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Clinical Paper

Development and validation of the Cerebral Performance Categories-Extended (CPC-E)☆

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ABSTRACT

Background: Optimizing resuscitation efforts after cardiac arrest (CA) requires valid and reliable measurements of functional outcomes. The Cerebral Performance Category (CPC), the historical "gold" standard outcome measure post-CA, lacks psychometric validation. The purpose of this study was to establish the psychometric properties of a revised CPC: the CPC-Extended (CPC-E).
Methods: The study had two phases: We established content validity of the CPC-E by identifying existing domains in the CPC, by adding new domains following a literature review, and iterative input from a panel of CA and rehabilitation experts. We tested the CPC-E's feasibility, intra-rater (IR) reliability and inter-rater reliability (IRR) using retrospective reviews of the electronic medical records (EMR) and "in-person" in-hospital administration.
Results: The CPC-E has 10 domains. For both IR and IRR record reviews, 5/10 domains had frequent missing data and in three instances, intraclass correlation coefficients (ICC) could not be calculated. Of the scores that could be calculated, ICC ranged from poor to high ($n = 30$; 0.46–1.0) and poor to high ($n = 50$; −0.16 to 0.93) for IR and IRR, respectively. No data were missing for the "in-person" IRR for the 10 domains and ICC ranged from good to excellent ($n = 26$; 0.79–1.00). In-hospital and post-discharge domains were completed in under 7 min.
Conclusions: The CPC-E is a valid and clinically feasible outcome measure for describing post-CA impairment and disability status. In-person hospital administration of the CPC-E yields more complete data and good to excellent inter-rater reliability compared to retrospective EMR review.

1. Introduction

The Cerebral Performance Category (CPC), a 5-category scale for measuring neurological status after cardiac arrest (CA), has been the historical gold standard.[1,2] Criticisms of the CPC include poorly defined subjective criteria that encompass multiple domains within each criterion (e.g., alert and ability to work are included in the same criterion), lack of psychometric validation, and weak associations with short- and long-term measures of disability and quality of life.[3,4]

This study addresses a need overlooked in post-CA care, that is, developing a valid outcome measure that informs clinicians about potential impairments (e.g., memory loss) and disabilities (e.g., dependence in daily activities) that may warrant further attention. A well-developed and well-validated tool has great potential to impact how and what is measured and will likely influence interventions or services recommended post-CA.[5,6]

The specific aims of the study were to establish the content validity, test the intra- and inter-rater reliability, and test the clinical feasibility of a new instrument to measure post-CA impairments and disability: the Cerebral Performance Category-Extended (CPC-E). The usefulness of any measure depends upon two prerequisites: validity and reliability. In this study, we established content validity of the CPC-E by identifying relevant domains through a literature review and a panel of CA and rehabilitation experts. Additionally, we tested the CPC-E's feasibility, intra-rater reliability, and

Abbreviations: CA, cardiac arrest; CPC, Cerebral Performance Category; CPC-E, Cerebral Performance Category-Extended; EMR, electronic medical record; PT, physical therapy; OT, occupational therapy.

