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Neurological and Functional Status Following Cardiac Arrest:

Method and Tool Utility

Ketki. D. Raina, PhD, OTR/L^{a,*}, Clifton. Callaway, MD, PhD^b, Jon. C. Rittenberger, MD, MS^b, and Margo. B. Holm, PhD, OTR/L^a

^aUniversity of Pittsburgh, School of Health and Rehabilitation Sciences, Department of Occupational Therapy, 5012 Forbes Tower, Pittsburgh, PA, 15260

^bUniversity of Pittsburgh, School of Medicine, Department of Emergency Medicine, 230 McKee Place, Suite 400, Pittsburgh, PA, 15213

Abstract

Introduction—Assessing the neurological and disability status of cardiac arrest (CA) survivors is important for evaluating the outcomes of resuscitation interventions. The Cerebral Performance Category (CPC) - the standard outcome measurement after CA - has been criticized for its poorly defined, subjective criteria, lack of information regarding its psychometric properties, and poor relationships with long-term measures of disability and quality of life (QOL). This study examined the relationships among the CPC and measures of global disability and QOL at discharge from the hospital and at 1-month after CA.

Methods—Twenty-one CA survivors participated in the study. A medical chart review was conducted at the time of discharge to determine CPC and Modified Rankin Scale (mRS) scores, while 1-month in-person interview was conducted to collect mRS and Health Utilities Index Mark 3 (HUI3) scores. Data collected during the interview were used to determine follow-up CPC scores.

Results—The strength of relationships among measures at discharge and 1-month ranged between fair to good. An examination of scatter plots revealed substantial variability and a wide distribution of chart review and 1-month mRS and HUI-3 scores within each CPC category. CPC scores obtained through chart review were significantly better than the CPC 1-month scores, thus overestimating the participants' cognitive and disability status 1-month later.

Conclusion—When compared to disability and quality of life measures, it is apparent that the CPC has limited ability to discriminate between mild and moderate brain injury. The validity of using the chart review method for obtaining scores is questionable.

Keywords

Cardiac arrest; cardiopulmonary resuscitation; disability; heart arrest; outcome; quality of life; neurologic dysfunction

*Corresponding author at: 5012 Forbes Tower, Department of Occupational Therapy, University of Pittsburgh, Pittsburgh, PA, 15260. Tel: 412-383-6614, E-mail address: kraina@pitt.edu
Please send reprint requests to Ketki D. Raina, PhD, OTR/L

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6. Conflict of Interest

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1. Introduction

Assessing the neurological and disability status of survivors of cardiac arrest (CA) is important for evaluating the outcomes of resuscitation interventions. Significant neurological injury is associated with the restoration of pulses after CA.¹ Moreover, decrements in neurological status after resuscitation are reported in several studies.²⁻⁴ The Cerebral Performance Category (CPC) is the gold standard for assessing neurological recovery after a CA.^{5, 6} Critical recommendations for patient care that may influence both short and long term outcomes such as disability and QOL are also based on CPC scores. However, the CPC has been criticized for its poorly defined, subjective criteria, lack of information regarding its psychometric properties, and poor relationships with long-term measures of disability and quality of life.^{7, 8}

Studies report poor to fair relationships between CPC at hospital discharge and disability and quality of life (QOL) measures 6 - 24 months after CA.^{7, 9} Little is known regarding the association of the CPC with disability and QOL measures prior to 6 months after the arrest. This knowledge is essential because neurological status may continue to improve for months after CA² and an accurate assessment of neurological recovery is necessary for decisions regarding placement and support services. This study examined the relationships among the CPC and measures of global disability and QOL at discharge from the hospital and at 1-month after the CA. The 1-month time point was deliberately selected because it was close enough to capture the neurological sequelae of the CA, but far enough so that it allowed the patients to be medically stabilized.

2. Materials and Methods

2.1 Design

Data were collected as part of a prospective longitudinal study of individuals who had survived cardiopulmonary resuscitation (CPR). This study examined relationships among the CPC, the Modified Rankin Scale (mRS), and the Health Utilities Index Mark 3 (HUI3), using a convenience sample of 21 participants.

