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REVIEW ARTICLE

PREDICTING LONG-TERM COGNITIVE IMPAIRMENTS IN SURVIVORS AFTER CARDIAC ARREST: A SYSTEMATIC REVIEW

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Objective: **International guidelines recommend early screening for identification of patients who are at risk of long-term cognitive impairments after cardiac arrest. However, information about predictors is not provided. A systematic review of the literature was performed to identify early predictors of long-term cognitive outcome after cardiac arrest.**

Methods: **Scopus and PubMed were systematically searched to identify studies on early predictors of long-term cognitive outcome in patients after cardiac arrest. The population included adult cardiac arrest survivors and potential early predictors were demographics, early cognitive screening scores, imaging measures, electroencephalographic measures, and levels of blood biomarkers. Two investigators reviewed studies for relevance, extracted data and assessed risk of bias.**

Results: **Five articles were included. Risk of bias was assessed as low or moderate. Most detected long-term cognitive impairments were in the domain of memory. Coma duration (2 studies), early cognitive impairments by the self-developed clinical Bedside Neuropsychological Test Battery (BNTB) screener (2 studies), and high S-100B levels on day 3 (2 studies) were the most prominent identified determinants of cognitive impairment on the group level. On the individual patient level, a score on the BNTB of ≤94.5 predicted cognitive impairments at 6 months after cardiac arrest (1 study without external validation). Studies on brain imaging and electroencephalography are lacking.**

Conclusion: **Early bedside cognitive screening can contribute to prediction of long-term cognitive impairment after cardiac arrest. Evidence is scarce for S-100B levels and coma duration and absent for measures derived from brain imaging and electroencephalography.**

Key words: prediction; long-term cognitive outcome; cardiac arrest survivors.

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LAY ABSTRACT

Survival rates of patients after cardiac arrest have increased significantly over the past decades. However, many cardiac arrest survivors have impairments in different domains of thinking (memory, attention, and executive functions, such as planning). Early identification of survivors at risk of such impairments could guide personalized rehabilitation. However, such predictors are currently unavailable. This study reviewed the literature to identify possible early predictors for patients at risk of long-term impairments in thinking. A short, early, bedside test to screen domains of thinking during hospital admission may help to predict long-term impairments. Certain blood markers and a long duration of coma have also been associated with long-term impairments of thinking, but the evidence is weak. There are no studies on brain imaging and electroencephalography in this context.

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Survival rates of out-of-hospital cardiac arrest up to hospital discharge have increased considerably in the US, the UK and the Netherlands since the 1990s, from 16% in 2006 up to 41% in 2016 in patients with a shockable rhythm (1, 2). In sharp contrast with increased survival, neurological outcome of survivors has changed only marginally over the past decades. Of those surviving up to hospital admission, more than three-quarters initially remain comatose as a result of diffuse anoxic-ischaemic brain damage. Half of all comatose patients die in the hospital (2). Reported long-term survival rates of those that survive until hospital discharge are nearly 83% at 3 years, 77% at 5 years and nearly 64% at 10 years (3). In survivors, impairments of cognition, disturbances of mood, and functional impairments have been recognized in 50–100% (4, 5). Rates of mortality, anxiety, and depression appear to be higher in women than in men (2, 4).

Previous studies on outcome prediction after cardiac arrest have focused on "awakening" from coma. Predicted poor or good outcomes were gross measures of functional recovery, such as the Cerebral Performance Category (CPC) or the Glasgow Outcome Scale (GOS). Absent cortical somatosensory evoked potentials (SSEP) and certain electroencephalography (EEG) patterns have been identified as reliable predictors of such outcomes (6). These are now included in guidelines (7).

Cognitive impairments are an important driver of functional recovery of survivors after cardiac arrest. In previous studies, half of all patients could not resume daily activities, three-quarters showed disturbances of participation in society (8), and cognitive impairments were strongly related to reduced quality of life (9).

Early identification of survivors at risk of impairments of cognition could guide rehabilitation and open avenues for targeted treatments. In fact, guidelines of the European Resuscitation Council advise following up signs of brain damage in cardiac arrest survivors (7). However, validated early predictors of long-term cognitive impairments are not provided in these guidelines. In some hospitals, multidisciplinary screening programmes analogous to those in patients with brain infarcts are used, but these programmes are not validated in patients after cardiac arrest. A recent analysis showed that the Montreal Cognitive Assessment (MoCA) is a valid screening instrument for detection of current cognitive impairments after cardiac arrest, but predictive values for long-term recovery remain unclear (10).

