impairment

If the additional cognitive impairment identified by the MOCA is related to vascular disease then cognitive impairment on the MOCA, particularly in visuo-executive and attentional domains, should be more strongly associated with hypertension and hypertensive arteriopathy than on the MMSE, identifying a population at increased risk of future cognitive decline10 In a population-based study of TIA and non-disabling stroke, we therefore compared the association between cognitive impairment on the MOCA and the MMSE with premorbid or current hypertension and hypertensive arteriopathy.

Methods

Consecutive patients were recruited between April 2008 and January 2012 from the Oxford Vascular Study (OXVASC) TIA and minor stroke clinic, usually within twenty-four hours of referral.13 The OXVASC population consists of about 92,000 individuals registered with 100 primary-care physicians in Oxfordshire, UK. Patients with possible TIA or minor stroke are referred by the OXVASC general practitioners (GPs) or Emergency Department staff to the OXVASC study clinic. All consenting patients with probable TIA or minor stroke are reviewed by a stroke physician including a standardised medical history and examination, ECG and routine blood tests, with face-to-face follow up at 1,3,6,12 and 60 months. Patients undergo a stroke protocol MRI brain and contrast-enhanced MRA of the extracranial brain-supplying arteries unless contraindicated, with the remaining patients having a CT-brain and either a carotid Doppler ultrasound or CT-angiogram. Most patients also undergo transcranial Doppler ultrasound, echocardiography and 5 days of ambulatory cardiac monitoring.

Procedures

The MMSE was administered at the beginning and the MoCA at the end of a 45-min appointment at 6 months follow up. Subjects who were unable to complete cognitive testing owing to dysphasia, inability to use the dominant arm, illness or poor English were excluded as described previously.9–10 A score of ≥27 on the MMSE14 and ≥25 on the MoCA15 indicated normal cognitive function, with scores of <23 on the MMSE and <20 on the MOCA indicating significant cognitive impairment likely to impair function, according to recommendations from previous TIA and stroke cohorts.8–9,16

Clinic BP was measured twice at ascertainment and the one month follow-up visit in the non-dominant arm, by trained personnel, in the sitting position after five minutes of rest. The lifetime medical record held by the primary care physician was manually reviewed and all recorded premorbid BPs ascertained. Up to 20 readings were used for determination of premorbid BP, with sensitivity analyses using readings during the last 5 years or from 5-10 years before the event.

From the day of recruitment to at least one month, patients performed sets of three home BP measurements (HBPM), three times daily (on waking, mid-morning and before sleep) with a Bluetooth-enabled, regularly-calibrated, telemetric IEM Stabil-o-Graph or A&D UA-767BT BP monitor. Patients were instructed to perform readings in the non-dominant arm, or the arm with the higher reading if the mean SBP differed by >20mmHg between arms, after 5 minutes of sitting. At the 1 month follow-up, 24-hour ambulatory measurements (ABPM) were performed with an A&D TM-2430 monitor in the non-dominant arm, fitted by a trained study nurse, at 30 minutes intervals during the day and 60 minute intervals at night. During readings, patients were asked to avoid excessive activity, to sit down, and to keep a diary of the day.

Patients continued HBPM after one month, if required, until adequate BP control was achieved. Mean BP was treated to a target of <130/80 on HBPM or ABPM, except in the presence of haemodynamically significant stenosis (bilateral carotid stenosis >70% or end-artery stenosis >70%) when targets were determined individually. Antihypertensive treatment was tailored to the individual patient but most commonly was a combination of perindopril arginine 5mg and indapamide 1.25mg, followed by amlodipine 5-10mg with subsequent choices at the physician's discretion.

Leukoaraiosis was assessed on axial T2 scans according to the Fazekas scale17 and on both MRI and CT on a simple 4 point scale: 'None', 'Mild,' 'Moderate' or 'Severe' by experienced observers (MS/LL) blinded to clinical and physiological data.18 Creatinine was measured at ascertainment. Finally, the nature and severity of the initial event was categorised as stroke or TIA, as a marker of degree of end-organ injury associated with a history of hypertension.