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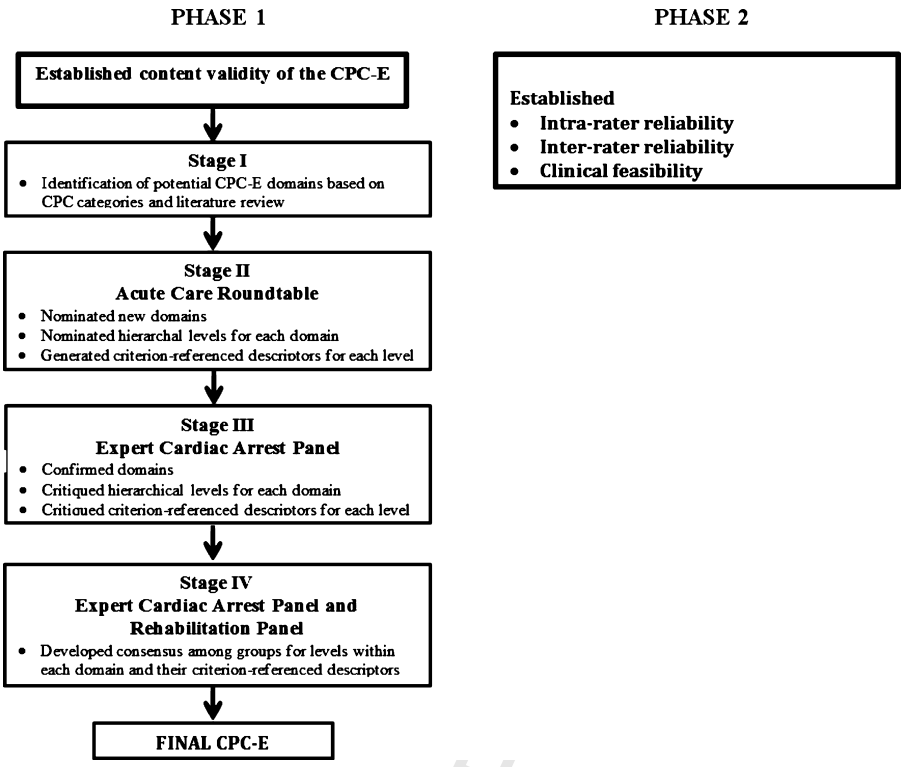

Fig. 1. Staged development of the Cerebral Performance Category-Extended Tool (CPC-E).

inter-rater reliability using retrospective reviews of the electronic medical record (EMR), and "in-person" in-hospital administration.

2. Methods

Content validity was established in Phase 1, while reliability and clinical feasibility were established in Phase II (Fig. 1).

2.1. Phase 1—content validity

2.1.1. Stage I: potential domains

Each category of the CPC encompasses multiple impairment and disability domains. Initially, these domains were disentangled. Then, domains were added following a thorough review of CA literature. Each domain includes five levels with corresponding criterion-referenced descriptors. Levels 1 and 5 represent the best and worst indicator, respectively, for each domain.

2.1.2. Stage II: acute care roundtable

In Stage II, five physicians, board-certified in emergency or critical care medicine with >5 years of clinical experience that included treating >250 post-CA patients at a regional referral hospital, were invited to discuss the proposed CPC-E. All physicians had published extensively regarding CA resuscitation. Discussion addressed the structure, additions and subtractions, and supporting references associated with each domain. Based on feedback, new levels for each domain and the criterion-referenced descriptors of each level were created.

2.1.3. Stage III: expert CA panel

The acute care physicians nominated an external expert panel of 10 board-certified and licensed physicians from North America to critique the Stage II CPC-E.

The Expert CA Panel provided feedback on the proposed CPC-E via a web-based survey. To ensure confidentiality, each panel member received a personal link to it.

The panel rated each domain on three questions: (1) Is the domain named correctly? (2) What is the importance of this domain for measuring outcomes post-CA? (3) Do the criterion-referenced descriptors for each level of the domain allow for appropriate differentiation of a patient's current status? The Expert CA Panel could suggest additional domains.

CPC-E domains and corresponding criterion-referenced descriptors for each level were revised based on Panel feedback. Some domains were designated to be assessed post-discharge. Hence, in Stage IV, feedback was sought from a Rehabilitation Panel experienced in treating CA survivors.

2.1.4. Stage IV: expert CA panel and rehabilitation panel

The Stage III CPC-E was presented to the Expert CA Panel and a Rehabilitation Panel. The Rehabilitation Panel included a physiatrist, neurologist, three physical therapists (PTs), and five occupational therapists (OTs). All 20 panel members rated each domain on the following questions via separate surveys: (1) Should the domain be kept as described? (2) If deletion is recommended, tell us why you would like to delete this domain? (3) Suggest additional modifications to the domains, levels, or criterion-referenced descriptors, if any.

2.1.5. Final version of CPC-E

Feedback from Stage IV was analyzed to yield the final version of the CPC-E (see Appendix A).

2.2. Phase 2—reliability and feasibility

Intra-rater and inter-rater reliability were examined through a retrospective EMR review and a prospective study. Clinical feasibility, that is, the time to complete the CPC-E, comprehensiveness of data, and distribution of CPC-E scores was examined through the prospective study.