The aim of this systematic literature review was to identify factors in an early phase after an out-of-hospital cardiac arrest that are predictive of long-term cognitive impairments in surviving patients.

MATERIALS AND METHODS

This systematic review is registered with the International Prospective Register of Systematic Reviews (PROSPERO: CRD42021238452). It is conducted in accordance with the Cochrane Handbook for Systematic Reviews of Interventions, and reported in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Protocols 2015 checklist.

Information sources and search strategy

The SCOPUS and PubMed databases were searched on 2 March 2021 for articles published in English or Dutch from inception until 1 March 2021. In addition, the references lists of included studies were screened for potential additional articles. The search strategy combined MESH terms and free-text terms to describe the population, outcome, study design, and publication type. The complete search strategy is shown in Tables SI and SII.

Selection criteria

Studies with a longitudinal design were included, in which early factors collected during hospital admission were associated with long-term cognitive outcomes. This included prospective and retrospective cohort studies and clinical trials. Case series, case reports, cross-sectional studies, reviews, randomized controlled trials, and meta-analyses were not included. Studies should be on surviving, adult patients (≥18 years) after out-of-hospital cardiac arrest. Studies on only in-hospital cardiac arrest or cardiac arrest secondary to non-cardiac conditions were not included. Mixed samples were included if ≥30% consist of patients after out-of-hospital cardiac arrest, with separate reporting for out-of-hospital cardiac arrest patients. The predefined primary outcome measure was cognitive outcome measured with a validated cognitive test at 3 months or longer after cardiac arrest. For the studies with multiple follow-up times, the longest follow-up period was chosen. No maximum follow-up duration was imposed.

Study selection and data extraction

Two reviewers (AG, MV) independently screened articles for eligibility based on titles and abstracts, using the online systematic review management software, Rayyan QCRI (11). Reasons for exclusion were documented. In case of disagreement between the 2 reviewers, their answers were unmasked, and disagreement was resolved through consensus. Selected full texts were screened by the same 2 reviewers. Again, disagreement was resolved through consensus. The first reviewer (AG) extracted the following data from selected articles: study type (prospective/retrospective), number of patients, cardiac event factors (e.g. cause of arrest, shockable rhythm, delay), targeted temperature management (TTM) information, predictive demographic factors, predictive factors from screening instruments, EEG, imaging or blood tests, timing of screening, cognitive impairments as determined by validated tests. For the definition of cognitive impairments in the included articles, the definition that was used by the authors of the article was followed.

Synthesis of results

The results are presented in a descriptive way. Given the observational nature of the expected datasets and the expected differences in settings and populations, it was

assumed that meta-analyses of data from the various included studies would not be possible.

Quality assessment

Quality assessment of the included studies was performed by 2 independent reviewers using the Quality in Prognosis Studies (QUIPS) tool (12). Herewith, the risk of bias is rated in 6 domains: study participation, study attrition, prognostic factor measurement, outcome measurement, study confounding, and statistical analysis and reporting. Levels of judgement are classified as high, moderate, or low. An overall score is awarded at the discretion of the reviewers, based on the scores in the 6 domains.

Ethics approval

Ethics approval was not required.

RESULTS

A total of 424 articles were identified, of which 361 were unique (Fig. 1). After screening of titles and abstracts, 35 articles remained for full-text inspection. Based on full-text inspection, 5 articles were included in this review (13–17).

Study characteristics

The characteristics and results of the 5 included studies are presented in Table I. All 5 were prospective longitudinal cohort studies. With the exception of 1 study (14), all were designed to identify early factors related to long-term cognitive outcome of cardiac arrest survivors. All studies related early (within 4 weeks) parameters to late cognitive functioning (3–6 months after cardiac arrest) (13–17), and 2 studies also related early parameters to late cognitive impairments (13, 14). In 4 studies, long-term cognitive outcome was the primary outcome, in 1 study cognitive outcome was included as secondary outcome measure (14). One study included only out-of-hospital cardiac arrest survivors (17), 4 also included survivors of in-hospital cardiac arrest. The number of cardiac arrest survivors per study ranged from 25 to 80. The mean age of the subjects varied between 59 and 61 years. The percentage of male participants varied between 54% and 91%. Follow-up time ranged between 3 and 6 months.