Analysis

Mean and maximum systolic BP (SBP) and diastolic BP (DBP) on HBPM were derived from the last 2 readings at each timepoint, including readings from 7 days after the initial assessment. Mean and maximum SBP and DBP on awake 24-hour ABPM were derived

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following automated and manual exclusion of artefactual measurements according to predefined criteria.19 Mean premorbid SBP and DBP were derived from the last 20 years recorded in the primary care record, from readings in the five years prior to the notification event and from readings 5-10 years prior to this event.

MoCA and MMSE scores were categorised as 'None', 'Mild' or 'Significant' cognitive impairment as defined above. Relationships with discrete variables were determined by chi-squared tests whilst relationships with continuous measures were determined by ANOVA, with post-hoc comparisons of 'Significant' vs 'None' (Tukey). Association of level of cognitive impairment with hypertensive arteriopathy, leukoaraiosis and demographic characteristics was determined by ordinal regression. All analyses were performed before and after adjustment for age and gender.

Results

Of 492 patients with cognitive assessments (95% of all patients), 463 (94%) had both an MMSE and a MoCA performed, of whom 452 (98%) performed HBPM, 427 (92%) had at least 3 premorbid BPs recorded and 422 (91%) had a 24-hour ABPM at 1 month. There were a median of 31 (22-71) days of HBPM (mean 8.7 readings per day) and 15 (6-31) premorbid BP readings on separate occasions per patient. The mean age was 69.2 (SD 12.9), 53% were men, 55% hypertensive, 15% diabetic, 40% had known dyslipidaemia and 14% were current smokers.

More patients had at least mild cognitive impairment (45% vs 28%, $p<0.001$) and more had significant cognitive impairment (14.3% vs 6.7%, $p<0.001$) on the MoCA versus the MMSE despite similar demographic characteristics (table I in the online-only Data Supplement). There was no significant difference in number of BPs performed by patients with significant cognitive impairment compared to non-cognitively impaired patients (mean home BPs: significantly impaired vs not: MOCA 102 vs 119, $p=0.12$; MMSE 92 vs 119, $p=0.08$).

Mean and maximum home SBP were higher in patients with significant cognitive impairment when defined by the MoCA than the MMSE compared to patients with mild or no cognitive impairment, with a significant trend across the three groups (table 1). There were no consistent differences for mean or maximum DBP when patients were classified according to either test. Awake mean and maximum SBP on ABPM at one month after ascertainment were also higher in patients with significant cognitive impairment, but only when defined according to the MoCA (table 1), whilst premorbid mean and maximum SBP increased systematically across all levels of cognitive impairment on the MoCA. In contrast, on the MMSE patients with mild cognitive impairment had the highest premorbid mean SBP, with no significant difference between significantly cognitively impaired patients and non-impaired patients (table 1). Markers of hypertensive arteriopathy were more strongly associated with cognitive impairment on the MoCA than the MMSE (table 2) with a stronger relationship for patients with stroke vs. TIA, a higher creatinine and more frequent and more severe leukoaraiosis, at least prior to adjustment.

All cognitive subdomains were more strongly associated with mean SBP on the MoCA than on the MMSE, except for orientation. However, the visuo-spatial/executive sub-domain of the MOCA was most strongly associated with mean SBP before and after adjustment for age and gender (table II in the online-only Data Supplement), with a 29% greater chance of a lower score per 10mmHg increase in SBP. Drawing inter-locking pentagons, the only visuo-spatial / executive test on the MMSE, was also strongly associated with mean SBP on HBPM (table 3), but the only other domains associated with mean BP were weak univariate associations with recall and orientation. This partly reflected a ceiling effect with the MMSE, with more patients achieving full marks in most domains: visuo-spatial (MMSE 84% vs MoCA 37.6%, $p<0.001$); language (91.4% vs 37.1%, $p<0.001$); naming (98.5% vs 82.3%, $p<0.001$); recall (52.9% vs 13%, $p<0.001$); orientation (74.7% vs 79.7%, $p<0.001$). However, the visuo-spatial domain determined a greater proportion of the inter-individual variance in total score with the MoCA compared to the MMSE (15.6% vs 8.1% of total variance uniquely explained by sub-domains).

