RESUSCITATION 172 (2022) 130–136

Available online at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

The Montreal Cognitive Assessment is a valid cognitive screening tool for cardiac arrest survivors

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Abstract

Aim: The survival rate of out-of-hospital cardiac arrest (OHCA) patients has increased over the past decades. This gives rise to a growing number of patients with hypoxic-ischemic brain damage and cognitive impairment. Currently, cognitive impairment is underdiagnosed in OHCA patients. There is a need for a validated cognitive screening instrument to identify patients with cognitive impairment. This study aimed to examine the diagnostic value of the Montreal Cognitive Assessment (MoCA) in patients after OHCA.

Methods: Survivors (age $\geq$ 18 years) of OHCA completed the MoCA and a gold standard neuropsychological test battery, including tests for memory, attention, perception, language, reasoning, and executive functioning, at around one year after OHCA. Results of the MoCA are related to the results of the neuropsychological test battery. Analyses of diagnostic accuracy included receiver operating characteristics and calculation of predictive values.

Results: We included 54 OHCA survivors (mean age = 57.3, 74% male). The area under the curve (AUC) was 0.8, 95% CI [0.67, 0.93]. The MoCA showed excellent sensitivity of 86%, 95% CI [57, 98] and adequate specificity of 70.0%, 95% CI [53, 83] to detect cognitive impairment at the regular cut-o score of 26. The positive predictive value of the MoCA was 50%, 95% CI [30, 70] and the negative predictive value was 93%, 95% CI [76, 99].

Conclusion: This study shows that the MoCA may be a valid cognitive screening instrument for use in the OHCA patient population.

Keywords: Cardiac arrest, Cognitive impairment, Montreal Cognitive Assessment tool, Cognitive screening tool

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https://doi.org/10.1016/j.resuscitation.2021.12.024
Received 5 November 2021; Received in Revised form 20 December 2021; Accepted 21 December 2021

Introduction

The global incidence of out-of-hospital cardiac arrest (OHCA) with cardiac aetiology is estimated at approximately 0.50 –0.55 events per 1000 citizens a year, with large variations across regions.[1] The survival rate of OHCA patients worldwide has drastically increased in the past decades.[2,3] This is due to education of basic life support to a wide range of civilians, widespread numbers of automated external defibrillators, and improvements in the healthcare system.

During a cardiac arrest, the bloodflow to the brain is temporarily disrupted. For some time, the brain is depleted from oxygen and glucose, which can lead to hypoxic-ischemic brain damage causing cognitive impairments. Roughly 50% of patients surviving cardiac arrest are left with cognitive impairments.[4–6] These impairments mainly involve the domains of memory, attention, and executive functioning.[5] The increasing rate of OHCA survivors gives rise to a growing number of people suffering from long-term cognitive consequences.

There is a discrepancy between reported cognitive complaints and objectively measured impairments. Contrary to, for example, stroke and traumatic brain injury, the percentage of complaints in cardiac arrest patients appears to be lower than the percentage of impairments.[7] Hence, a large proportion of the patients is unlikely to report complaints or seek help.

Nevertheless, the impairments do influence daily functioning of the patient. Studies have shown that cognitive impairments of OHCA patients are significantly associated with lower participation in society and decreased quality of life.[8,9]

Because cognitive complaints are not always indicative of actual cognitive impairments in OHCA patients, it is crucial to actively identify patients with cognitive impairments. Early recognition and attention for cognitive impairments have a positive effect on the quality of life a year after cardiac arrest.[10] In the literature, the Montreal Cognitive Assessment (MoCA) is suggested as a suitable screening instrument to identify cognitive impairments after OHCA.[11,12] The MoCA has been reported to have good internal consistency (Cronbach's alpha = 0.83),[13] and good construct validity[14] in both healthy controls as in several patient populations. The MoCA has shown to be a valid and reliable instrument for cognitive impairment screening in stroke[15] and other forms of acquired brain injury,[16] but has not been validated yet in OHCA patients.