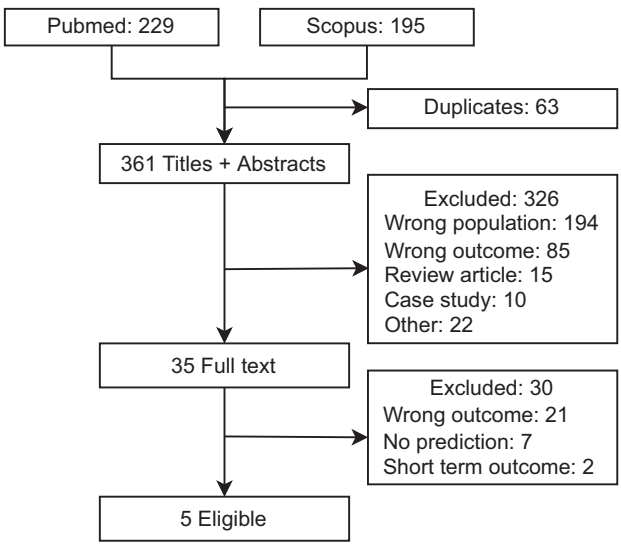

Fig. 1. Flow chart of article selection process.

Cognitive outcome

The 5 studies tested each 4–6 cognitive domains. Tested cognitive domains differed per study, but all studies tested the domains attention and memory. Per cognitive domain, different studies used different neuropsychological tests (Table SIII). If test scores were 1–2 standard deviations below the normative mean (13, 16, 17) or if T-score was <36 (15), cognitive outcome was impaired. One study did not specify their cut-off values (14). Further details are shown in Table I.

Tested factors

The tested possible predictors varied over the studies. These included demographic variables (17), medical history variables (17), cardiac arrest associated variables (15–17), cardiac function (15), mood variables (15, 16), blood levels of neurobiochemical markers (neuron-specific enolase (NSE) and astroglial protein S-100B) (13, 14), neurological clinical examination results (13, 14), somatosensory evoked potentials (SEP) (N10, N20 and N70) (13, 14), and early cognitive screening results by the self-developed Bedside Neuropsychological Test Battery (BNTB) (13, 14). BNTB includes the Mini-Mental State Examination (MMSE) supplemented by orientation/general knowledge and digit spans (both: Wechsler Memory Scale-Revised (WMS-R)), word fluency (f-words, animal names; Cognitive Minimal Screening), and picture memory. No studies on the predictive value of measures derived from computed tomography (CT), magnetic resonance imaging (MRI), or electroencephalography (EEG) were found.

Study results

The following factors were independently associated with cognitive impairments in either a multivariate general linear model, hierarchical regression analyses, or receiver operating characteristic (ROC) analysis. Most detected impairments were in the domain of memory (mainly verbal domain tested; immediate recall, delayed recall, recognition).