Discussion

Cognitive impairment detected by the MoCA after TIA or non-disabling stroke was strongly associated with hypertensive arteriopathy and an elevated mean and maximum SBP on post-event HBPM, on 24-hour ABPM and on premorbid BP readings. The MoCA test was significantly more sensitive than the MMSE at screening for hypertension-associated cognitive impairment due to stronger associations within all cognitive sub-domains and a greater contribution of visuo-spatial / executive tests to the total MOCA score.

Dementia affects 5-7% of people ≥60 years old worldwide, costing EU-15 countries approximately $189 billion per year, increasing to approximately 115 million people by 2050.20 However, there is currently no effective treatment for the prevention of either the onset or progression of cognitive impairment. Hypertension5 and cerebrovascular disease2 are particularly strongly associated with dementia and are the most modifiable risk factors for the prevention of cognitive decline. Unfortunately, whilst randomisation to a nitrendipine-based regimen in the Syst-Eur trial21 reduced the future risk of cognitive decline, this has not been consistently replicated in secondary prevention studies6–7 and not confirmed by meta-analyses.22 However, trials have predominantly used the MMSE for cognitive screening even though it is insensitive to milder impairment and to visuo-spatial/executive dysfunction, which are preferentially affected in vascular cognitive impairment6 and result in significant functional impairment and death.23

In previous studies, the MoCA defined more patients as being cognitively impaired than the MMSE in populations with cerebrovascular disease,10–12 had a greater sensitivity for cognitive impairment defined by a gold-standard neuropsychological battery9,11 and showed greater differences in cognitive profile between TIA and stroke patients, memory research subjects23 and patients with coronary disease.24 Unfortunately, these studies, including those from our group, have not compared tests with physiological measures that are independent of cognitive assessment, and could simply indicate that the MoCA is a harder test. Our study demonstrated a strong physiological association between the additional cognitive impairment identified by the MoCA test and both premorbid

hypertension and hypertensive arteriopathy, including powerful markers of systemic small-vessel arteriopathy that occurs both as a result and cause of hypertension, such as creatinine25 and leukoaraiosis,4 suggesting a physiological basis for the additional sensitivity of the MoCA.

The improved sensitivity of the MoCA for hypertension-associated cognitive impairment was found across multiple cognitive domains due to ceiling effects with the MMSE, but the strongest association was for visuo-spatial/executive dysfunction. This contributed more to variation in the overall MoCA score than in the MMSE score, resulting in greater overall sensitivity for vascular-type cognitive impairment associated with hypertension10 and cerebrovascular disease.1 Previous studies have not validated the subdomains of the MoCA, despite these domains being built into its design. Therefore, our study also provides the first objective validation of these subdomains for vascular-type cognitive impairment. Furthermore, our study suggests that the failure of RCTs to demonstrate improvements in cognitive dysfunction with BP-reduction may partly result from the low sensitivity of the MMSE for screening for hypertension-associated, vascular cognitive impairment. Use of the MoCA should be more effective at detecting clinically important reductions in cognitive decline following BP treatment.

After a stroke, cognitive dysfunction can result from the effects of the cerebrovascular event itself,8 from associated small vessel disease,10 from recurrent events8 or from a combination of these and co-existing neurodegenerative disease.8,26 Therefore, cognitive impairment on the MoCA may identify patients at a particularly increased risk of future cognitive decline due to both chronic cerebrovascular disease and recurrent cerebrovascular events, who may particularly benefit from BP reduction. Trials utilising the MoCA in this population may be more sensitive to benefits of BP-lowering treatment, which has previously been difficult to demonstrate in primary prevention populations.

Our study has limitations. Firstly, although our sample was population-based it included relatively healthy patients with cerebrovascular disease able to perform HBPM, and excluded patients with severe dementia or major stroke. This limits generalizing the results to patients with major stroke but reduces the probability of selection bias favouring patients with right hemisphere strokes. However, this is the ideal population where strategies to prevent cognitive decline may bring the greatest benefits. Secondly, there is currently insufficient follow-up to determine whether the MoCA was sensitive or specific for the progression of hypertension-associated cognitive impairment or the development of dementia. The alternative approach of validating the MoCA and MMSE against more detailed neuropsychological testing also suggested that the MoCA had greater diagnostic accuracy for MCI.9 However, simply because one cognitive test is better correlated with another does not necessarily mean that it is the best. Our new observations that the MoCA is more strongly associated with physiological measures provides additional evidence of utility that avoids the shortcomings of using other cognitive tests as the gold standard. Thirdly, there was no formal assessment of depression which could have an effect on the cognitive scores. Fourthly, the MMSE was routinely performed at the start and the MoCA at the end of each follow up appointment, and therefore there is a theoretical risk of some systematic difference in performance. However, this would not be expected to bias the associations with

