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Clinical paper

Performance of clinical risk scores to predict mortality and neurological outcome in cardiac arrest patients

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Abstract

Aim: Several scores are available to predict mortality and neurological outcome in cardiac arrest patients admitted to the intensive care unit (ICU). The aim of the study was to externally validate the prognostic value of four previously published risk scores.

Methods: For this observational, single-center study, we prospectively included 349 consecutive adult cardiac arrest patients upon ICU admission. We calculated two cardiac arrest specific risk scores (OHCA and CAHP) and two general severity of illness scores (APACHE II and SAPS II). The primary endpoint was in-hospital mortality. Secondary endpoints were neurological outcome at hospital discharge and 30-day mortality.

Results: 170 patients (49%) died until hospital discharge. All scores were independently associated with outcomes in logistic regression analysis and showed acceptable discrimination for in-hospital mortality with highest AUCs of the cardiac arrest specific risk scores (OHCA: 0.80 (95%CI 0.75–0.85) and CAHP: 0.84 (95%CI 0.79–0.88) compared to the severity of illness scores (APACHE II: 0.78 (95%CI 0.73–0.83) and SAPS II: 0.77 (95%CI 0.72–0.82). Results were robust in subgroup analysis except for worse performance in elderly patients (>75 years) and patients with respiratory cause of cardiac arrest. Results were similar for 30-days mortality and slightly higher for neurological outcome.

Conclusions: This study confirms the good prognostic performance of cardiac arrest specific scores to predict mortality and neurological outcomes in cardiac arrest patients. Routine use of OHCA or CAHP score helps to objectively risk stratify these vulnerable patients and thereby may improve therapeutic decisions.

Keywords: Cardiac arrest, Prognosis, Risk score, CAHP, OHCA, Cardiopulmonary resuscitation

Abbreviations: APACHE, Acute Physiology And Chronic Health Evaluation; AUC, area under the curve; BLS, basic life support; CAHP, Cardiac Arrest Hospital Prognosis; CI, confidence interval; CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; GCS, Glasgow Coma Scale; ICU, intensive care; NPV, negative predictive value; OHCA, out-of-hospital cardiac arrest; OR, odds ratio; PPV, positive predictive value; ROC, receiver-operating characteristic; ROSC, return of spontaneous circulation; SAPS, Simplified Acute Physiology Score.

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Introduction

Patients presenting after cardiac arrest still have a low probability of survival.[1,2] Also, the risk for neurological deficits is high leading to disability and high morbidity. Therapeutic management of this patient population is challenging because patients are usually unconscious upon admission to the intensive care unit (ICU). Temperature management often associated with intubation and sedation may further delay active involvement of patients in the decision process.[3–5] Therefore, discussions about therapeutic options often involves relatives acting as surrogate decision makers. An objective assessment of a patient's risk of death or neurological deficits is important for these discussions and may influence therapeutic decisions.[6]

For the purpose of risk prediction, several clinical tools have recently been developed. Two scores were specifically developed for cardiac arrest patients including the out-of-hospital cardiac arrest (OHCA) score and the Cardiac Arrest Hospital Prognosis (CAHP) score.[7,8] The OHCA score was developed in 2006 by Adrie and colleagues in France and is based on different variables available on ICU admission.[7,9] The score was later validated in a small two-center US study showing similar performance compared to the initial report.[9] The CAHP score was developed later by Maupain and colleagues and additionally includes resuscitation specific variables (e.g., location of cardiac arrest, epinephrine dose).[10] In addition to these cardiac arrest specific scores, more general ICU severity of illness scores such as the APACHE II (Acute Physiology And Chronic Health Evaluation) and SAPS II (Simplified Acute Physiology Score) may provide prognostic information for this population.[11,12] However, it is important to note that these two scores rely on the most severe values during the initial 24 h of ICU and the scores are thus not designed to improve initial risk stratification at ICU admission.

Comparison and external validation is an important step before wide-spread implementation in clinical routine. Herein, we compared the prognostic performance of these four scores in a relatively large-scale, prospective cohort of cardiac arrest patients. In addition, we performed subgroup analysis to better understand the robustness of the scores in defined patient populations.

Methods

Study setting

We performed a prospective observational study from October 2012 until July 2017 with data obtained in the COMMUNICATE trial at the University Hospital Basel, Switzerland. The COMMUNICATE trial collects data of patients with cardiac arrest and their relatives.

Because most patients after cardiac arrest were unable to sign the informed consent due to unconsciousness or sedation, their relatives were allowed to sign the informed consent form to express the presumed will of the patient. In case no family member was available, a physician – who was not involved in the study – certified that there were no objections for inclusion in the study.

Overall research aim

The main aim of this study is to validate and compare the performance of four risk scores for predicting mortality and neurological outcome in patients admitted to ICU after cardiac arrest.