Table I. Summary of included studies

Author, year of publication	Study design	Population *N = participants study* **N = participants analysis** Age = mean age, years % = % male	Follow-up time after cardiac arrest W = weeks M = months	Predicted outcome	Classification outcome	Tested factors **Identified potential predictors**	Analysis	Significant outcomes **Identified predictors**	Q
Sauvé 1996a (16)	Prospective longitudinal cohort design	OHCA + IHCA *N: 25* **N: 17** Age: 59 %: 68	22–25 W	Cognitive functioning according to NPE, T-scores, tested domains: attention, concentration, orientation, memory (early recall, early retention, late recall) reasoning, motor (speed, variability)	Graded as impaired = scores 1 and 1.5 SD below normative mean	Mood (anxiety and depression and positive affect), ejection fraction, **time to awakening**, New York Heart Association (NYHA) functional class	1) Pearson's r 2) Hierarchical regression analysis	1) Pearson's r, $p \leq 0.05$, 2-tailed Depression – attention, concentration, memory (late recall): $-0.51 \leq r \leq -0.74$ Time to awakening – attention, concentration, memory (late recall), motor (speed): $-0.51 \leq r \leq -0.74$ 2) **Time to awakening explained significant portion of variance in attention and delayed recall, no number reported for 6 months**	-
Sauvé 1996b (15)	Prospective longitudinal cohort design	OHCA + IHCA *N: 45* **N: 38** Age: 61 %: 84	22–25 W	Cognitive functioning according to NPE, T-scores, tested domains: attention, orientation, memory (immediate recall, early recall, delayed recall, recognition) reasoning, motor (speed, variability)	Graded as normal (T: ≥ 36), mild (T: 31–35), moderate to moderately severe (T: 16–30), severe (T: ≤ 15)	CPR associated factors (CPR onset, CPR Rx => definitive therapy (defibrillation/medication) time to definitive therapy, **time to awakening**), left ventricular (LV) function and mood state	1) Pearson's r 2) Hierarchical regression analysis	1) Pearson's r, $p \leq 0.05$, 2-tailed CPR duration – memory (immediate recall, delayed recall, recognition), motor (tapping variability): $-0.34 \leq r \leq -0.43$ Time to awakening – orientation, memory (immediate recall, early recall, delayed recall, recognition): $-0.33 \leq r \leq -0.66$ Ejection fraction – attention: $r = -0.51$ Ejection fraction – motor (tapping speed): $r = 0.42$ NYHA – motor (tapping speed): $r = -0.42$ Tension – motor (tapping speed): $r = -0.36$ Anger – motor (tapping speed): $r = -0.43$ Depression – motor (tapping speed, tapping variability): $-0.35 \leq -0.43$ 2) Hierarchical regression analysis memory delayed recall CPR variables: $R^2 = 0.35$, $p = 0.01$ **Time to awakening: $\beta = -0.63$, $p = 0.00$** Motor tapping speed LV function: $R^2 = 0.24$, $p = 0.02$	-
Prohl 2007 (14)	Prospective longitudinal cohort design	OHCA + IHCA *N: 80* **N: 26** Age: 61 %: 54	6 M	Cognitive functioning according to NPE, T scores, tested domains: attention, learning/ memory, executive function, visuospatial skill	Graded as normal (impairment on 0–1 test), mild (2–5), moderate (7–10), severe (globally 18–22)	Serial blood samples (NSE **& S-100B**), clinical examinations, SEP N10 N20 **N70**, Bedside **Neuropsychological Test Battery (BNTB)**[a]	1) Pearson's r 2) Spearman rank correlation	1) Pearson correlations with neuropsychological tests: S-100B day $3 = 0.34 \leq r \leq 0.59$, $n = 16$ SEP N70 day $4 = 0.41 \leq r \leq 0.71$, $n = 15$ neuropsychological bedside screening $0.34 \leq r \leq 0.75$, $n = 25$ 2) Spearman rank correlation Cognitive impairment index[b]: S-100B day 3 $r = 0.51$ SEP N70 day 4 $r = -0.54$ bedside screening $r = -0.86$	-