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2.2.1. Retrospective medical record review

Two OTs conducted retrospective EMR reviews to determine CPC-E scores. Raters were trained to extract EMR entries from a 650-bed tertiary care hospital that serves as a regional referral center for critically ill patients. Data collected from the EMR included: demographics, comorbidities, resuscitation details, location of CA, initial CA rhythm, hypothermia treatment, neurological dysfunction determined using the Full Outline of UnResponsiveness score motor and brainstem components,[7] rehabilitation services received, length of stay, CPC, modified Rankin Scale,[8,9] and discharge disposition. Raters were directed to extract all 10 domains of the CPC-E from the EMR physician, nursing, and rehabilitation notes.

Decision rules for data extraction were established a priori and included: (a) physician, nursing, and rehabilitation notes closest to the discharge date were used to score the domains, (b) when data in the clinical notes were conflicting, the raters were to use the worst outcome, (c) data not available were coded as missing, (d) if a subject was transferred to inpatient rehabilitation, the raters were to use the intake assessment by OT, PT, speech language pathology, and nutrition as the discharge assessment, provided no interventions occurred in between hospital discharge and rehabilitation admission, and (e) raters selected entries that were considered domain-specific for each profession (e.g., motor = PT; basic activities of daily living = OT).

To extract data for intra-rater reliability, Rater 1 reviewed and scored the CPC-E using 30 randomly selected medical records of patients who were admitted with a CA between January 2010–November 2013. Rater 1 rescored the records 2 days later. The rater was masked to the results of the first scoring.

To extract data for inter-rater reliability, Raters 1 and 2 independently reviewed and scored the CPC-E using medical records for 50 consecutive patients who were admitted after a CA between January 2010 and November 2013. Each rater was masked to the scores of the other rater.

2.2.2. Prospective reliability study

A convenience sample of 26 CA survivors was recruited. Inclusion criteria were: ≥18 years of age and resuscitated following a CA. We defined CA as a loss of pulse requiring chest compressions, rescue shock, or both. Exclusion criterion was a CA attributable to stroke or trauma.

Domains 1.1–1.6 of the CPC-E were administered prior to hospital discharge. Two members of the 9-member investigative team simultaneously and independently scored the CPC-E. Raters were masked to each other's scores. Domains 1.7–1.10 were collected via telephone by the primary author (SB) between 7 and 32 days (mean 15.7 ± 7.9) post-discharge.

Clinical feasibility was assessed by recording the time to complete in-hospital and post-discharge assessments, comprehensiveness of data, and distribution of CPC-E scores.

2.3. Data analysis

2.3.1. Content validity

Responses by CA and Rehabilitation Panels were recorded. For each question, the percent agreement between panel members was calculated. Consensus among panel members was defined as ≤62% agreement for a panel of 10 members.[10] Qualitative data were downloaded by domain, level, and descriptor, and summarized by response themes.

2.3.2. Reliability

Quantitative data were transferred to SPSS 21.0 for Windows (Chicago, IL). Descriptive statistics were used to analyze demographics and EMR data, and score distribution for each CPC-E domain. Power analysis for the intraclass correlation coefficients (ICCs), with an alpha of 0.05, a power of 0.80, and a correlation coefficient of 0.70, yielded a minimum sample size of 11.

Intra-rater and inter-rater reliability are reported in three ways: decision consistency, mean percent agreement, and intraclass correlation coefficients. Decision consistency was calculated as the number of agreements/number of possible agreements. Given the criterion-referenced characteristics of the CPC-E, it was clinically relevant to measure decision consistency among raters based on a mutual ability to collect information from the EMR retrospectively, not the probabilistic reliability of estimating a subject's "true" score.[11] Mean percent agreement was calculated by converting the decision consistency fraction into a percentage. We categorized the strength of agreement according to fraction agreement with 0–0.20 as slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.0 as almost perfect agreement. Intra-rater data were analyzed using one rater and the ICC (3, 1). Inter-rater reliability data were analyzed using ICC (2, k). ICC values greater than 0.90 were categorized as high, 0.75–0.90 as good, and below 0.75 as poor to moderate reliability.[12]

3. Results

3.1. Content validity

3.1.1. Stage I: potential domains

To identify the CPC-E domains, descriptors in the CPC were identified. They were: (1) Arousal (e.g., conscious, coma); (2) Attention (e.g., alert, unaware); (3) Short-term Memory (e.g., mild to severe dementia); (4) Motor (e.g., hemiplegia to severe paralysis,); (5) Everyday Activities (e.g., dressing, food preparation); and (6) Return to Work (e.g., full-time or part-time). Fatigue, Mood, and Social Support domains were nominated following a literature review (Fig. 2).