By routinely implementing a time-efficient cognitive screening tool like the MoCA, cognitive impairments in OHCA patients can be identified at an early stage and proper care can be provided.[4] To our knowledge, one previous study has examined the MoCA as a screening tool for cognitive impairment after cardiac arrest.[17] These findings were promising. This will be the first study to examine the MoCA as a cognitive screening tool after cardiac arrest in the long-term outcome phase. This study aimed to investigate the diagnostic value of the MoCA in OHCA survivors.

Methods

Study design

This was a prospective cross-sectional cohort study using convenience sampling. Participants were recruited from several medical centres in the Netherlands (MUMC+, Rijnstate hospital, RadboudUMC, Medisch Spectrum Twente, and VieCuri) between October 2018 and August 2021. The study was conducted according to the Code of Conduct for Medical Research of the Council of the Dutch Federation of Medical Scientific Societies. The STARD 2015 was used as guideline to report the findings of this study.[18]

Participants

A minimum of 50 participants was aimed to include based on the criteria of Terwee et al.[19] Inclusion criteria were an objectified cardiac arrest for which hospital admission was necessary, age between 18–70 years, and sufficient knowledge of the Dutch language. Exclusion criteria were cognitive decline prior to the cardiac arrest and absence of written informed consent.

Procedure

Data were collected in two ways. First, upon discharge home from the hospital or when they visited the outpatient clinic of the MUMC+, they were asked by a clinician whether they were interested to participate in this study. If so, their name was forwarded to the researcher. The researcher informed the patient about the study by phone and provided an information letter. The patient was invited to come to the hospital before or after one of the regular appointments in the hospital or at his/her convenience. The patients were tested by a trained researcher and a specialized staff member of the medical psychology department in a quiet room after informed consent was signed. All participants completed first the MoCA and then a brief neuropsychological assessment. The performance on the MoCA and the NPA were available for the assessor. Assessment took approximately 1 hour. This procedure was approved by the medical ethics committee of the Maastricht University Medical Center (METC 2017–0136). Seventeen patients were included via this route.

Secondly, data of patients participating in other ongoing cohort studies investigating cognitive functioning in OHCA survivors were used for this study (Rijnstate hospital, RadboudUMC, Medisch Spectrum Twente, and VieCuri). The principal investigator and study coordinators of these cohort studies (authors JH, HK, and SN) provided the data anonymously. Data were extracted from these datasets when participants fulfilled the criteria as described above. Informed consent was obtained at data collection. This procedure was approved by The Medical Ethical Commission Twente (NL64594.044.18) and CMO Arnhem Nijmegen (NL62151.091.17; NL69767.091.19). Thirty-seven patients were available for inclusion via this route.

Measures

The Montreal Cognitive Assessment

The MoCA is a widely used screening instrument for cognitive impairment.[13] This screening tool assesses the following cognitive domains: Executive functioning, visuospatial abilities, attention, concentration, working memory, language, abstract reasoning, memory, and orientation. The test is administered in approximately 10 minutes and scores range from 0 to 30. The MoCA corrects for educational level, by giving those with 12 or fewer years of formal education an extra point. This is done to reduce the risk of classifying low-educated subjects as cognitively impaired. In general, a score of $\geq$26 is considered normal.[13]

Neuropsychological assessment (NPA)

We used a short neuropsychological test battery as gold standard. The test battery consisted of tests recommended by the Dutch organization of psychologists[20] and has been used in the past to validate the Barrow Neurological Institute (IBNI) Screen for Higher Cerebral functions in stroke patients.[21] This brief NPA consists of six neuropsychological tests, that each cover a cognitive domain: Star Cancellation Test (perception), Boston Naming Test (language), Rey Auditory Verbal Learning Test (memory), Trail Making Test A and B (attention), Raven's Advanced Progressive Matrices (reasoning), and Stroop Color and Word Test (executive functioning). More detailed descriptions of the neuropsychological tests can, among other sources, be found in the handbook of neuropsychological assessment.[22]

The Star Cancellation Test[23] (SCT) screens for unilateral spatial neglect. The score ranges from 0 to 54. A cut-off value of <51 was used to indicate possible unilateral spatial neglect.