2.2 Participants

The study was approved by the Institutional Review Board at the University of Pittsburgh and at Mercy Hospital of Pittsburgh. All patients 18 years or older admitted to University of Pittsburgh Medical Center Presbyterian Hospital or Mercy Hospital, who survived CPR for more than 3 days were eligible for participation. CPR was defined as (1) chest compressions delivered by a health care professional or (2) a rescue shock delivered by any person to terminate pulseless ventricular dysrhythmia. Potential participants or their family members were not approached prior to 3 days because of potential involvement with acute or end-of-life decision-making. In order to maximize recruitment no restrictions on the circumstances of the CPR (in-hospital, out-of-hospital, etc.) were imposed. Patients who sustained a traumatic cardiac arrest (the pathophysiology, epidemiology, and expected outcomes from traumatic CA differs from medical CA)¹⁰⁻¹² or whose CA was primarily caused by a cerebrovascular accident were excluded from the study. Informed consent was obtained from patients or their authorized representatives.

2.2 Instrumentation

The primary measure was the CPC,¹³⁻¹⁵ a 5-category scale for measuring neurological status after CA. The 5 categories are: CPC 1, conscious and alert with good cerebral performance; CPC 2, conscious and alert with moderate cerebral performance; CPC 3, conscious with severe

cerebral disability; CPC 4, comatose or in persistent vegetative state; and CPC 5, dead. To the best of our knowledge, no reliability and limited validity information has been reported for the CPC. The CPC has demonstrated poor concurrent validity with functional status and QOL assessments.⁷

Global disability was measured with the mRS.¹⁶⁻¹⁹ The mRS has face similarity with the CPC and can be determined through chart review²⁰ or interview.¹⁸ Disability is rated on a 7 point scale ranging from 0 (no symptoms at all) to 6 (death). The mRS has been shown to be a reliable and valid instrument in patients with stroke,¹⁶ brain injury,²¹ and neurosurgical patients with in-hospital CAs.²²

QOL was measured at 1-month following CA using the HUI3.^{23, 24} It is a 41 item self- or proxy report interviewer-administered instrument. Although the HUI3 is a QOL measure, it links QOL to disability by assessing 8 attributes of health (vision, hearing, speech, mobility, dexterity, emotion, cognition, and pain). Algorithms are used to convert patient/proxy responses to multi-attribute level scores and an overall QOL score. Scores range from 1 (perfect health/no disability) to 0 (death). A utility score of 1.00 represents perfect health/no disability, scores from 0.99 through 0.89 represent mild disability, from 0.88 through 0.70 moderate disability, and <0.70 severe disability (Furlong & Feeney, personal communication. January 3, 2008). Utility scores less than zero describe a health state worse than death. HUI3 has demonstrated adequate reliability and validity in various populations,^{25, 26} including a cohort of 268 CA survivors.^{9, 27}

2.3 Procedures

Medical chart reviews were conducted at the time of discharge to determine chart-review CPC (c-CPC) and mRS (c-mRS) scores. Investigators (CC, JR) who did not have in-person contact with the participant performed these reviews without knowledge of the in-person assessment. Physician, nursing, and rehabilitation notes were scanned for specific data about residual symptoms and participants' ability to understand instructions, perform toileting and self-care, transfer, walk, and perform daily activities. When specific data about these activities could not be found or when notes were conflicting, the raters assumed the worst outcome.

At the 1-month follow-up, an interviewer (KDR) administered the in-person mRS (i-mRS) and HUI3 (i-HUI3) to the patient or to a proxy if the patient could not communicate. Data collected during the interviews were used to determine in-person CPC (i-CPC) scores.

2.4 Statistics

Descriptive statistics were generated for all discharge and 1-month follow-up measures. Inter-rater reliabilities were calculated for both medical chart audits and patient interviews. Kendall's tau correlation coefficients were used to explore relationships among measures. The Kendall's tau was selected due to the tied ranks produced when calculating the Spearman's correlation coefficient. Correlations ranging from .00 to .25 indicated little or no relationship (poor); those from .26 to .50 suggested a fair degree of relationship; values of .51 to .75 indicated a moderate relationship; and values above .76 were considered a good relationship.²⁸ Scatter plots were then generated to examine these relationships for individual participants. Dependent samples *t*-tests were conducted to compare CPC and mRS scores at discharge and 1-month. Statistical calculations were performed using statistical software packages (Stata 9.0, StataCorp LP, College Station, Texas, USA; SPSS 14.0, SPSS Inc., Chicago, IL, USA).

3. Results

3.1 Patient Population

Table 1 includes demographic and CA data for all 21 participants. Participants were more likely to be male, and to have sustained a witnessed ventricular fibrillation arrest. Notably, two participants were not comatose after the arrest. Only one participant was not intubated after his arrest. Six patients received therapeutic hypothermia. On average, participants were following commands one day after admission and had short ICU stays.