3.1.2. State II: acute care roundtable

The Acute Care Roundtable nominated a new domain (Disorganized Thinking) and adjustments were made to other domains (i.e., Arousal became Alert; Everyday Activities was separated into Basic and Instrumental Activities of Daily Living) (Fig. 2).

3.1.3. Stage III: expert CA panel

Consensus among the Expert CA Panel was 80–100% in all domains for question 1: "Is the domain named correctly?," with the exception of Disorganized Thinking, which received only 40% agreement (Table 1). Based on the rating and supporting recommendations to rename this domain, this domain was changed to: Logical Thinking. While there was 80% consensus among the panel members for Instrumental Activities of Daily Living, we renamed the domain Complex Activities of Daily Living based on the Panel's feedback.

Question 2 addressed "What is the importance of this domain for measuring outcomes post-CA?" All domains were rated as "important" or "very important" 70–100% with the exception of the Fatigue and Social Support domains. The Fatigue domain received 50% consensus. Several reviewers noted that fatigue in the inpatient setting can be multifactorial and compounded by the hospital environment (e.g., disruption of sleep, stress). Two reviewers questioned the value of measuring fatigue. Our previous work with CA survivors suggested fatigue was a common complaint.[13,14] We proposed that fatigue post-CA is likely prevalent, a major barrier to completion of activities of daily living and achievement of a satisfactory quality of life, and inadequately addressed by clinicians, thus warranting its inclusion as a new domain in the CPC-E. While the Fatigue domain was retained, it was moved to the post-discharge assessment. The Social Support domain generated the most comments and only 50% of the Panel rated it as an important domain for inclusion. It was

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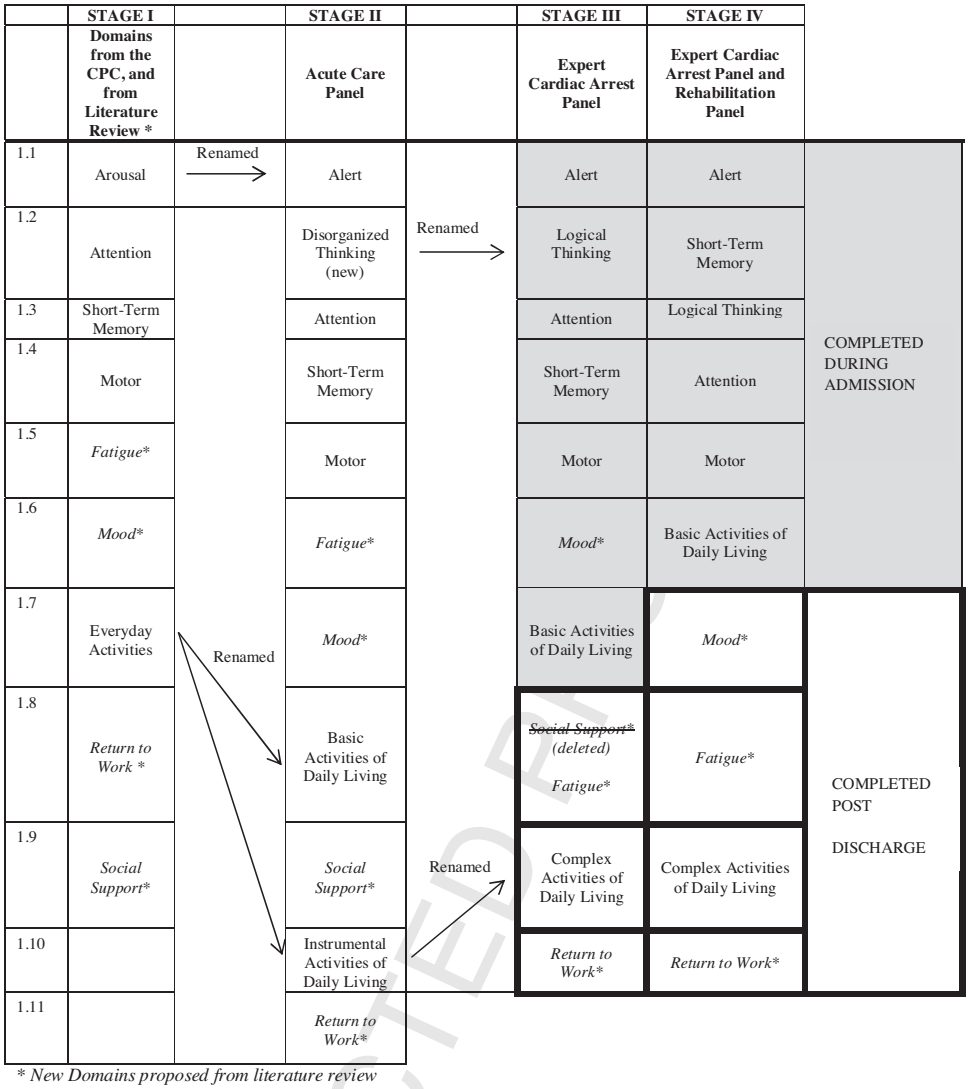