independent physiological measures or selectively affect the association with more specific vascular cognitive subdomains. Fifthly, there were non-significantly fewer BPs recorded by patients with greater cognitive impairment. However, less accurate recordings in more cognitively impaired patients would be expected to increase the variance in readings in this group, and reduce any association with hypertension. Finally, premorbid BP readings were not available in some patients, but these were largely young patients without any cognitive impairment.

Conclusions

The MoCA identified more hypertension-associated cognitive impairment than the MMSE, implying a pathophysiologically relevant basis for differences between scores. This results from a greater sensitivity to hypertension-associated cognitive impairment in multiple subdomains, but particularly due visuo-spatial/executive dysfunction. The poor sensitivity of the MMSE to hypertension-associated cognitive impairment may explain the lack of efficacy of antihypertensive medications in RCTs. Future studies should determine whether the MoCA may identify a cohort of patients at a particularly increased risk of future cognitive decline in whom targeted BP-lowering treatment may be of benefit.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

We acknowledge the use and facilities of the Acute Vascular Imaging Centre, Oxford.

Funding Sources

OXVASC is funded by the Wellcome Trust, UK Medical Research Council, Dunhill Medical Trust, Stroke Association, National Institute for Health Research (NIHR), Thames Valley Primary Care Research Partnership, and the NIHR Biomedical Research Centre, Oxford. PMR is in receipt of a NIHR and Wellcome Trust Senior Investigator Awards.

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References

1. Verdelho A, Madureira S, Moleiro C, Ferro JM, Santos CO, Erkinjuntti T, et al. the LADIS Study. White matter changes and diabetes predict cognitive decline in the elderly: the LADIS study. Neurology. 2010; 75:160–167. [PubMed: 20625169]
2. Pendlebury ST, Rothwell PM. Prevalence, incidence and factors associated with pre-stroke and post-stroke dementia: a systematic review and meta-analysis. Lancet Neurol. 2009; 8:1006–1018. [PubMed: 19782001]
3. Rothwell PM, Giles MF, Flossman E, Lovelock CE, Redgrave JNE, Warlow CP, et al. A simple score (ABCD) to identify individuals at high early risk of stroke after transient ischaemic attack. Lancet. 2005; 366:29–36. [PubMed: 15993230]
4. Khan U, Porteous L, Hassan A, Markus HS. Risk factor profile of cerebral small vessel disease and its subtypes. JNNP. 2007; 78:702–706.
5. Qiu C, Winblad B, Fratiglioni L. The age-dependent relation of blood pressure to cognitive function and dementia. Lancet Neurol. 2005; 4:487–499. [PubMed: 16033691]
6. The PROGRESS Collaborative Group. Effects of blood pressure lowering with perindopril and indapamide therapy on dementia and cognitive decline in patients with cerebrovascular disease. Arch Intern Med. 2003; 163:1069–1075. [PubMed: 12742805]