Table I (Continued...). Summary of included studies

Author, year of publication	Study design	Population *N = participants study* **N = participants analysis** Age = mean age, years % = % male	Follow-up time after cardiac arrest W = weeks M = months	Predicted outcome	Classification outcome	Tested factors **Identified potential predictors**	Analysis	Significant outcomes **Identified predictors**	Q
Prohl 2009 (13)	Prospective longitudinal cohort design	OHCA + IHCA *N: 26* **N: 26** Age: 61 %: 54	6 M	Cognitive functioning according to NPE, T scores, tested domains: attention, learning/memory, executive function, visuospatial skill	Graded as cognitive impairment if 2 or more neuropsychological tests scores were 1.5 SD or 1 test score 2 SD below normative mean	Serial blood samples (NSE & **S-100B**), **Bedside Neuropsychological Test Battery (BNTB)**[a]	1) Hierarchical multiple regressions (blood samples) 2) ROC analysis (bedside screening (BNTB))	1) hierarchical regression learning/memory NSE & S100B: $R^2 = 0.41$, $p \leq 0.05$ **S-100B: β = −0.49, $p \leq 0.02$** executive functioning NSE & S100B: $R^2 = 0.42$, $p \leq 0.04$ **S-100B: β = −0.51, $p \leq 0.02$** 2) ROC analysis, BNTB **AUC=0.88 (SE = 0.77, $p \leq 0.01$; CI = 0.73–1.03)** **BNTB threshold 6 months = 94.5** **sensitivity = 90%** **specificity = 82%**	+
Ørbo 2014 (17)	Prospective longitudinal cohort design	OHCA *N: 45* **N: 45** Age: 60 %: 91	3 M	Cognitive functioning according to NPE, *Z*-scores and cognitive composite score (mean *Z*-scores neuropsychological tests), tested domains psychomotor speed, attention, working memory, executive functions, fine-motor functions, verbal- and visual learning and memory	Cut-off 1,5 SD below normative mean graded as unimpaired (all mean test scores above cut-off), mild impairment (1 or 2 mean test scores below cut-off), moderate to severe impairment (> 3 mean test scores below cut-off)	**Coma duration**, age above 70, years of education, time to ROSC, previously diagnosed cardiac condition, HADS scores and **hypothermia treatment (yes/no)**	1) Linear stepwise regression (backwards selection) 2) Multivariate general linear model	1) linear stepwise regression final models: a) for all patients, and b) for patients unconscious upon admission a) Cognitive composite score (All patients ($n = 45$): $R^2 = 0.45$, $p \leq 0.001$) **Coma duration: β = −0.01, $p \leq 0.001$** **Hypothermia: β = 0.44, $p \leq 0.05$** b) Cognitive composite score (Patients who were unconscious upon admission ($n = 32$) $R^2 = 0.48$, $p \leq 0.001$) **Coma duration: β = −0.01, $p \leq 0.001$** **Hypothermia: β = 0.56, $p \leq 0.05$** 2) multivariate general linear model Coma duration CVLT II: $\eta^2 = 0.33$, $p < 0.001$ Rey's complex figure: $\eta^2 = 0.28$, $p < 0.001$ WMS-3 memory span: $\eta^2 = 0.33$, $p < 0.001$ DK Trail-Making test 1–5: $\eta^2 = 0.12$, $p = 0.03$ DK Color-Word: $\eta^2 = 0.24$, $p = 0.001$ DK Verbal Fluency: $\eta^2 = 0.13$, $p = 0.02$ Grooved Pegboard: $\eta^2 = 0.18$, $p = 0.005$ Hypothermia CVLT II: $\eta^2 = 0.09$, $p < 0.05$ DK Color-Word: $\eta^2 = 0.24$, $p = 0.001$ DK Verbal Fluency: $\eta^2 = 0.15$, $p = 0.01$	+

[a]Included the Mini-Mental State Examination (MMSE) supplemented by the following tasks: orientation/general knowledge and digit spans (Wechsler Memory Scale-Revised (WMS-R)), word fluency (f-words, animal names) (Cognitive Minimal Screening), picture memory. Different test scales, for scoring, correct responses were counted.

[b]Cognitive impairment index was calculated by the number of impaired test (below mean) divided through all applied tests.

OHCA: out-of-hospital cardiac arrest; IHCA: in-hospital cardiac arrest; NPE: neuropsychological examination, CPR: cardiopulmonary resuscitation; NSE: neurone-specific enolase; S-100B: protein S-100B; CVLT II: California Verbal Learning Test-II; WMS-3: Wechsler Memory Scale-III; DK: Delis-Kaplan. Q: Quality Assessment score; −: moderate, +: low.