The short form of the Boston Naming Test[24] (BNT) was used to assess language performance. During this test, patients have to name what they see on a line drawing. A score of $\geq$12.5 is considered normal.

The Rey Auditory Verbal Learning Test[25] (RAVLT) is a memory test. It measures immediate recall, delayed recall, and retention. The score on immediate recall ranges from 0 to 75, and delayed recall from 0 to 15. The retention score is the delayed recall score divided by the trial in the immediate recall with the most remembered words. The cut-off used in this study was two standard deviations below the mean of the norm group.

Trail Making Test AB[26] (TMT) is a measure of psychomotor speed (part A) and executive functioning (part B). The final score is the completion time of part B, corrected for the psychomotor speed obtained in part A. The cut-off used in this study was two standard deviations below the mean of the norm group.[27]

9-item form of the Raven's Advanced Progressive Matrices[28] (Raven) was used to determine the level of abstract reasoning. Based on data from a previous study,[29] a cut-off score of 3 was used, meaning that a score of 3 or lower was considered impaired.

The Stroop Colour and Word Test[30] (Stroop) is a measure of executive functioning consisting of three parts. The first two parts assess the speed of information processing, and the third part measures response inhibition. The outcome measure used was the interference score. This is the completion time of the last part corrected for the first two parts. The cut-off used in this study was two standard deviations below the mean of the norm group.

Statistical analysis

Data analyses were performed using SPSS Statistics 25.0 for Windows.[31] Descriptive statistics were used to describe the sample characteristics (age, sex, level of education), information related to the OHCA (time since OHCA, time to return of spontaneous circulation (ROSC)), and the performance on the MoCA and NPA. The distributions of the MoCA scores, age, time since OHCA, time to ROSC, and level of education were tested for normality with the Shapiro-Wilk test. Based on the significant results of this test, Spearman correlations were used to examine associations between the MoCA score and age, sex, level of education, time to ROSC, and time since OHCA. The scores on the tasks in the NPA were standardized into Z-scores using the Maasnorms.[32] Ceiling effects for the tests in the NPA were defined as less than 10% of the sample scoring impaired on a test. Tests with a ceiling effect in this sample were not taken into account in further analyses of the sensitivity and specificity of the MoCA. The floor- and ceiling effects of the MoCA were defined as more than 15% of the sample scoring the highest or lowest score possible.[19] In case of missing values, pairwise deletion was applied.

To investigate the diagnostic value of the MoCA as a cognitive screening tool after OHCA, it was compared with the NPA. Patients that scored more than two standard deviations below the mean of a norm group of healthy individuals of their age and education level or below the corresponding cut-off score on two or more tests of the NPA were considered cognitively impaired. In the secondary analysis patients who scored more than 1.5 SD below the mean of the norm group or the corresponding cut-off score on two or more tests were considered cognitively impaired. Cross-tabulations were used to investigate the sensitivity, specificity, false positives, and false negatives of various cut-off scores of the MoCA. A Receiver Operating Curve (ROC) was made, specifying the area under the curve (AUC). A cognitive screening instrument should have a good to excellent sensitivity (>80%) and reasonable specificity (>60%).[33]

Results

Sample characteristics

We included 54 participants. The majority was male (40(74%)). Further sample characteristics can be found in Table 1.

Performance on the MoCA

Table 2 shows the properties of the MoCA in our sample. Less than 15% of the participants obtained the highest or lowest score possible, indicating no floor- or ceiling effects.[19] The distribution of scores was skewed to the left. Almost half (44%) of the participants scored below the recommended MoCA cut-off score of 26 (see Table 3). The mean score on the MoCA was 25.8 (SD = 3.6). Higher education was significantly correlated with higher scores on the MoCA ($r = 0.532$, $p < 0.001$). The MoCA score was not significantly associated with age ($r = -0.106$, $p = 0.446$), sex ($r = -0.070$, $p = 0.616$), time to ROSC ($r = 0.095$, $p = 0.526$), or time since OHCA ($r = 0.122$, $p = 0.381$).