7. Diener HC, Sacco RL, Yusuf S, Cotton D, Ounpuu S, Lawton WA, et al. Effects of aspirin plus extended-release dipyridamole versus clopidogrel and telmisartan on disability and cognitive function after recurrent stroke in patients with ischaemic stroke in the Prevention Regimen for Effectively Avoiding Second Strokes (PRoFESS) trial: a double-blind, active and placebo-controlled study. Lancet Neurol. 2008; 7:875–884. [PubMed: 18757238]
8. Pendlebury ST, Cuthbertson FC, Welch SJ, Mehta Z, Rothwell PM. Underestimation of cognitive impairment by Mini-Mental State Examination versus the Montreal Cognitive Assessment in patients with transient ischaemic attack and stroke: a population-based study. Stroke. 2010; 41:1290–1293. [PubMed: 20378863]
9. Pendlebury ST, Mariz J, Bull L, Mehta Z, Rothwell PM. MoCA, ACE-R and MMSE versus the NINDS-CSN VCI Harmonisation Standards Neuropsychological Battery after TIA and stroke. Stroke. 2012; 43:464–469. [PubMed: 22156700]
10. Pendlebury ST, Markwick A, de Jager CA, Zamboni G, Wilcock GK, Rothwell PM. Differences in cognitive profile between TIA, stroke and elderly memory research subjects: A comparison of the MMSE and MoCA. Cerebrovasc Dis. 2012; 34:48–54. [PubMed: 22759627]
11. Godefroy O, Fickl A, Roussel M, Auribault C, Bugnicourt JM, Lamy C, et al. Is the Montreal Cognitive Assessment superior to the Mini-Mental State Examination to detect poststroke cognitive impairment? A study with neuropsychological evaluation. Stroke. 2011; 42:1712–1716. [PubMed: 21474808]
12. Dong Y, Sharma VK, Chan BP, Venketasubramanian N, Teoh HL, Seet RC, et al. The Montreal Cognitive Assessment (MoCA) is superior to the Mini-Mental State Examination (MMSE) for the detection of vascular cognitive impairment after acute stroke. J Neurol Sci. 2010; 299:15–18. [PubMed: 20889166]
13. Rothwell PM, Giles MF, Chandratheva A, Marquardt L, Geraghty O, Redgrave JNE, et al. on behalf of the Early use of Existing Preventive Strategies for Stroke (EXPRESS) study. Lancet. 2007; 370:1432–1442. [PubMed: 17928046]
14. Tombaugh TN, Mcintyre NJ. The Mini-Mental State Examination: a comprehensive review. J Am Geriatr Soc. 1992; 40:922–935. [PubMed: 1512391]
15. Damian AM, Jacobson SA, Hentz JG, Belden CM, Shill HA, Saggagh MN, et al. The Montreal Cognitive Assessment and the Mini-Mental State Examination as screening instruments for cognitive impairment: item analyses and threshold scores. Dement Geriatr Cogn Disord. 2011; 31:126–131. [PubMed: 21282950]
16. Nasreddine ZS, Phillips NA, Bédirian V, Charbonneau S, Whitehead V, Collin I, et al. The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. J Am Geriatr Soc. 2005; 53:695–699. [PubMed: 15817019]
17. Pantoni L, Simoni M, Pracucci G, Schmidt R, Barkhof F, Inzitari D. Visual rating scales for age-related white matter changes leukoaraiosis): can the heterogeneity be reduced? Stroke. 2002; 33:2827–2833. [PubMed: 12468777]
18. Simoni M, Li L, Paul NL, Gruter BE, Schulz UG, Küker W, Rothwell PM. Age- and sex-specific rates of leukoaraiosis in TIA and stroke patients: population-based study. Neurology. 2012; 79:1215–22. [PubMed: 22955138]
19. Casadei R, Parati G, Pomidossi G, Gropelli A, Trazzi S, Di Rienzo M, et al. 24-Hour blood pressure monitoring: evaluation of Spacelabs 5300 monitor by comparison with intra-arterial blood pressure recording in ambulant subjects. J Hypertens. 1988; 6:797–803. [PubMed: 3198917]
20. Prince M, Bryce R, Albanese E, Wimo A, Ribeiro W, Ferri CP. The global prevalence of dementia: a systematic review and metaanalysis. Alzh Dement. 2013; 9:63–75.
21. Forette F, Seux ML, Staessen JA, Thijs L, Birkenhager WH, Babarskiene MR, et al. Prevention of dementia in randomised double-blind placebo-controlled Systolic Hypertension in Europe (Syst-Eur) Trial. Lancet. 1998; 352:1347–1351. [PubMed: 9802273]
22. McGuiness B, Todd S, Passmore P, Bullock R. Blood pressure lowering in patients without prior cerebrovascular disease for prevention of cognitive impairment and dementia (Review). Cochrane Database of Systematic Reviews. 2009; (4) Art.No:CD004034.
23. Smith T, Gildeh N, Holmes C. The Montreal Cognitive Assessment: validity and utility in a memory clinic setting. Can J Psychiatry. 2007; 53:329–332. [PubMed: 17542384]