Fig. 2. Identification and refinement of CPC-E domains from Stage I through Stage IV.

not retained because social support is considered a moderator of medical and rehabilitation outcomes, and not a direct consequence of CA.

Question 3 addressed "Do the criterion-referenced descriptors for each level of the domain allow for appropriate differentiation of a patient's current status?" The Panel rated 8/10 domains below the acceptable 62% agreement (Table 1). Based on the Panel feedback, criterion-referenced descriptors for the Alert, Logical Thinking, Attention, Motor, Fatigue, Mood, and Return to Work domains were revised.

3.1.4. Stage IV: expert CA panel and rehabilitation panel

Consensus between the Expert CA Panel and the Rehabilitation Panel for the question "Should the domain be kept as described?" was 80–100 and 90–100%, respectively.

3.2. Reliability

Demographic and medical data for the three cohorts are presented in Table 2.

3.2.1. Retrospective medical record review

For both intra-rater and inter-rater record reviews 5/10 domains had large proportions of missing data (40–80%) while Mood, Fatigue, and Complex Activities of Daily Living domains had missing data 100% of the time (Table 3). Of the scores that could be calculated, intra-rater percent agreement ranged from 73.3 to 100% and inter-rater percent agreement ranged from 60 to 100%. ICCs ranged from poor to high for intra-rater ($n = 30$; 0.46–1.0) and inter-rater reliability ($n = 50$; −0.16 to 0.93), respectively.

3.2.2. Prospective reliability study

No data were missing for the inter-rater reliability-hospital for the 10 domains (Table 3). Inter-rater percent agreement ranged from 88.5 to 100%, while ICCs ranged from good to excellent (0.79–1.0).

3.3. Clinical feasibility

Time to complete all in-hospital domains ranged from 4 min, 57 s to 7 min, 17 s, with a mean (±SD) of 6.03 (±1.06) min. Comprehensiveness of data was achieved during the hospital visit with no missing data from columns 1.1 to 1.6. All raters ($n = 9$) found the CPC-E to be quick and easy to administer. Time to complete follow-up domains via telephone was 6.54 ± 1.67 min. We were unable to complete four out-of-hospital follow-up assessments due to death ($n = 1$) and inability to contact the participants ($n = 3$). The

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Table 1
Expert Cardiac Arrest Panel and Rehabilitation Panel Consensus.