Cognitive functioning according to the NPA

In Table 3 the results of the NPA are shown. The TMT B (corrected for motor speed by TMT A), BNT, and SCT showed a ceiling effect (<10% scored impaired) and were therefore not used for further analyses of the sensitivity and specificity of the MoCA. The memory domain was most often affected, both direct recall (28%) and delayed recall (28%). Twelve (23%) of the participants were cognitively impaired according to the NPA.

Sensitivity and specificity of the MoCA

In the main analysis, patients were considered cognitively impaired if they scored more than two standard deviations below the mean of the norm group or the corresponding cut-off score on two or more tests. The receiver operating characteristic curve (ROC-curve) is plotted in Fig. 1. In this figure, the sensitivity and 1-specificity are plotted for different cut-off values, ranging from the smallest observed test value minus 1 (10–1 = 9) to the largest observed test value plus 1 (30 + 1 = 31). All the other cutoff values are the averages of two consecutive ordered observed test values. The AUC was 0.8, 95% CI [0.67, 0.93], indicating acceptable to excellent discrimination.[34] Cut-offs from 25 to 29 were investigated for their diagnostic value. In our sample, the cut-off score of 26 yielded good to excellent sensitivity of 86%, 95% CI [57, 98] and good specificity

Table 1 – Sample Characteristics (n = 54).

Variable	N (%) or M (SD)
Age (SD)	57 (12)
Range	23–79
Sex, female (%)	14 (26)
Level of education [a] (%)	
Low	11 (20)
Average	19 (35)
High	24 (44)
OHCA characteristics (SD)	
Time since OHCA in months	12 (8)
Time range	1–44
Time to ROSC in minutes[b]	14 (11)
Time range	2–63

Note.
SD = standard deviation.
OHCA = Out of Hospital Cardiac Arrest.
ROSC = return of spontaneous circulation.
[a] Level of education according to Verhage (1–4 = low, 5 = average, 6–7 = high).[32]
[b] n = 47.

Table 2 – Descriptives and Floor- and Ceiling Effects of the MoCA (n = 54).

Mean (SD)	Min-max	Median	IQR	Skewness	Kurtosis	% lowest score	% highest score
25.8 (3.6)	10–30	27.0	4	−1.9	6.4	0.0	7.4

Note.
SD = standard deviation, IQR = Interquartile range.

Table 3 – Descriptive statistics of study variables MoCA and NPA (n = 54).

Measure	Domain	Range	Min-Max	Mean (SD)	Impaired (n)[a]
MoCA	Global cognitive functioning	0–30	10–30	25.8 (3.55)	44 % (24)
NPA					
RAVLT	Verbal memory				
Total	Learning	0–75	12–61	35.6 (11.6)	28% (15)
Delayed	Recall	0–15	0–15	6.8 (4.0)	28% (15)
Stroop interference[b]	Response inhibition	RT	−1–253	48.3 (44.9)	13% (7)
Raven[d]	Non-verbal reasoning	0–9	1–9	4.5 (2.3)	21% (11)
BNT[d]	Naming	0–15	11–15	14.4 (0.8)	2% (1)
SCT[d]	Visual inattention	0–54	51–54	53.6 (0.7)	0% (0)
TtMT B (out of A)[c]	Selective attention	–	–	–	4% (2)
Trail A (sec)		RT	13–85	34.4 (15.6)	
Trail B (sec)		RT	36–386	86.5 (55.4)	