Study population

Between October 2012 and July 2017, 349 consecutive patients with cardiac arrest surviving until admission to ICU were included in the study. Specifically, patients with out-of-hospital cardiac arrest (OHCA) or unobserved in-hospital cardiac arrest (IHCA) who consented or had a family member consenting to take part were included. There were no exclusion criteria regarding the patient's characteristics and type or duration of the cardiac arrest. Only adult patients ($\geq$16 years) were allowed to participate.

Data collection

All scores were calculated as suggested in the original publications.[7,8,11,12] We used data collected on the first day of admission. Resuscitation data were collected from clinical records, including no-flow time (time from cardiac arrest to start of basic life support (BLS)), low-flow time (time from start of BLS to return of spontaneous circulation (ROSC)), initial rhythm, setting and location of arrest, epinephrine dose given as well as information on whether bystanders observed the cardiac arrest and started cardiopulmonary resuscitation (CPR). Clinical parameters (i.e., heart rate blood pressure, Glasgow Coma Scale (GCS), respiratory rate, temperature, urine output), socio-demographics (i.e., age, gender, family situation, socio-economic status), comorbidities (i.e., coronary disease, congestive heart failure, hypertensions, chronic obstructive pulmonary disease (COPD), malignant disease, diabetes, renal failure, liver failure) and cardiovascular risk factors (i.e., smoking status, diabetes, high blood lipids, family history) were recorded from medical records or during an interview with patients' relatives. Blood markers (i.e., sodium, potassium, pH, bicarbonate, lactate, haematocrit, white blood cell count, creatinine, urea, bilirubin) were assessed as well.

Risk categories

Calculated point values of OHCA and CAHP scores were grouped into predefined risk categories, as proposed in the original publication (CAHP) and a validation study (OHCA).[8,9] Specifically, we divided patients into four OHCA categories (i.e., $<$20, 20–40, 40–60, $>$60 points) and into three CAHP categories (i.e., $<$150, 150–200, $>$200 points). For both scores, higher categories are associated with higher probability of unfavourable outcome.[7–9] For APACHE II and SAPS II, no such a priori risk categories are defined.[11,12]

Outcome

In line with the original publications, the primary endpoint was all-cause in-hospital mortality. Secondary outcomes were neurological outcome at hospital discharge as defined by the 5 levels of Cerebral Performance Category (CPC) scale and all-cause mortality at 30 days after cardiac arrest.[13] In line with previous studies, levels 1 (good recovery) and 2 (moderate disability) were considered as favourable neurological outcome, whereas levels 3 (severe disability), 4 (vegetative state) and 5 (death) were defined as unfavourable outcome.[7,8] Another secondary outcome was mortality at 30 days.

Statistical analysis

We used descriptive statistics such as medians and inter-quartile ranges for continuous variables and counts and proportions for binary or categorical variables to characterize our patient cohort.

We then calculated scores and risk categories based on cut-off levels as suggested in previous publications.[7,8,11,12] We had complete data in 86% for calculation of OHCA, 70% for CAHP, 80% for APACHE and 84% for SAPS. To account for missing score values, imputed datasets using multiple imputations over 5 datasets by chained equations were used for comparisons between scores. Imputations were calculated using multiple covariables (i.e. socio-demographics, comorbidities, resuscitation information, vital signs) also including main outcomes (death, neurological outcome) to reduce bias as previously suggested.[14] Score performance of imputed scores were also compared to crude values to check consistency (data not shown). To assess performance of the different scores, we first compared scores between survivors and non-survivors using medians and inter-quartile ranges. Second, we studied associations of scores and outcomes using logistic regression analysis with calculation of odds ratios (OR) and 95% confidence intervals (CI). Scores were divided into deciles for standardization and better comparability. We calibrated the scores using Hosmer-Lemeshow tests. Third, we computed receiver-operating characteristic (ROC) curves and corresponding areas under the curve (AUC) to show discrimination. To understand the prognostic value of different predefined cut-off-levels of OHCA and CAHP score in our cohort, we calculated sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and positive and negative likelihood ratios of every category and for each outcome. We also illustrated survival after 30 days and numbers at risk in each predefined category of OHCA and CAHP score with Kaplan-Meier-Curves.

Finally, we looked at performance of these scores in different predefined subgroups of patients including gender (female, male), age (<55, 55–75, >75 years), arrest setting (out-of-hospital, in-hospital), comorbidities (coronary artery disease, congestive heart disease), arrest cause (coronary artery disease, rhythmic, respiratory), and temperature management (hypothermia/isothermia vs no targeted temperature management).

We used STATA 12.0 for all statistical analyses and a p-value $\leq$ 0.05 was considered significant.

Results

Baseline characteristics

A total of 385 patients were admitted to the ICU of the University Hospital of Basel after cardiac arrest between October 2012 and July

Table 1 – Baseline characteristics.