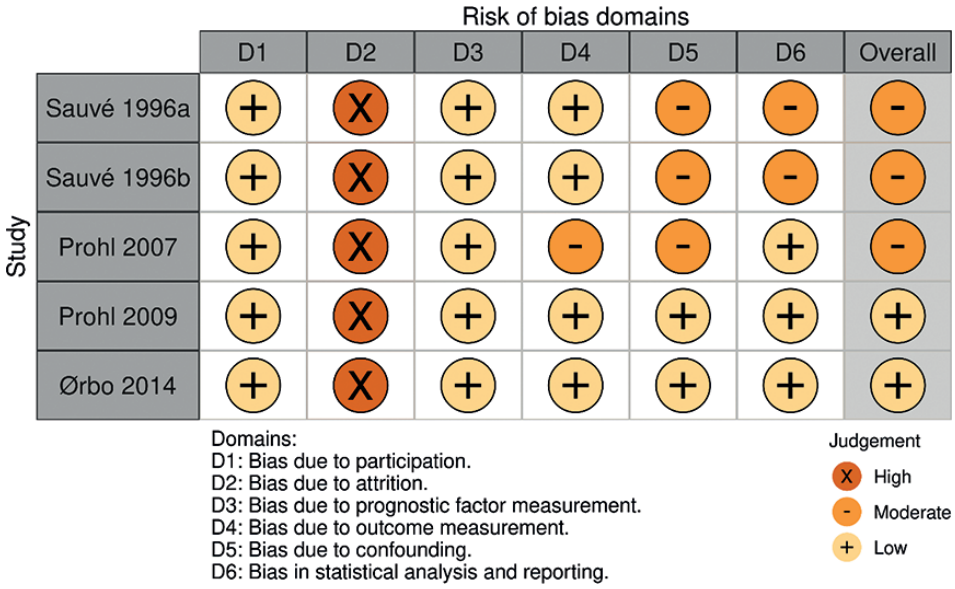

Fig. 2. Risk of bias, assessed using the Quality in Prognosis Studies (QUIPS) tools and visualized with risk-of-bias visualization (robvis) (25).

Coma duration

A longer "time to awakening" was predictive for long-term impairments of memory (delayed recall) at 3 months after cardiac arrest (15, 16). Longer coma duration predicted a poorer cognitive composite score and poorer performance in 5 cognitive domains (executive functions, attention, memory, visuospatial ability, and fine motor functioning) at 3 months after cardiac arrest (17).

Early treatment factors

Hypothermia treatment (yes) predicted a better cognitive composite score and a better performance in the memory domain (tested by California Verbal Learning Test II) and executive functions domain (tested by Delis Kaplan Color-Word and Verbal Fluency) (17).

Cardiac function measures

Reduced left ventricular (LV) function after cardiac arrest predicted a lower motor tapping speed. However, none of the individual components in this hierarchical regression model, such as ejection fraction and New York Heart Association (NYHA) functional class, reached statistical significance (15).

Early cognitive screening measures

The self-developed BNTB included different test scales. For scoring, correct responses were counted. The observed scores ranged from 45 to 104. Neuropsychological bedside screening results by BNTB during hospital admittance after cardiac arrest correlated strongly with the cognitive impairment index at 6 months after cardiac arrest (14) and could discriminate between those with and without cognitive impairments (13). A BNTB cut-off value of 94.5 yielded the greatest combined sensitivity and specificity for prediction of cognitive impairments in individual patients (90% and 82%, respectively) (13).

Blood levels of neurobiochemical marker

Elevated S-100B concentration (i.e. >0.12 ng/L (95th percentile)) on day 3 was negatively associated with the cognitive impairment index at 6 months after cardiac arrest (14). Elevated S-100B concentration level on day 3 predicted a poorer performance in memory and executive functions at 6 months after cardiac arrest (13).

Somatosensory evoked potential (SEP) measures

Presence of long latency SEP (N70) on day 4 was negatively associated with the cognitive impairment index at 6 months after cardiac arrest (14).

The following tested factors did not reach significance in either univariate tests, hierarchical regression analyses, or correlation tests: demographic variables (17), mood variables (15–17), some cardiac arrest variables (15, 16), clinical examination variables (14), blood levels of NSE (13, 14), and SEP N10 or N20 results (13, 14).

Quality assessment

Two studies were classified as low risk of bias and 3 studies as moderate risk of bias (Fig. 2).

DISCUSSION

This systematic review identified 5 studies on early prediction of long-term cognitive outcome after cardiac

arrest. Coma duration, score on the BNTB screener, and high S-100B levels were the most prominent identified determinants on the group level. Most detected impairments were in the domain of memory, which is in line with previous literature on cognitive impairment in cardiac arrest survivors (5).

The only analysis yielding clear predictive values for cognitive impairments in individual patients after cardiac arrest was on early cognitive screening by the BNTB screener. A score of ≤94.5 predicted cognitive impairments at 6 months with a sensitivity of 90% and specificity of 82%. However, to our knowledge, this was only shown in a small sample (n=26) and not validated in a separate study. International opinion papers (18) and guidelines (7) unambiguously recommend early screening for long-term cognitive outcome after cardiac arrest and mostly refer to the Montreal Cognitive Assessment (MoCA). Although the MoCA has been validated for instantaneous detection of cognitive impairments after cardiac arrest, predictive properties have not been studied (10).