24. Volonghi I, Pendlebury ST, Welch SJ, Mehta Z, Rothwell PM. Cognitive outcomes after acute coronary syndrome: a population based comparison with transient ischaemic attack and minor stroke. Heart. 2013; 99:1509–14. [PubMed: 23872589]

25. Turner ST, Rule AD, Schwartz GL, Kullo IJ, Mosley TH, Jack CR, et al. Risk factor profile for chronic kidney disease is similar to risk factor profile for small artery disease. J Hypertens. 2011; 29:1796–801. [PubMed: 21720267]

26. Pendlebury ST, Wadling S, Silver LE, Mehta Z, Rothwell PM. Transient cognitive impairment in TIA and minor stroke. Stroke. 2011; 42:3116–3121. [PubMed: 21903955]

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Table 1

Differences in mean and maximum SBP on home, ambulatory and premorbid readings, in patients with different degrees of cognitive impairment defined by MMSE versus MOCA.

Differences across levels of impairment are compared by ANOVA, with post-hoc comparisons between no impairment and significant impairment, with and without adjustment for age and gender. *p<0.05, **p<0.01, ***p<0.001.

	Degree of cognitive impairment						Unadjusted		Adjusted	
	Significant		Mild		None		ANOVA p-val	None vs Sig	ANOVA p-val	None vs Sig
HBPM										
Mean										
MOCA	**129.9**	(125.9 - 133.9)	**124.6**	(122.7 - 126.6)	**121.7**	(120.2 - 123.2)	<0.001***	<0.001***	<0.001***	<0.001***
MMSE	**127.3**	(122.8 - 131.7)	**125**	(122.4 - 127.7)	**123**	(121.6 - 124.4)	0.12	0.19	0.38	0.27
Maximum										
MOCA	**159.3**	(153.3 - 165.3)	**153.6**	(150.6 - 156.5)	**148.2**	(145.9 - 150.6)	<0.001*	<0.001*	0.044*	0.017*
MMSE	**156.5**	(148.7 - 164.3)	**153.6**	(149.7 - 157.6)	**150.3**	(148.2 - 152.5)	0.12	0.22	0.74	0.61
ABPM										
Mean										
MOCA	**131.4**	(127.2 - 135.7)	**126.9**	(124.7 - 129.1)	**126.5**	(125.1 - 127.9)	0.028*	0.022*	0.009**	0.002**
MMSE	**128.5**	(123.1 - 133.9)	**127**	(124.4 - 129.7)	**127.3**	(125.9 - 128.6)	0.87	0.88	0.8	0.5
Maximum										
MOCA	**168.4**	(161.9 - 174.8)	**162.6**	(159.3 - 165.9)	**160.8**	(158.2 - 163.4)	0.045*	0.035*	0.15	0.17
MMSE	**165.5**	(155.5 - 175.5)	**162.6**	(158.3 - 166.9)	**161.9**	(159.7 - 164.2)	0.68	0.66	0.68	0.39
Premorbid										
Mean										
MOCA	**143.4**	(140.3 - 146.5)	**140.2**	(138.2 - 142.2)	**135.3**	(133.4 - 137.1)	<0.001***	<0.001****	0.018*	0.01**
MMSE	**138.9**	(134.6 - 143.2)	**141.8**	(139.5 – 144.1)	**136.7**	(135.2 - 138.3)	0.007**	0.68	0.05	0.58
Maximum										
MOCA	**170.9**	(164.9 - 176.9)	**164.5**	(161.1 - 167.9)	**155.9**	(153.0 – 158.96)	<0.001***	<0.001***	<0.001***	<0.001***
MMSE	**162.9**	(155.4 – 170.4)	**168.0**	(163.5 – 172.6)	**158.5**	(155.9 – 161.0)	0.002**	0.56	0.02*	0.61

Stroke. Author manuscript; available in PMC 2016 July 28.

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Table 2

Risk of lower cognitive scores on the MOCA or MMSE with increased markers of hypertensive arteriopathy.