Stage III Expert Cardiac Arrest Panel ($n = 10$)			
Domain	Domain named correctly? Yes % (n)	Importance of domain for measuring CA outcomes? Important % (n)	Criteria for each level allow for appropriate differentiation of patient's status % (n)
Alert	80(8)	90(9)	60(6)
Disorganized thinking	40(4)	80(8)	50(5)
Attention	80(8)	80(8)	40(4)
Short-term memory	90(9)	100(10)	90(9)
Motor	90(9)	90(9)	30(3)
Fatigue	80(8)	50(5)	40(4)
Mood	80(8)	70(7)	40(4)
Basic activities of daily living	100(10)	100(10)	70(7)
Social support	90(9)	50(5)	50(5)
Complex activities of daily living	80(8)	90(9)	80(8)
Return to work	90(9)	70(7)	50(5)
Stage IV Expert Cardiac Arrest Panel ($n = 10$)			
	Should the domain be kept as described? Yes % (n)		
Alert	100(10)		
Logical thinking	80(8)		
Attention	90(9)		
Short-term memory	90(9)		
Motor	100(10)		
Basic activities of daily living	90(9)		
Mood	90(9)		
Fatigue	100(10)		
Complex activities of daily living	100(10)		
Return to work	80(8)		
Stage IV Rehabilitation Panel ($n = 10$)			
Alert	90(9)		
Logical thinking	100(10)		
Attention	90(9)		
Short-term memory	90(9)		
Motor	100(10)		
Basic Activities of Daily Living	100(10)		
Mood	90(9)		
Fatigue	100(10)		
Complex Activities of Daily Living	100(10)		
Return to work	100(10)		

score distributions for the CPC-E domains are depicted in Fig. 3. We observed little variation in the Alert, Logical Thinking, and Attention domains where >70% of subjects scored the highest. Scores for all other domains were distributed across the score range.

4. Discussion

Given increased survival rates after CA, it is important to assess patients for effective rehabilitation interventions to address

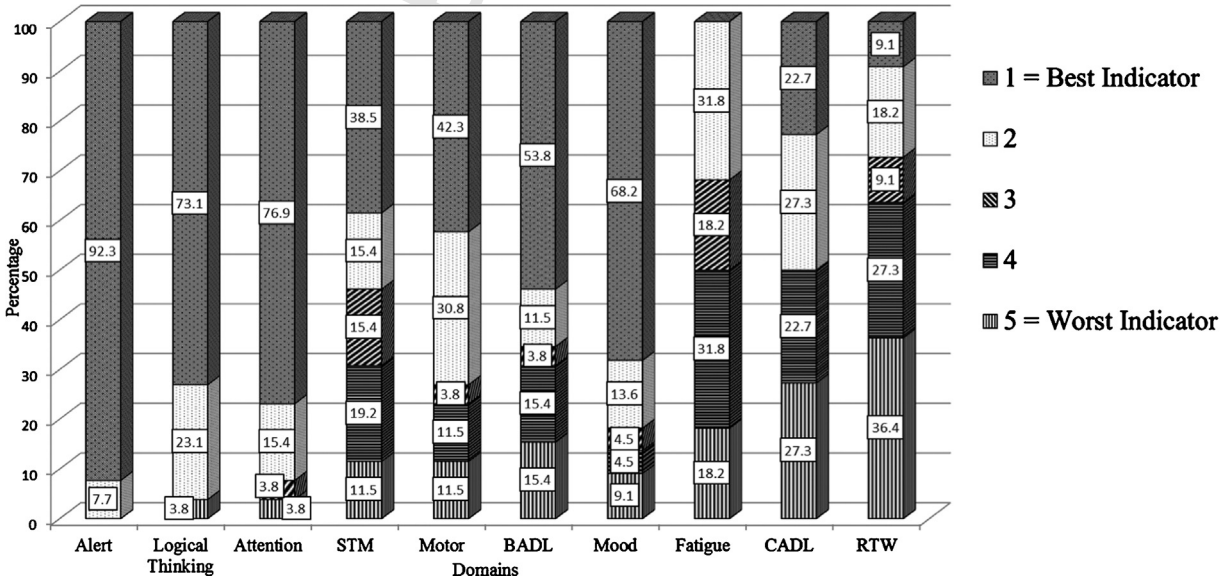

Fig. 3. Score distributions for the CPC-E domains. Notes. STM, short-term memory; BADL, basic activities of daily living; CADL, complex activities of daily living; RTW, return to work.