Although coma duration and S-100B levels correlated with cognitive outcome at the the group level, cut-off values for prediction at the individual patient level are lacking. Some other factors yielded an association with cognitive outcome, such as measures of severity of cardiac arrest and cardiac function, but lack of cut-off values hampers conclusions on the clinical value. Direct measures of encephalopathy severity, such as EEG or MRI measures, have shown significant added value for prediction of gross neurological outcome of comatose cardiac arrest patients (19, 20). However, associations with cognitive outcome have not been reported.

Early MoCA scores have been associated with cognitive impairment in patients with ischaemic or haemorrhagic stroke, although the thresholds proposed by general normative datasets underestimated patients at risk of persistent cognitive impairments (21). In patients with stroke or traumatic acute brain injury, diffuse and/or focal slowed EEG activity (22, 23), reduction in intra-hemispheric connectivity and impeded inter-hemispheric imbalance (22), and lower volume of hippocampus on MRI (24) have been associated with poorer cognitive functioning. However, in these patient groups also, the evidence of EEG or MRI measures on cognitive outcome prediction is scarce.

This review study has some limitations. Most importantly, the 2 studies by Prohl and the 2 by Sauvé probably included overlapping patient samples. This reduces the already limited population size and the strength of this review. The heterogeneity of tested factors is another limitation. Only coma duration and mood variables were tested by different groups. All the other tested factors were studied by a single research group. In addition, the various studies tested different cognitive domains and used divergent cognitive tests.

In conclusion, despite unequivocal recommendations on early screening for identification of patients at risk of long-term cognitive impairments after cardiac arrest, evidence on the value of scores from screening instruments is scarce. Bedside cognitive screening holds potential to contribute, but needs prospective validation. Evidence is scarce for S-100B levels and lacking for measures derived from EEG and MRI.

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The authors have no conflicts of interest to declare.

REFERENCES

1. Husain S, Eisenberg M. Police AED programs: a systematic review and meta-analysis. Resuscitation 2013; 84: 1184–1191.
2. Zijlstra JA, Radstok A, Pijls R, Nas J, Beesems SG, Hulleman M, et al. Hoofdstuk 1. Overleving na een reanimatie buiten het ziekenhuis: vergelijking van de resultaten van 6 verschillende Nederlandse regio's [Chapter 1: Survival after CPR outside the hospital: comparison of the results of 6 different Dutch regions]. In: Reanimatie in Nederland [Resuscitation in the Netherlands]. Den Haag: Hartstichting, 2016.
3. Amacher SA, Bohren C, Blatter R, Becker C, Beck K, Mueller J, et al. Long-term survival after out-of-hospital cardiac arrest: a systematic review and meta-analysis. JAMA Cardiol 2022; 7: 633–643.
4. Green CR, Botha JA, Tiruvoipati R. Cognitive function, quality of life and mental health in survivors of our-of-hospital cardiac arrest: a review. Anaesth Intensive Care 2015; 43: 568–576.
5. Moulaert VR, Verbunt JA, van Heugten CM, Wade DT. Cognitive impairments in survivors of out-of-hospital cardiac arrest: a systematic review. Resuscitation 2009; 80: 297–305.
6. Glimmerveen AB, Ruijter BJ, Keijzer HM, Tjepkema-Cloostermans MC, van Putten M, Hofmeijer J. Association between somatosensory evoked potentials and EEG in comatose patients after cardiac arrest. Clin Neurophysiol 2019; 130: 2026–2031.
7. Nolan JP, Sandroni C, Bottiger BW, Cariou A, Cronberg T, Friberg H, et al. European Resuscitation Council and European Society of Intensive Care Medicine Guidelines 2021: Post-resuscitation care. Resuscitation 2021; 161: 220–269.
8. Wachelder EM, Moulaert VR, van Heugten C, Verbunt JA, Bekkers SC, Wade DT. Life after survival: long-term daily functioning and quality of life after an out-of-hospital cardiac arrest. Resuscitation 2009; 80: 517–522.
9. Moulaert VR, Wachelder EM, Verbunt JA, Wade DT, van Heugten CM. Determinants of quality of life in survivors of cardiac arrest. J Rehabil Med 2010; 42: 553–558.
10. van Gils P, van Heugten C, Hofmeijer J, Keijzer H, Nutma S, Duits A. The Montreal Cognitive Assessment is a valid cognitive screening tool for cardiac arrest survivors. Resuscitation 2022; 172: 130–136.