Note. RT = Reaction Time; SD = standard deviation; MoCA = Montreal Cognitive Assessment; NPA = Neuropsychological Assessment: RAVLT = Rey Auditory Verbal Learning Test, BNT = short Boston Naming Test, SCT = Star Cancellation Test.
[a] Impaired performance: MoCA score < 26; RAVLT, Stroop, TMTB (out of A) < -2.0 SD beneath the norm; Raven score < 3; SCT < 51; BNT < 12,5.
[b] Stroop interference = Time stroop 3 – (time stroop 1 + time stroop 2)/2).
[c] TMTB (out of A) is calculated with the formula used in Maasnorms.[33]

of 70%, 95% CI [53, 83] for detection of cognitive impairment (Tables 4 and 5). There were two false negatives. They were both impaired in the memory domain, on the delayed and total immediate recall of the RAVLT. One of them was also impaired on the Stroop (response inhibition) and Raven (non-verbal reasoning). There were twelve false positives. On average they scored below the norm group on the memory domain (-1.5 SD on the RAVLT delayed recall and −1.0 SD on the RAVLT total). No other cut-off value showed a better sensitivity/specificity balance for a screening tool. The positive predictive value of the MoCA was 50%, 95% CI [30, 70] and the negative predictive value was 93%, 95% CI [76, 99].

In the secondary analysis, patients were considered cognitively impaired if they scored more than 1.5 standard deviations below the mean of the norm group or the corresponding cut-off score on

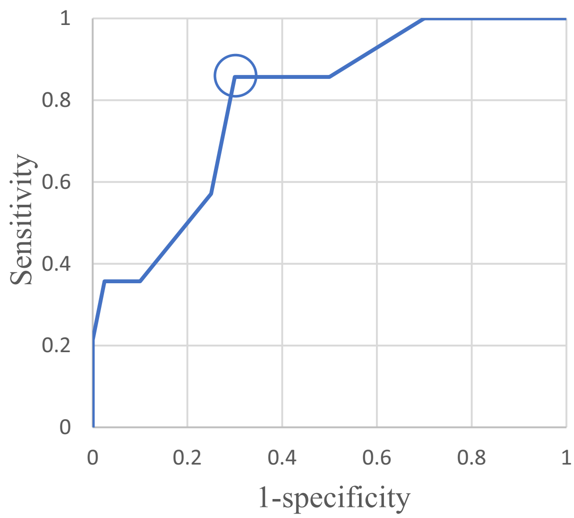

Fig. 1 – ROC-curve of the MoCA for detection of mild cognitive impairment. The circle indicates the optimal cut-off of the MoCA (26) for detection of cognitive impairments. A sensitivity of 86% at 70% specificity was obtained.

two or more tests. The AUC was 0.8, 95% CI [0.63, 0.89], indicating acceptable to excellent discrimination[34] (Supplementary Fig. 1). The cut-off score of 26 yielded reasonable sensitivity of 76%, 95% CI [53, 92] and specificity of 76%, 95% CI [58, 89]. There were five false negatives and eight false positives (Supplementary Table 1). No other cut-off value showed a better sensitivity/specificity balance (Supplementary Table 2). The positive predictive value of the MoCA was 67%, 95% CI [45, 84], and the negative predictive value was 83%, 95% CI [65, 94].

Discussion

We investigated the diagnostic value of the MoCA as a screening tool for cognitive impairments after OHCA. The sensitivity and specificity of the MoCA were based on a standard neuropsychological test battery as gold standard. The results showed excellent sensitivity (86%) and good specificity (70%) for the cut-off score of 26.

In our study, there were two false negatives and twelve false positives. For screening purposes, it is important to have a low percentage of false negatives. This is because patients with a negative screening result will not be evaluated for further neuropsychological assessment, while patients with positive screening results will.

We screened patients on average one year post OHCA within a broad time range (1– 44 months) and found no correlation between cognitive functioning and time since injury. This implies that our findings concerning diagnostic performance can be generalized over an extended period of time. Thus, the MoCA can identify patients with cognitive disturbances both in the early and in the later time windows after cardiac arrest. However, the optimal timing of cognitive screening remains to be identified. Early detection probably contributes to effective cognitive rehabilitation therapy and could thus be of help to improve neurological recovery. According to several studies[35,36] recovery after a cardiac arrest reaches a plateau after approximately 90 days postarrest. Although recovery speed differs between patients, a suitable moment for cost- and time efficient cognitive

Table 4 – Sensitivity and specificity of the MoCA with various cut-off values for detection of cognitive impairment (n = 54).