3.2 Inter-rater reliability

Inter-rater reliabilities were calculated for both medical chart audits and participant interviews. The percentage of agreement for medical chart audits ($n = 13$) between 2 raters for discharge c-CPC scores was 92.31% ($\kappa = .87$) and for c-mRS scores was 61.54% ($\kappa = .51$). The percentage of agreement for patient interviews ($n = 10$) between 2 raters for i-CPC scores was 70.0% ($\kappa = .60$), i-mRS scores was 80% ($\kappa = .67$), and i-HUI3 scores was 97.3 ($\kappa = .96$).

3.3 Descriptive statistics for measures

The distributions of CPC, mRS, and HUI3 multi-attribute level and QOL utility scores are presented in Figure 1. The mean c-CPC score at discharge was 1.90 ± 1.00 . The mean i-CPC score at 1-month had increased to $2.57 \pm .68$ indicating greater neurological impairment and disability. The mean c-mRS score was 2.81 ± 1.63 at discharge and 3.14 ± 1.23 at 1-month indicating an increase in global disability. The mean i-HUI3 multi-attribute utility scores ranged from .84 (ambulation) to .98 (speech). The mean multi-attribute utility scores were indicative of none to mild disability. However, the mean i-HUI3 QOL score was $0.43 \pm .45$ at 1-month, which is indicative of severe disability.

3.4 Relationships among c-CPC and c-mRS; and i-CPC, i-mRS and i-HUI3 scores

The Kendall's tau correlation between the discharge measures (c-CPC and c-mRS) was significant and its strength was good (upper panel of Table 2). At 1-month, correlations among i-CPC, i-mRS and i-HUI3 were significant and moderately strong (lower right panel of Table 2).

However, an examination of the scatter plots revealed gross variability of the discharge c-mRS scores for each c-CPC category (Fig. 2). For example, of the 10 participants who had c-CPC scores of 1 (good cerebral performance), 1 had a c-mRS score of 0 (no symptoms at all), 7 had c-mRS scores of 1 (no significant disability), 1 had a c-mRS score of 3 (moderate disability) and 1 had a c-mRS score of 4 (moderately severe disability). The variability of the 1-month i-mRS scores for each i-CPC category was even more marked. For example, of the 11 participants who had an i-CPC of 3 (severe cerebral disability), 1 had an i-mRS score of 2 (slight disability), 3 had an i-mRS score of 3 (moderate disability), 4 had an i-mRS score of 4 (moderately severe disability), and 3 had an i-mRS score of 5 (severe disability).

The within category i-CPC scores, when compared to participants' corresponding i-HUI3 scores, also revealed substantial variation and overlap (Fig. 2). For participants rated as 2 (moderate cerebral performance) on the i-CPC, the i-HUI3 scores ranged from 0.25 (severe disability) to 1.00 (no disability). For participants rated as 3 (severe cerebral disability) on the i-CPC, the i-HUI3 scores ranged from -0.23 (state worse than death) to 0.32 (severe disability). Participants scored as 1 (good cerebral performance) and 4 (coma/vegetative state) on the i-CPC had i-HUI3 scores of 1.0 (no disability) and -0.35 (state worse than death), respectively.

3.5 Relationships among c-CPC and i-CPC, i-mRS, and i-HUI3 scores

Kendall's tau correlations between the discharge (c-CPC) and 1-month (i-CPC, i-mRS, i-HUI3) measures are shown in the lower left panel of Table 2. The strength of the correlations were fair to moderate, as well as significant.

However, scatter plots revealed a wide distribution of 1-month i-CPC, i-mRS, and i-HUI3 scores for each discharge c-CPC category (Fig. 3). For a c-CPC 1 score (good cerebral performance), the i-CPC scores ranged from 1 (good cerebral performance) to 3 (severe cerebral disability); the i-mRS scores ranged from 1 (no significant disability) to 5 (severe disability); and i-HUI3 scores ranged from 0.07 (severe disability) to 1.00 (no disability). Similarly, for c-CPC 2 scores (moderate cerebral performance), the i-CPC scores ranged from 2 (moderate cerebral performance) to 3 (severe cerebral performance); the i-mRS scores ranged from 2 (slight disability) to 5 (severe disability); and i-HUI3 scores ranged from -0.23 (state worse than death) to 1.00 (no disability). The c-CPC 3 scores (severe cerebral disability) corresponded with i-CPC 3 scores, but i-mRS scores ranged from 3 (moderate disability) to 5 (severe disability); and i-HUI3 scores ranged from -0.05 (state worse than death) to 0.77 (moderate disability). The c-CPC 4 score (coma/vegetative state) corresponded with an i-CPC score of 4, i-mRS score of 5 (severe disability), and i-HUI3 score of -0.34 (health state worse than death).