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Table 2
Demographic information for participants in the retrospecitice and intra-rater reliability and inter-rater reliability.

	Intra-rater reliability – medical record review ($n = 30$)	Inter-rater reliability – medical record review ($n = 50$)	Inter-rater reliability – hospital evaluation ($n = 26$)
Age, years, mean (SD)	55.1 (17.4)	55.3 (14.5)	55.5 (17.9)
Male, *n* (%)	17 (56.7)	32 (64)	15 (57.7)
Race, *n* (%)			
White	23 (76.7)	42 (84)	22 (84.6)
Black	3 (10.0)	3 (6)	2 (7.7)
Other			2 (7.7)
OHCA, *n* (%)	22 (73.3)	37 (74)	19 (73.1)
Hypothermia Treatment, *n* (%)	20 (66.7)	31 (62)	3 (11.5)
Rhythm, *n* (%)			
VF/VT	22 (73.3)	37 (74.0)	16 (61.5)
PEA	7 (23.3)	8 (16.0)	3 (11.5)
Asystole	1 (3.3)	3 (6.0)	2 (7.7)
Unknown	0	2 (4.0)	5 (19.2)
FOUR			
Initial motor score, *n* (%)			
0	1 (3.3)	4 (8.0)	3 (11.5)
1	0	0	0
2	14 (46.7)	19 (38.0)	5 (19.2)
3	0	0	0
4	10 (33.3)	19 (38.0)	14 (53.8)
Initial Brainstem Score, *n* (%)			
0	1 (3.3)	1 (2.0)	0
1	0	0	0
2	1 (3.3)	8 (16.0)	5 (19.2)
3	0	0	0
4	23 (76.7)	34 (68.0)	16 (61.5)
Length of stay, days, mean (SD)	15.4 (9.15)	15.0 (10.6)	13.73 (7.94)
CPC at hospital discharge, *n* (%)			
1	10 (33.3)	18 (36.0)	1 (3.8)
2	11 (36.7)	18 (36.0)	4 (15.4)
3	9 (30.0)	13 (26.0)	20 (77.0)
4	0	0	1 (3.8)
5	0	1 (2.0)	0
mRS at hospital discharge, *n* (%)			
0	4 (13.3)	5 (10.0)	0
1	6 (20.0)	9 (18.0)	2 (7.7)
2	7 (23.3)	16 (32.0)	2 (7.7)
3	6 (20.0)	12 (24.0)	9 (34.6)
4	7 (23.3)	7 (14.0)	11 (42.3)
5	0	0	2 (7.7)
6	0	1 (2.0)	0
Disposition at hospital discharge, *n* (%)			
Home—no services	8 (26.7)	22 (44.0)	14 (53.8)
Home care	7 (23.3)	11 (22.0)	2 (7.7)
Acute care hospital	2 (6.7)	1 (2.0)	2 (7.7)
Skilled nursing facility	5 (16.7)	7 (14.0)	5 (19.2)
Long-term acute care	8 (26.7)	8 (16.0)	1 (3.85)
Traumatic brain injury unit	0	0	1 (3.85)
Hospice	0	0	1 (3.85)

When *n* is less than sample number, data could not be found.

remaining impairments. A valid and reliable update of the CPC was necessary to provide actionable and domain-specific assessment of CA survivors. To address the multiple constructs in the original CPC, we developed the multi-domain CPC-Extended and examined its psychometric properties and feasibility. This study has demonstrated a valid, reliable tool that can be administered in the clinical setting in less than 7 min. More importantly, the CPC-E yields a profile of current impairments and disabilities at the time of discharge and during follow-up. This CPC-E profile has the potential to "signal" a referral to rehabilitation or community support services associated with a particular domain.

In Phase I, we identified and refined 10 domains to establish content validity. Because the CA and rehabilitation experts provided input individually, the panel members neither met one another nor knew the source of the opinions expressed by other members. This methodology reduced bias and promoted full expression of minority opinions. Interestingly, the majority of Expert CA Panel voted against keeping the Fatigue domain in the CPC-E. However, based on previous clinical and research experience, we chose to retain it, although we moved it to post-discharge assessment. Fatigue is the only domain for which participants did not select the best indicator (e.g., "I feel fatigued none of the time"), highlighting the need to explore this impairment in CA survivors.