Cut-off value	Sensitivity (95% CI)[a]	Specificity (95% CI)[a]	False positive n (%)	False Negative n (%)
25	57.1 (29.6–81.2)	75.0 (58.5–86.8)	10 (25.0)	6 (42.9)
26	85.7 (56.2–97.5)	70 (53.3–82.9)	12 (30.0)	2 (14.3)
27	85.7 (56.2–97.5)	67.5 (48.6–80.9)	13 (32.5)	2 (14.3)
28	85.7 (56.2–97.5)	50.0 (34.1–65.9)	20 (50.0)	2 (14.3)
29	100.0 (73.2–100.0)	30.0 (17.1–46.7)	28 (70.0)	0 (0.0)

Note.

All values are percentages unless stated otherwise.

[a] CI = Confidence interval.

Table 5 – Test results of the MoCA with a cut-off score of 26.

	CA outcome		
NPA outcome	Not impaired	Impaired	Total
Not impaired	28	12	40
Impaired	2	12	14
Total	30	24	54

screening with the MoCA would be roughly three months after hospital discharge.

In the secondary analysis, we explored the sensitivity and specificity of the MoCA when using a cut-off of 1.5 SD below the mean on two or more tests of the NPA instead of the more conservative 2 SD used in the main analysis. This secondary analysis showed the best combination of sensitivity and specificity with the same optimal cut-off value of 26 for the MoCA. These results indicate that the MoCA is a good screening tool to detect more severe cognitive impairment and reasonable for detecting milder forms of cognitive impairment.

There are some limitations to this study. First, since there is no specific test battery available for cognitive impairment after cardiac arrest, we used a neuropsychological test battery designed for cognitive disorders in general, irrespective of underlying etiology, but targeting the most common cognitive domains. Consequently, some tests did not have predictive value, which was expected based on the diffuse brain damage after cardiac arrest. Neglect (SCT) and aphasia (BNT) are more common after stroke (focal brain damage) and were not expected to be disturbed in this group. This expectation appeared to be correct, which is why these tests were and had to be excluded from the final analysis (SCT, TMTB(out of A), and BNT). Secondly, in this study patients were included up to the age of 70. This was done to decrease the risk of including individuals with neurocognitive disorders unrelated to cardiac arrest. Therefore, the generalizability of the findings in this study is limited to patients up to 70 years. Lastly, the sample size was relatively small. Although it satisfies the criterium of a minimum of 50 participants for evaluating psychometric properties,[19] a larger sample size and replication in another sample would provide more robust results.

This study shows promising results for implementation of the MoCA after OHCA to identify patients with cognitive impairments. However, more validation studies are necessary. If implemented, a large portion of patients with cognitive impairments that might otherwise be overlooked could receive appropriate care.

Conclusions

This study shows that the MoCA is a valid screening tool for cognitive impairment in OHCA patients. We recommend regular cognitive screening after OHCA.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Pauline van Gils: Investigation, Data curation, Formal analysis, Writing – original draft. **Caroline van Heugten:** Conceptualization, Methodology, Supervision, Project administration, Writing – review & editing. **Jeannette Hofmeijer:** Supervision, Writing – review & editing. **Hanneke Keijzer:** Investigation, Writing – review & editing. **Sjoukje Nutma:** Investigation, Writing – review & editing. **Annelien Duits:** Conceptualization, Methodology, Supervision, Writing – review & editing.

Acknowledgements

The authors thank Roos Roberts, Marlies van Wijk, Rachel ter Bekke, Zafer Geijk for helping with data collection and recruiting patients the MUMC, Ilja Klabbers and Lieke Teunisen for performance of NPA in the Radboudumc and Rijnstate hospital, respectively, and Karen Meeske, Bonita van Es, Elise Rooijakkers, Joy Grotenhuis and Mandy Helmstrijd for performance of NPA in Medisch Spectrum Twente. Jeannette Hofmeijer is supported by a clinical established investigator grant of the Dutch Heart Foundation (Grant Number 2018T070).

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resuscitation.2021.12.024.

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