3.6 Differences

Even though the discharge and 1-month follow-up CPC and mRS measures were significantly correlated, we chose to examine differences between discharge and 1-month scores because of the substantial variability in the ratings over time. Dependent samples *t*-tests revealed that i-CPC scores were significantly worse than c-CPC scores ($t = -4.64$, $p < .001$), while i-mRS and c-mRS scores were comparable ($t = -1.23$, $p = .23$).

4. Discussion

The CPC is the conventional measure used to assess neurological sequelae after CA. The Utstein Style recommends the use of the CPC as an outcome variable.^{29, 30} Critical recommendations for patient care that may influence both short and long term outcomes such as disability and QOL are also based on CPC scores.³¹ However, the CPC has been shown to have a poor to fair correlation with long-term QOL.⁷ The relationship between CPC scores at discharge and short-term QOL was not known. Hence the purpose of our study was to examine the relationships among the CPC and measures of global disability and QOL at discharge from the hospital and at 1-month after the CA.

While the correlation coefficients between the c-CPC and c-mRS, and i-CPC, i-mRS and i-HUI3 appear to be moderate to good, an examination of the scatter plots revealed substantial variability of c-mRS, i-mRS and i-HUI3 scores within each CPC category. For example, at 1 month participants rated as having moderate cerebral performance (CPC 2), had i-HUI3 scores ranging from severe disability (.25) to no disability (1.00). Moreover, we had expected that as participants were rated as having more neurological impairment on the CPC, their corresponding HUI3 scores would have been incrementally partitioned and would not overlap. However, this was not the case. Similarly, in a study by Tiainen et al.,³² while 93% of the participants treated with hypothermia after a CA had achieved "good" outcome (CPC 1 or CPC 2), neuropsychological testing revealed that 34% of the participants had moderate to severe cognitive deficits. Thus, the wide variability and overlap of scores within and between CPC categories suggests that the CPC may be insensitive to differences in impairments and disability among persons with good, moderate, and severe cerebral disability. This may be attributed in part to the criteria for grading each CPC category. For instance, the criteria for a CPC of 2

(moderate cerebral performance) is “Conscious. Sufficient cerebral function for part-time work in sheltered environment or independent activities of daily life (dress, travel by public transportation, food preparation). May have hemiplegia, seizures, ataxia, dysarthria, or permanent memory or mental changes.” These criteria encompass neurological impairment and disability concepts, thus “lumping” together disparate concepts that do not allow for an accurate estimation of participants’ cognitive impairment or level of disability. In contrast, the HUI3 measures 8 distinct attributes of health allowing the participant to determine which attributes are most affected after the CA.

The most common method of collecting CPC data in large studies is through chart review.^{13, 14} An estimation of the CA patients’ subsequent quality of life is often made based on chart review of CPC scores.⁷ However, examining the relationship among c-CPC and i-CPC, i-mRS, and i-HUI3 scores revealed that c-CPC scores are not a good estimate of recovery or QOL 1-month later. The strength of the relationship between discharge CPC and 1-month CPC, mRS, and HUI3 scores ranged from fair to moderate. CPC scores obtained through chart review were significantly better than the CPC 1-month scores, thus overestimating the participants’ cognitive and disability status 1-month later. Our findings are similar to those reported by Hsu et al (1996), who reported a fair to moderate correlation between CPC at discharge and CPC 12-24 months later ($R^2 = .32$) and CPC at discharge and the Functional Status Questionnaire - a QOL measure ($R^2 = .13$) 12-24 months later. The lack of relevant factual data in the medical chart and subjective CPC criteria that mixes fact and inference may have resulted in a method scoring bias for the hospital discharge CPC. For instance, to determine a score of CPC 2, chart data were clear on level of consciousness, but raters were left to infer whether a patient would only be able to work part-time or carry out daily activities independently. No notes were found in the charts related to travel by public transportation or food preparation, although many mentioned dressing. At the 1-month follow-up, the patient interview allowed exploration of CPC criteria that were unclear (e.g., travel by public transportation, food preparation) thus leading to a more accurate estimation of the participant’s level of cerebral performance. In addition, when these subjects attempt to return to daily life, they may perceive greater disability resulting from lack of participation in everyday life. Hence our initial data indicate that the utility of using chart review for rating the CPC at discharge needs to be further validated, especially in light of the overestimation of cerebral function, which in turn can put patients at risk leading to non-referral for rehabilitation services, non-support of disability leaves, and misperceptions of “malingering.”