Odds ratios (OR) are derived from ordinal regression for the risk of being in a lower category of each score: no impairment, mild impairment or significant impairment. ORs are given per 10 μmol/L for creatinine.

	MOCA			MMSE		
	OR	**CI**	**P-val**	**OR**	**CI**	**P-val**
Univariate Model						
Creatinine	3.99	(2.06 – 7.73)	<0.001*	2.16	(1.08 – 4.33)	0.029*
Stroke vs TIA	1.53	(1.06 – 2.19)	0.022*	1.23	(0.81 – 1.85)	0.33
Leukoaraiosis						
Any	2.02	(1.39 – 2.94)	<0.001*	1.60	(1.05 – 2.46)	0.03*
Moderate/Severe	2.09	(1.42 – 3.06)	<0.001*	1.34	(0.87 – 2.07)	0.18
Adjusted Model						
Creatinine	2.81	(1.35 – 5.85)	<0.001*	1.81	(0.83 – 3.94)	0.14
Stroke vs TIA	1.52	(1.05 – 2.21)	0.03*	1.20	(0.79 – 1.81)	0.40
Leukoaraiosis						
Any	1.25	(0.82 – 1.90)	0.30	1.06	(0.66 – 1.72)	0.81
Moderate/Severe	1.33	(0.88 – 2.02)	0.18	0.91	(0.57 – 1.46)	0.70

Table 3

Risk of having a lower score on each subdivision of the MOCA and MMSE per 10mmHg increase in mean SBP.

Effect sizes are derived from ordinal regression for each cognitive subdomain, adjusted for age and gender. HBPM = home BP monitoring; ABPM = ambulatory BP monitoring; premorbid = up to the last 20 readings recorded in primary care.

	MOCA			MMSE		
	OR	**CI**	**P-val**	**OR**	**CI**	**P-val**
HBPM						
Visuo-Spatial	1.24	(1.08 - 1.42)	0.002**	1.29	(1.07 - 1.56)	0.009**
Attention	1.26	(1.10 - 1.45)	<0.001***	1.09	(0.95 - 1.26)	0.20
Language	1.18	(1.03 - 1.35)	0.015*	1.17	(0.92 - 1.49)	0.20
Naming	1.18	(0.97 - 1.42)	0.1	0.91	(0.49 - 1.71)	0.78
Recall	1.13	(1.00 - 1.29)	0.06	1.06	(0.92 - 1.22)	0.41
Orientation	1.14	(0.96 - 1.36)	0.14	1.13	(0.96 - 1.33)	0.13
Abstraction	1.09	(0.95 - 1.26)	0.21	-		
ABPM						
Visuo-Spatial	1.08	(0.94 - 1.25)	0.29	1.04	(0.84 - 1.29)	0.71
Attention	1.2	(1.03 - 1.39)	0.016*	1.15	(0.99 - 1.33)	0.06
Language	1.18	(1.03 - 1.36)	0.02*	1.06	(0.81 - 1.4)	0.66
Naming	1.25	(1.02 - 1.52)	0.033*	0.89	(0.45 - 1.79)	0.75
Recall	1.06	(0.92 - 1.21)	0.43	0.95	(0.82 - 1.11)	0.52
Orientation	1.17	(0.97 - 1.41)	0.09	1.11	(0.94 - 1.33)	0.23
Abstraction	1.03	(0.88 - 1.19)	0.75	-		
Premorbid						
Visuo-Spatial	1.29	(1.12 - 1.48)	<0.001***	1.05	(0.85 - 1.31)	0.64
Attention	1.18	(1.02 - 1.36)	0.025*	1.07	(0.92 - 1.24)	0.38
Language	1.22	(1.06 - 1.41)	0.005**	0.91	(0.69 - 1.2)	0.5
Naming	1.07	(0.86 - 1.33)	0.56	0.86	(0.44 - 1.67)	0.66
Recall	1.06	(0.93 - 1.21)	0.4	1.07	(0.93 - 1.25)	0.34
Orientation	0.92	(0.76 - 1.12)	0.4	0.96	(0.81 - 1.15)	0.69
Abstraction	1.16	(0.99 - 1.35)	0.044*	-		