	All	Survivors	In-hospital death	p-value
N	349	179	170	
Sociodemographics				
Age [years]	65 (56, 75)	62 (53, 73)	69 (59, 77)	0.001
Male gender	255 (73.1%)	144 (80.4%)	111 (65.3%)	0.002
Comorbidities				
Coronary artery disease	227 (65.0%)	130 (72.6%)	97 (57.1%)	0.002
Congestive heart failure	61 (17.5%)	29 (16.2%)	32 (18.8%)	0.57
COPD	34 (9.7%)	12 (6.7%)	22 (12.9%)	0.070
End-stage liver disease	6 (1.7%)	2 (1.1%)	4 (2.4%)	0.44
Hypertension	178 (51.0%)	96 (53.6%)	82 (48.2%)	0.34
Diabetes	86 (24.6%)	35 (19.6%)	51 (30.0%)	0.026
Renal failure	55 (15.8%)	25 (14.0%)	30 (17.6%)	0.38
Malignant disease	41 (11.7%)	13 (7.3%)	28 (16.5%)	0.008
Neurological disease	35 (10.0%)	18 (10.1%)	17 (10.0%)	1.00
Resuscitation Information				
No-flow time [min]	0 (0, 8)	0 (0, 5)	5 (0, 10)	<0.001
Low-flow time [min]	15 (10, 25)	12 (8, 20)	20 (12, 30)	<0.001
Observed cardiac arrest	288 (82.8%)	164 (91.6%)	124 (73.4%)	<0.001
Bystander CPR	216 (62.1%)	127 (70.9%)	89 (52.7%)	<0.001
Epinephrine during resuscitation [mg]	1 (0, 3)	0 (0, 1)	2 (1, 4)	<0.001
Arrest setting *				
At home	128 (36.8%)	48 (27.0%)	80 (47.1%)	<0.001
In public	162 (46.6%)	99 (55.6%)	63 (37.1%)	
In hospital	58 (16.7%)	31 (17.4%)	27 (15.9%)	
Initial heart rhythm				
Ventricular fibrillation	173 (49.6%)	113 (63.1%)	60 (35.3%)	<0.001
Ventricular tachycardia	19 (5.4%)	12 (6.7%)	7 (4.1%)	
Asystole	66 (18.9%)	15 (8.4%)	51 (30.0%)	
Pulseless electrical activity	77 (22.1%)	29 (16.2%)	48 (28.2%)	
Unknown	14 (4.0%)	10 (5.6%)	4 (2.4%)	
Initial blood values at ICU admission				
Initial lactate [mmol/l]	6.6 (4.2, 9.7)	4.9 (3.1, 7.3)	8.4 (5.6, 11.1)	<0.001
Initial pH	7.26 (7.19, 7.33)	7.28 (7.22, 7.34)	7.23 (7.11, 7.30)	<0.001

Data presented as n (%) or median (interquartile range). COPD, chronic obstructive pulmonary disease; CPR, cardiopulmonary resuscitation.
* n = 348, 1 out-of-hospital unknown setting.

Table 2 – Comparison between scores to predict primary and secondary endpoints.

A: In-hospital death

	OHCA	CAHP	APACHE II	SAPS II
Score points in all (349)	23 (9, 39)	163 (125, 202)	30 (26, 36)	66 (56, 75)
Score points in survivors (179)	12 (2, 24)	132 (105, 160)	28 (25, 33)	63 (52, 68)
Score points in In-hospital non-survivors (170)	34 (23, 46)	187 (163, 220)	34 (29, 38)	72 (63, 80)
p-value	<0.001	<0.001	<0.001	<0.001
OR per decile	1.55 (1.40, 1.71), p < 0.001	1.69 (1.51, 1.88), p < 0.001	1.47 (1.34, 1.61), p < 0.001	1.46 (1.34, 1.61), p < 0.001
ROC AUC	0.80 (0.75, 0.85)	0.84 (0.79, 0.88)	0.78 (0.73, 0.83)	0.77 (0.72, 0.82)

B: Death within 30 days

	OHCA	CAHP	APACHE II	SAPS II
Score points in all (349)	23 (9, 39)	163 (125, 202)	30 (26, 36)	66 (56, 75)
Score points in survivors (167)	12 (2, 24)	128 (105, 157)	28 (25, 32)	62 (51, 68)
Score points in non-survivors within 30 days (180)	33 (22, 45)	187 (163, 220)	34 (29, 38)	72 (63, 80)
p-value	<0.001	<0.001	<0.001	<0.001
OR per decile	1.56 (1.41, 1.72), p < 0.001	1.73 (1.55, 1.94), p < 0.001	1.52 (1.38, 1.67), p < 0.001	1.50 (1.36, 1.64), p < 0.001
ROC AUC	0.80 (0.75, 0.85)	0.85 (0.80, 0.89)	0.80 (0.75, 0.84)	0.78 (0.73, 0.83)