Our study had several strengths. First, we established inter-rater reliability between all our raters, especially between the 2 raters who scored the c-CPC (agreement = 92.31%; kappa = .87). Second, we collected follow-up data at a fixed interval of 1-month post-resuscitation.

While the findings from our study seem to appear very promising due to the high resolution data collected for each subject, its generalizability may be limited by a small sample size ($n = 21$). An additional limitation may be selection bias. A large proportion of subjects with CPC 1 and CPC 2 scores reflect the fact that subjects were recruited after having survived for at least 72 hours. The most devastated survivors of CPR often have withdrawal of care near that time, and would not be included in this study. This distribution of CPC categories in our study is representative of most series of CPR survivors in North America,^{9, 33} including in-hospital CPR.³⁴ However, we would anticipate that this bias would over-estimate the return to normal function after CA. Thus, the persistent impairments observed in this study, may actually be worse for many patients.

5. Conclusion

Although considered the gold standard for evaluating outcomes in persons who have had a CA, the CPC has several limitations. When compared to disability and QOL measures such as the mRS and the HUI3, the CPC may have limited ability to discriminate between mild and moderate brain injury. The validity of using the chart review method for obtaining scores also needs to be studied further. The findings from this study are limited due to a small sample size and a potential selection bias towards individuals with good post-CA outcomes. Further research should better describe the time-course of recovery after a CA using multiple measures of neurological and functional recovery at multiple time points.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

7. Acknowledgments

This manuscript, including related data, figures, and tables has not been previously published and the manuscript is not under consideration elsewhere.

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Abbreviations

c-CPC, chart review Cerebral Performance Category; c-mRS, chart review Modified Rankin Scale; i-CPC, in-person Cerebral Performance Category; i-mRS, in-person Modified Rankin Scale; i-HUI, in-person Health Utilities Index Mark 3.

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Figure 1.

Histograms demonstrating the distribution of scores for the discharge and 1-month follow-up measures

Abbreviations: mRS = Modified Rankin Scale, CPC = Cerebral Performance Category, HUI3 = Health Utilities Index Mark 3 system.

Figure 2.

Scatter plots comparing measures at discharge and at 1-month

Abbreviations: mRS = Modified Rankin Scale, CPC = Cerebral Performance Category, HUI3 = Health Utilities Index Mark 3 system.

Figure 3.

Scatter plots comparing Cerebral Performance Category at discharge to 1-month follow-up measures

Abbreviations: mRS = Modified Rankin Scale, CPC = Cerebral Performance Category, HUI3 = Health Utilities Index Mark 3 system.

Table 1

Demographic data

Age in years (SD)	56 (18)
Male gender, n (%)	13 (62)
Race, n (%)	
Caucasian	13 (62)
African American	3 (14)
Unknown	5 (24)
OHCA, n (%)	15 (71)
Presumed cardiac etiology, n (%)	19 (90)
Witnessed, n (%)	17 (81)
Bystander CPR, n (%)	11 (52)
Rhythm, n (%)	
VF/VT	17 (71)
PEA	3 (14)
Asystole	3 (14)
Rescue shocks delivered (SD)	2.38 (1.89)
Hypothermia, n (%)	9 (43)
Median Duration of Coma in days (95% CI)	1 (1-2)
Median Duration of Intubation in days (95% CI)	2.5 (1-4)
Median ICU Length of Stay in days (95% CI)	5 (4-9)
Median Total Length of Stay in days (95% CI)	13 (10-22)

Abbreviation: SD = Standard deviation; OHCA = Out-of-hospital cardiac arrest; CPR = Cardiopulmonary resuscitation; VF/VT = ventricular fibrillation/ventricular tachycardia; PEA = pulseless electrical activity; CI = confidence interval

Table 2
Intercorrelations among the measures at discharge and 1 month

	Discharge c-CPC	1 month i-CPC
Discharge c-CPC	1.00	
c-mRS	.79 [*]	
1 month		
i-CPC	.72 [*]	1.00
i-mRS	.47 [*]	.70 [*]
i-HUI3	-.41 [*]	-.71 [*]

Abbreviations: c-CPC = chart review Cerebral Performance Category; c-mRS = chart review Modified Rankin Scale; i-CPC = Interviewer administered Cerebral Performance Category; i-mRS = Interviewer administered Modified Rankin Scale, i-HUI3 = interviewer administered Health Utilities Index Mark 3 system.

*
p< .05