The psychometric properties of the CPC-E are good to excellent when used "in-person" in the hospital or at follow-up. In contrast, large proportion of missing data (40–100%) across domains makes the reliabilities obtained through retrospective EMR review less robust. Alert and motor domains had the least amount of missing data as this information is routinely documented in the medical record. Conversely, domains such as mood, fatigue, and CADL had data missing 100% of the time because patient status in these domains may not be routinely documented.

The feasibility of the in-hospital CPC-E was deemed excellent, as it was quick and easy to administer in-person and via the follow-up telephone call. Anecdotally, the raters reported that it

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Table 3
Reliability Data for the CPC-E.

Domain	Missing data (%)	Decision consistency	Percent agreement	Intraclass correlation coefficient (ICC)
Intra-rater reliability—medical record review (*n* = 30)				
Alert	3.3	30/30	100	1.00
Logical thinking	40	25/30	83.0	0.90
Attention	70	28/30	93.3	0.92
Short-term memory	40	22/30	73.3	0.80
Motor	0	22/30	73.3	0.78
Basic activities of daily living	76.7	26/30	86.7	0.46
Mood	100	30/30	100	–
Fatigue	100	30/30	100	–
Complex activities of daily living	100	30/30	100	–
Return to work	76.7	23/30	76.7	0.61
Inter-rater reliability—medical record review (*n* = 50)				
Alert	6	46/50	92	0.63
Logical thinking	70	34/50	68	0.62
Attention	62	30/50	60	0.37
Short-term memory	58	33/50	66	0.54
Motor	8	46/50	92	0.93
Basic activities of daily living	80	44/50	88	0.64
Mood	100	50/50	100	–
Fatigue	100	50/50	100	–
Complex activities of daily living	100	50/50	100	–
Return to work	84	40/50	80	−0.16
Inter-rater reliability—hospital (*n* = 26)				
Alert	0	24/26	92.3	0.79
Logical thinking	0	24/26	92.3	0.97
Attention	0	24/26	92.3	0.98
Short-term memory	0	25/26	96.2	0.97
Motor	0	23/26	88.5	0.99
Basic activities of daily living	0	25/26	96.2	0.99
Mood[a]	0	3/3	100	–
Fatigue[a]	0	3/3	100	–
Complex activities of daily living[a]	0	3/3	100	1.0
Return to work[a]	0	3/3	100	–

ICC could not be calculated due to lack of variance.
[a] *n* = 23.

took them between 45and 60 min to extract data from the EMR for each patient.

The CPC-E has utility as a screening measure and an outcome measure. We previously demonstrated that many patients with significant deficits are discharged to home without adequate referral to rehabilitation services. [14] The CPC-E may be used as a screening measure to signal a referral to rehabilitation or community support services. Additionally, the use of the CPC-E as an outcome measure has the potential to alter our current approach to measuring and understanding outcomes after CA. We anticipate that the CPC-E will offer an efficient, yet comprehensive approach to track associations between specific CA interventions and outcomes with sufficient texture to provide us with insights into specific domains and quality of life outcomes.

4.1. Limitations

Limitations of this study include a small sample size to test the feasibility of the tool's use, testing at only one regional hospital, and including only four subjects with mild-moderate alertness deficits. Evaluating a population with a wider range of deficits in future studies is necessary to test reliability in the full range of each domain. Since survival rates after CA vary depending on regional differences,[15] testing the CPC-E in multiple locations is desirable. Further, direct participation of CA survivors or their caregivers in tool development may provide additional insights.

5. Conclusion

The CPC-E is a novel, rapidly administered, screening and outcome measure that measures several domains after CA. The CPC-E demonstrates good to excellent inter-rater reliability when administered "live" in-hospital and at follow-up. The CPC-E can facilitate future work in epidemiological and intervention studies to provide more detailed outcome descriptions after CA. Furthermore, this scale will aid clinicians in targeting rehabilitation and community services most essential for the patients.

Conflict of Interest Statement

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Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resuscitation.2015.05.013

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