C: Neurological performance at hospital discharge

	OHCA	CAHP	APACHE II	SAPS II
Score points in all (349)	23 (9, 39)	163 (125, 202)	30 (26, 36)	66 (56, 75)
Score points in CPC 1-2 (151)	10 (1, 21)	120 (103, 148)	28 (24, 32)	60 (49, 67)
Score points in CPC 3-5 (198)	33 (21, 45)	185 (159, 219)	33 (29, 38)	70.5 (63, 79)
p-value	<0.001	<0.001	<0.001	<0.001
OR per decile	1.61 (1.45, 1.79), p < 0.001	1.79 (1.59, 2.02), p < 0.001	1.49 (1.35, 1.63), p < 0.001	1.50 (1.37, 1.65), p < 0.001
ROC AUC	0.81 (0.77, 0.86)	0.86 (0.82, 0.90)	0.79 (0.74, 0.83)	0.78 (0.73, 0.83)

Data presented as median (interquartile range) or mean (95% confidence interval); APACHE = Acute Physiology and Chronic Health Evaluation (-score); AUC = area under the curve; CAHP = Cardiac Arrest Hospital prognosis (-score); CPC = cerebral performance category; OHCA = Out-of-Hospital Cardiac Arrest (-score); OR, odds ratio; ROC, receiver operating characteristics curve; SAPS = Simplified Acute Physiology Score.

2017. A total of 36 patients were not included in the final analysis, because we were unable to get informed consent, or because patients suffered from a monitored in-hospital cardiac arrest. The final study population thus includes 349 patients. Of these, 170 (48.7%) patients died until hospital discharge. Out of 179 survivors, 28 (15.6%) had a poor neurological outcome.

Baseline characteristics in patients stratified by the primary endpoint are presented in Table 1. Older age (median 69 vs. 62 years) and female gender were associated with higher mortality. Information about resuscitation differed between groups. Specifically, survivors had a shorter no-flow and low-flow time, were more likely to have a witnessed cardiac arrest and bystander CPR and few received epinephrine during resuscitation. Concerning arrest location, mortality was significantly higher if cardiac arrest occurred at home while public cardiac arrests showed better survival. Shockable initial heart rhythms (i.e. ventricular fibrillation and ventricular tachycardia) presented significantly better survival than non-shockable rhythms such as pulseless electrical activity or asystole.

Association between scores and in-hospital mortality

All scores were associated with in-hospital mortality in logistic regression analysis (Table 2). The OHCA and CAHP scores had the highest standardized ORs (OR per decile increase 1.55 (95%CI 1.40–1.71), p < 0.001 and 1.69 (95%CI 1.51–1.88), p < 0.001, respectively). APACHE II and SAPS II also had significant but lower ORs (OR per

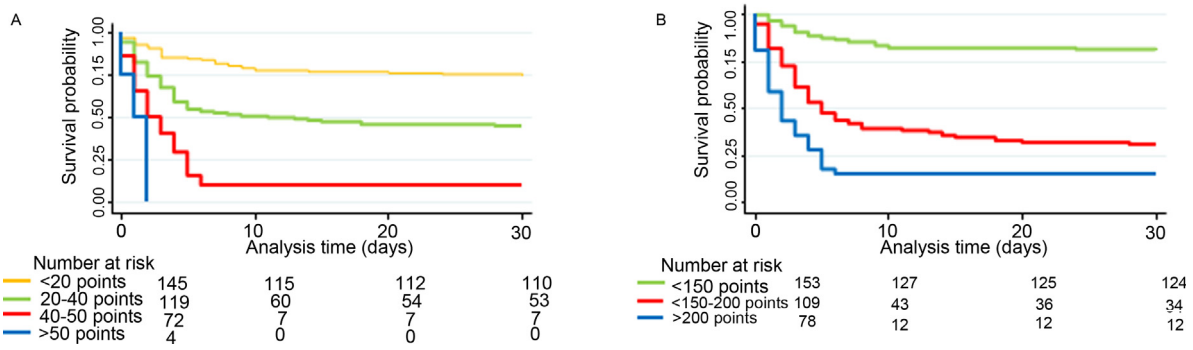

Fig. 1 – Kaplan-Meier survival estimate OHCA (A) and CAHP (B), split into predefined categories.

decile increase 1.47 (95%CI 1.34–1.61), p < 0.001and OR 1.46 (95% CI 1.34–1.61), p < 0.001). Also, all scores showed acceptable discrimination for in-hospital mortality with highest AUCs of the cardiac arrest specific risk scores (OHCA: 0.80 and CAHP: 0.84) compared to the severity of illness scores (APACHE II: 0.78 and SAPS II: 0.77). Goodness-of-fit test showed no evidence for miscalibration (p-value OHCA 0.1; p-value CAHP 0.76).

In a next step, we calculated prognostic accuracy at predefined cut-offs focusing on the cardiac arrest specific scores. For the OHCA score we used the four predefined categories (<20 points, 20–40 points, >40–60 points and >60 points) (Fig. 1A and Table 3). In our cohort, only 4 patients were assigned to the highest category with all of them having died until hospital discharge. The NPV in the lowest category was 78% with a sensitivity of 81%. PPV in the highest category 100% with also 100% specificity. The optimal cut-off was at 27 points with a sensitivity and specificity of 67% and 80%.