11. Mourad Ouzzani, Hossam Hammady, Zbys Fedorowicz, Ahmed Elmagarmid. Rayyan — a web and mobile app for systematic reviews. Systematic Reviews (2016) 5:210, DOI:10.1186/s13643-016-0384-4
12. Hayden JA, van der Windt DA, Cartwright JL, Cote P, Bombardier C. Assessing bias in studies of prognostic factors. Ann Intern Med 2013; 158: 280–286.
13. Prohl J, Bodenburg S, Rustenbach SJ. Early prediction of long-term cognitive impairment after cardiac arrest. J Int Neuropsychol Soc 2009; 15: 344–353.
14. Prohl J, Röther J, Kluge S, de Heer G, Liepert J, Bodenburg S, et al. Prediction of short-term and long-term outcomes after cardiac arrest: a prospective multivariate approach combining biochemical, clinical, electrophysiological, and neuropsychological investigations. Crit Care Med 2007; 35: 1230–1237.
15. Sauve MJ, Doolittle N, Walker JA, Paul SM, Scheinman MM. Factors associated with cognitive recovery after cardiopulmonary resuscitation. Am J Crit Care 1996; 5: 127–139.
16. Sauve MJ, Walker JA, Massa SM, Winkle RA, Scheinman MM. Patterns of cognitive recovery in sudden cardiac arrest survivors: the pilot study. Heart Lung 1996; 25: 172–181.
17. Ørbo M, Aslaksen PM, Larsby K, Norli L, Schäfer C, Tande PM, et al. Determinants of cognitive outcome in survivors of out-of-hospital cardiac arrest. Resuscitation 2014; 85: 1462–1468.
18. Cronberg T, Greer DM, Lilja G, Moulaert V, Swindell P, Rossetti AO. Brain injury after cardiac arrest: from prognostication of comatose patients to rehabilitation. Lancet Neurology 2020; 19: 611–622.
19. Ruijter BJ, Tjepkema-Cloostermans MC, Tromp SC, van den Bergh WM, Foudraine NA, Kornips FHM, et al. Early electroencephalography for outcome prediction of postanoxic coma: a prospective cohort study. Ann Neurol 2019; 86: 203–214.
20. Hirsch KG, Fischbein N, Mlynash M, Kemp S, Bammer R, Eyngorn I, et al. Prognostic value of diffusion-weighted MRI for post-cardiac arrest coma. Neurology 2020; 94: e1684–e1692.
21. Salvadori E, Cova I, Mele F, Pomati S, Pantoni L. Prediction of post-stroke cognitive impairment by Montreal Cognitive Assessment (MoCA) performances in acute stroke: comparison of three normative datasets. Aging Clin Exp Res 2022; 34: 1855–1863.
22. Keser Z, Buchl SC, Seven NA, Markota M, Clark HM, Jones DT, et al. Electroencephalogram (EEG) with or without transcranial magnetic stimulation (TMS) as biomarkers for post-stroke recovery: a narrative review. Front Neurol 2022; 13: 827866.
23. Doerrfuss JI, Kilic T, Ahmadi M, Holtkamp M, Weber JE. Quantitative and qualitative EEG as a prediction tool for outcome and complications in acute stroke patients. Clin EEG Neurosci 2020; 51: 121–129.
24. Selnes P, Grambaite R, Rincon M, Bjornerud A, Gjerstad L, Hessen E, et al. Hippocampal complex atrophy in post-stroke and mild cognitive impairment. J Cereb Blood Flow Metab 2015; 35: 1729–1737.
25. McGuinness LA, Higgins JPT. Risk-of-bias VISualization (robvis): an R package and Shiny web app for visualizing risk-of-bias assessments. Res Synth Methods 2021; 12: 55–61.