For the CAHP score we also used the predefined categories (<150 points, 150–200 points and > 200 points) (Fig. 1B and Table 4). The NPV in the lowest category was 81% with a sensitivity of 82%. PPV in the highest category was 81% with 91% specificity. The optimal cut-off was at 161 points with a sensitivity and specificity of 78% and 79%, respectively.

Association of scores and secondary endpoints

The performance of the scores for secondary endpoints was similar to in-hospital mortality. ORs were all significant and AUCs for 30-day mortality ranged between 0.80 and 0.85. For neurological outcome, results were also significant in logistic regression analysis and AUCs were slightly higher for CAHP (0.86) and OHCA (0.81). Tables 3 and 4 display the prognostic performance for secondary endpoints at different cut-offs for the OHCA score and the CAHP score.

Table 3 – Performance of the OHCA score at different cut-off points to predict adverse outcome (A. In-hospital death; B. Death within 30 days; C. adverse neurological outcome).

A: In-hospital death

OHCA category	> I, cut-off 20 points	> II, cut-off 40 points	> III, cut-off 60 points	Youden-Index, cut-off 27 points
Total number of patients (n=)	201	79	4	170
Survivors (n=)	64	10	0	56
In-hospital death (n=)	137	69	4	114
Sensitivity	80.6 (73.8, 86.2)	40.6 (33.1, 48.4)	2.4 (0.6, 5.9)	67.1 (59.4, 74.1)
Specificity	64.2 (56.8, 71.3)	94.4 (90, 97.3)	100 (98, 100)	79.9 (73.3, 85.5)
PPV	68.2 (61.2, 74.5)	87.3 (78.0, 93.8)	100 (39.8, 100)	76.0 (68.4, 82.6)
NPV	77.7 (70.1, 84.1)	62.6 (56.5, 68.4)	51.9 (46.5, 57.3)	71.9 (65.1, 78.0)
LLR+	2.25 (1.83, 2.78)	7.27 (3.87, 13.63)	N/A	3.33 (2.44, 4.55)
LLR-	0.30 (0.22, 0.42)	0.63 (0.55, 0.72)	0.98 (0.95, 1.00)	0.41 (0.33, 0.52)

B: Death within 30 days

OHCA category	> I, cut-off 20 points	> II, cut-off 40 points	> III, cut-off 60 points	Youden-Index, cut-off 27 points
Total number of patients (n=)	201	79	4	180
Survivors (n=)	59	7	0	62
Death within 30 days (n=)	142	72	4	118
Sensitivity	78.9 (72.2, 84.6)	40.0 (32.8, 47.6)	2.2 (0.6, 5.6)	65.6 (58.1, 72.5)
Specificity	65.1 (57.4, 72.2)	95.9 (91.7, 98.3)	100 (97.8, 100)	81.1 (74.3, 86.7)
PPV	70.6 (63.8, 76.8)	91.1 (82.6, 96.4)	100 (39.8, 100)	78.7 (71.2, 84.9)
NPV	74.3 (66.5, 81.1)	60.0 (53.9, 65.9)	49.0 (43.6, 54.4)	68.8 (61.9, 75.2)
LLR+	2.26 (1.81, 2.81)	9.66 (4.58, 20.38)	N/A	3.46 (2.49, 4.81)
LLR-	0.32 (0.24, 0.44)	0.63 (0.55, 0.71)	0.98 (0.96, 1.00)	0.42 (0.34, 0.53)

C: Neurological performance at hospital discharge

OHCA category	> I, cut-off 20 points	> II, cut-off 40 points	> III, cut-off 60 points	Youden-Index, cut-off 27 points
Total number of patients (n=)	201	79	4	198
CPC 1-2 (n=)	46	5	0	70
CPC 3-5 (n=)	155	74	4	128
Sensitivity	78.3 (71.9, 83.8)	37.4 (30.6, 44.5)	2 (0.6, 5.1)	64.6 (57.6, 71.3)
Specificity	69.5 (61.5, 76.8)	96.7 (92.4, 98.9)	100 (97.6, 100)	85.4 (78.8, 90.6)
PPV	77.1 (70.7, 82.7)	93.7 (85.8, 97.9)	100 (39.8, 100)	85.3 (78.6, 90.6)
NPV	70.9 (62.9, 78.1)	54.1 (47.9, 60.1)	43.8 (38.5, 49.2)	64.8 (57.8, 71.4)
LLR+	2.57 (2.00, 3.31)	11.29 (4.68, 27.23)	N/A	4.44 (2.98, 6.62)
LLR-	0.31 (0.23, 0.42)	0.65 (0.58, 0.72)	0.98 (0.96, 1.00)	0.41 (0.34, 0.51)

Data presented as mean (95% confidence interval); CPC = cerebral performance category; LLR+ = positive likelihood ratio; LLR- = negative likelihood ratio; NPV = negative predictive value; OHCA = Out-of-Hospital Cardiac Arrest (-score); PPV = positive predictive value.

Subgroup analysis

Finally, we performed a subgroup analysis to determine the robustness of data. For the OHCA score, AUCs were similar in subgroups according to gender, setting (in-hospital vs out of hospital), comorbidity, resuscitation parameters and temperature management (Fig. 2). However, the OHCA score performed worse in elderly patients (AUC 0.67 in patients ≥75 years) and if patients had a respiratory reason for cardiac arrest (AUC 0.67). For the CAHP score, the same subgroups had worse performance measures (Fig. 3).

Discussion

We independently and externally validated two cardiac arrest specific scoring systems and two general severity of illness scores to predict mortality and neurological outcome in a prospective cohort of cardiac arrest patients followed for 30 days. While all scores showed acceptable measures of discrimination, the CAHP score had the best prognostic performance characteristics followed by the OHCA score. Both scores were also reliable to predict poor neurological outcome. In line with a previous validation study, the OHCA score showed a higher positive predictive value to predict death compared to the CAHP score.[9] Based on the previous derivation studies and our prospective validation, these scores may be used in clinical practice for objective risk stratification of cardiac arrest patients.

Both scores were developed specifically for out-of-hospital cardiac arrests.[7,8] Within our cohort, we validated the scores in patients with any type of cardiac arrest. Subgroup analysis showed a better performance for out-of-hospital compared to in-hospital not-monitored cardiac arrest patients. Still, the scores showed acceptable discrimination in the subgroup of in-hospital cardiac arrest patients. As our sample size of this subgroup was limited, further research should look at this specific patient population. Our

Table 4 – Performance of the CAHP score at different cut-off points.

A: In-hospital death

CAHP category	> I, cut-off 150 points	> II, cut-off 200 points	Youden-Index, cut-off 161 points
Total number of patients (n=)	191	82	170
Survivors (n=)	51	160	37
In-hospital death (n=)	140	66	133
Sensitivity	82.4 (75.8, 87.8)	38.8 (31.5, 46.6)	78.2 (71.3, 84.2)
Specificity	71.5 (64.3, 78.0)	91.1 (85.9, 94.8)	79.3 (72.7, 85.0)
PPV	73.3 (66.4, 79.4)	80.5 (70.3, 88.4)	78.2 (71.3, 84.2)
NPV	81.0 (74.0, 86.8)	61.0 (54.9, 66.9)	79.3 (72.7, 85.0)
LLR+	2.89 (2.27, 3.68)	4.34 (2.62, 7.19)	3.78 (2.81, 5.10)
LLR-	0.25 (0.18, 0.35)	0.67 (0.59, 0.76)	0.27 (0.20, 0.37)

B: Death within 30 days

CAHP category	> I, cut-off 150 points	> II, cut-off 200 points	Youden-Index, cut-off 161 points
Total number of patients (n=)	191	82	180
Survivors (n=)	45	12	42
Death within 30 days (n=)	146	70	138
Sensitivity	81.1 (74.6, 86.5)	38.9 (31.7, 46.4)	76.7 (69.8, 82.6)
Specificity	73.4 (66, 79.9)	92.9 (87.9, 96.3)	81.1 (74.3, 86.7)
PPV	76.4 (69.8, 82.3)	85.4 (75.8, 92.2)	81.2 (74.5, 86.8)
NPV	78.5 (71.2, 84.6)	58.8 (52.6, 64.8)	76.5 (69.6, 82.5)
LLR+	3.05 (2.35, 3.95)	5.48 (3.08, 9.74)	4.05 (2.93, 5.59)
LLR-	0.26 (0.19, 0.35)	0.66 (0.58, 0.74)	0.29 (0.22, 0.38)

C: Neurological performance at hospital discharge

CAHP category	> I, cut-off 150 points	> II, cut-off 200 points	Youden-Index, cut-off 161 points
Total number of patients (n=)	191	82	198
CPC 1-2 (n=)	31	10	50
CPC 3-5 (n=)	160	72	148
Sensitivity	80.8 (74.6, 86)	36.4 (29.7, 43.5)	74.7 (68.1, 80.6)
Specificity	79.5 (72.1, 85.6)	93.4 (88.2, 96.8)	85.4 (78.8, 90.6)
PPV	83.8 (77.8, 88.7)	87.8 (78.7, 94.0)	87.1 (81.1, 91.7)
NPV	75.9 (68.5, 82.4)	52.8 (46.6, 58.9)	72.1 (64.9, 78.5)
LLR+	3.94 (2.86, 5.43)	5.49 (2.93, 10.28)	5.13 (3.46, 7.61)
LLR-	0.24 (0.18, 0.33)	0.68 (0.61, 0.76)	0.30 (0.23, 0.38)

Data presented as mean (95% confidence interval); CAHP = Cardiac Arrest Hospital prognosis (-score); CPC = cerebral performance category; LLR+ = positive likelihood ratio; LLR- = negative likelihood ratio; NPV = negative predictive value; PPV = positive predictive value.

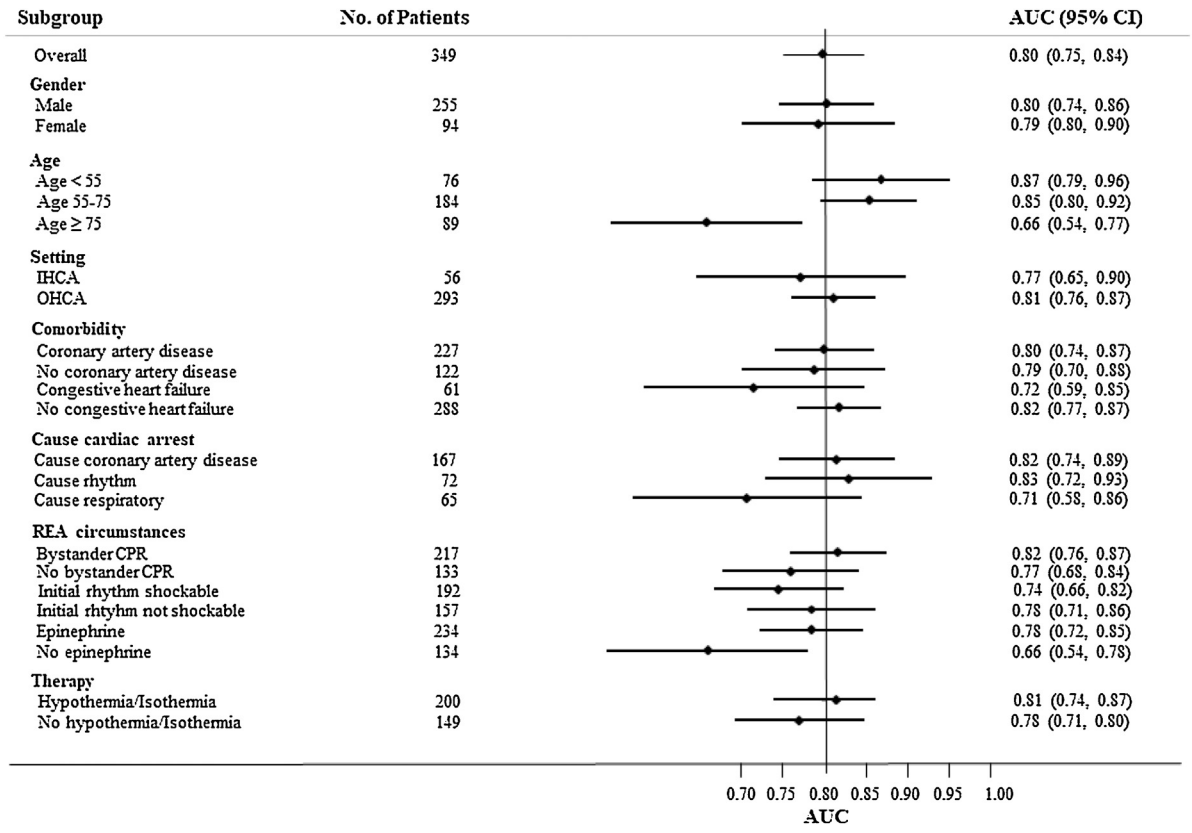

Fig. 2 – Subgroup analysis of OHCA score for endpoint death before hospital discharge. OHCA, out-of-hospital cardiac arrest; IHCA, in-hospital cardiac arrest; CPR, cardiopulmonary resuscitation; AUC, area under the curve.

cohort included consecutive cardiac arrest patients and with no selection of patients. Our patients were older compared to previous studies and the performance in the elderly showed worse performance compared to younger patients. This may explain why AUCs were slightly higher in previous studies for both, CAHP and OHCA scores.[7–9]

Interestingly, the two severity of illness scores also showed acceptable discrimination for all outcomes assessed. Yet, an advantage of the cardiac-arrest specific scores is that their calculation is based on initial ICU parameters readily available. This allows early risk stratification and may support doctors in decision-making regarding initial management. APACHE II and SAPS II are based on the most severe values within 24 h which introduces a time delay until the scores are ready for use. Also, their performance was inferior in our cohort and in previous studies.[15,16]

Applying the OHCA score to our cohort, only 4 patients were assigned to the highest category (>60 points). Although all of these patients died and specificity and PPV were thus high, the categories suggested by a validation study seem to be suboptimal for our cohort. Regarding the CAHP score, no category reached a very high specificity or sensitivity. However, a high specificity was reached at the higher cut-off and a high sensitivity was found at the lower cut-off which seems helpful for ruling-in and ruling-out adverse outcome.

Importantly, these scores rely on resuscitation information reported by relatives, paramedics and the medical staff. The no-flow time is known to be difficult to estimate. However, every additional minute adds to the score and is associated with a 7–10% increase in poor outcomes.[17] We used the assessment reported at ICU admission, which allowed us to evaluate the scores under real-life conditions including possible errors.

There are some limitations to our study. First, this is a single-center study performed at one University Hospital in Switzerland. Our cohort shows slightly better survival than studies from other countries particularly for hospital discharge.[18–20] This may have several reasons, like fast emergency medical services responses and short rescue distances in the urban area of Basel possibly impeding generalizability of the results to other hospitals and health care systems. Second, the study was observational, and we do not know if use of these scores influences therapeutic decisions, since they are not used in clinical routine yet. Interventional research is needed to understand the effect of risk scores on patient management.

Conclusions

In conclusion, our single center study confirms that CAHP and OHCA score are useful risk stratification tools in cardiac arrest patients

Conflicts of interest

None.

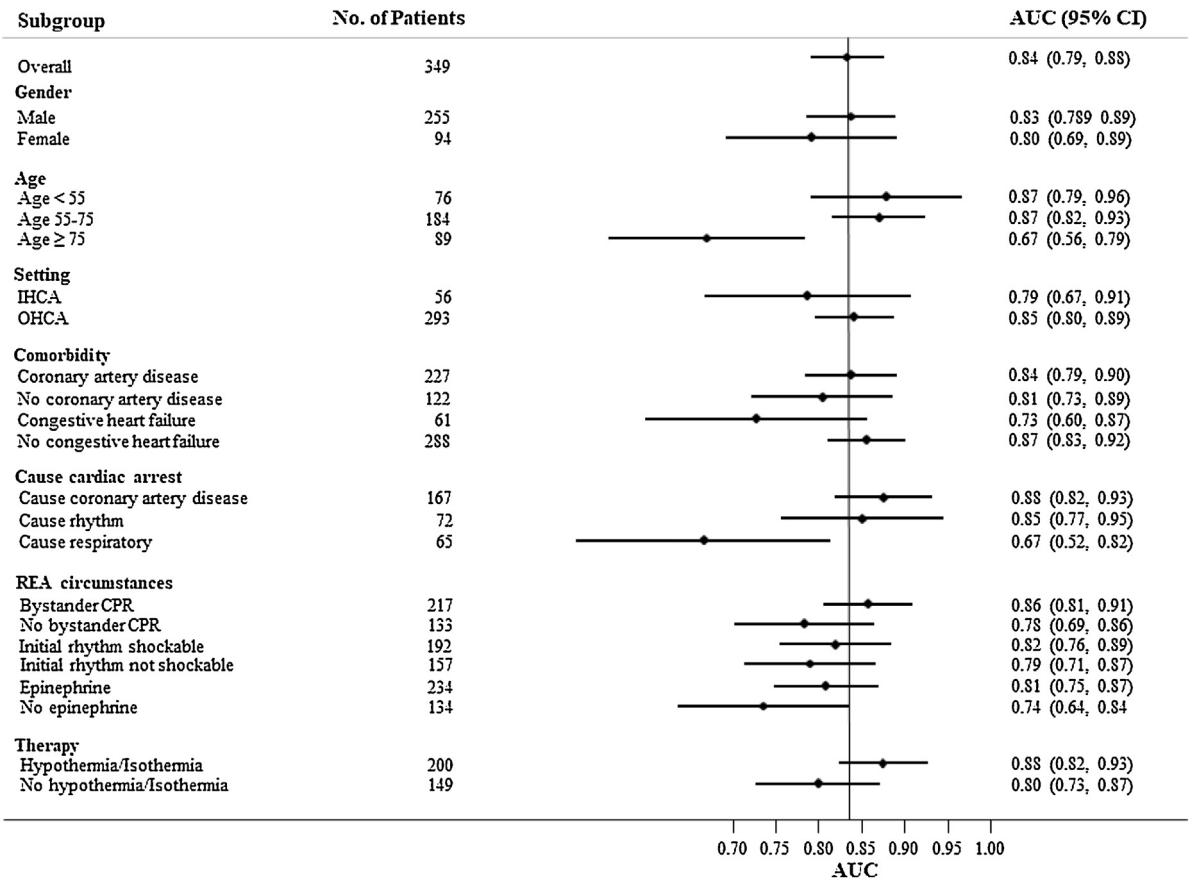

Fig. 3 – Subgroup analysis of CAHP score for endpoint death before hospital discharge. OHCA, out-of-hospital cardiac arrest; IHCA, in-hospital cardiac arrest; CPR, cardiopulmonary resuscitation; AUC, area under the curve.

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None of the authors has financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work.

Ethics approval and patient consent

Our study complies with the Declaration of Helsinki. The Ethics Committee of Northwest and Central Switzerland (Ethikkommission Nordwest- und Zentralschweiz, EKNZ) approved this study. The approval reference number is EKNZ 373/11. Either informed consent was obtained from the patient itself or, if unconscious or sedated, from a family member who served as the surrogate decision-maker.

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