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ORIGINAL SCIENTIFIC PAPER
Acute Coronary Syndromes

Comparison of risk prediction models in infarct-related cardiogenic shock

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Aims Several prediction models have been developed to allow accurate risk assessment and provide better treatment guidance in patients with infarct-related cardiogenic shock (CS). However, comparative data between these models are still scarce. The objective of the study is to externally validate different risk prediction models in infarct-related CS and compare their predictive value in the early clinical course.

Methods and results The Simplified Acute Physiology Score (SAPS) II Score, the CardShock score, the IABP-SHOCK II score, and the Society for Cardiovascular Angiography and Intervention (SCAI) classification were each externally validated in a total of 1055 patients with infarct-related CS enrolled into the randomized CULPRIT-SHOCK trial or the corresponding registry. The primary outcome was 30-day all-cause mortality. Discriminative power was assessed by comparing the area under the curves (AUC) in case of continuous scores. In direct comparison of the continuous scores in a total of 161 patients, the IABP-SHOCK II score revealed best discrimination [area under the curve (AUC = 0.74)], followed by the CardShock score (AUC = 0.69) and the SAPS II score, giving only moderate discrimination (AUC = 0.63). All of the three scores revealed acceptable calibration by Hosmer–Lemeshow test. The SCAI classification as a categorical predictive model displayed good prognostic assessment for the highest risk group (Stage E) but showed poor discrimination between Stages C and D with respect to short-term-mortality.

Conclusion Based on the present findings, the IABP-SHOCK II score appears to be the most suitable of the examined models for immediate risk prediction in infarct-related CS. Prospective evaluation of the models, further modification, or even development of new scores might be necessary to reach higher levels of discrimination.

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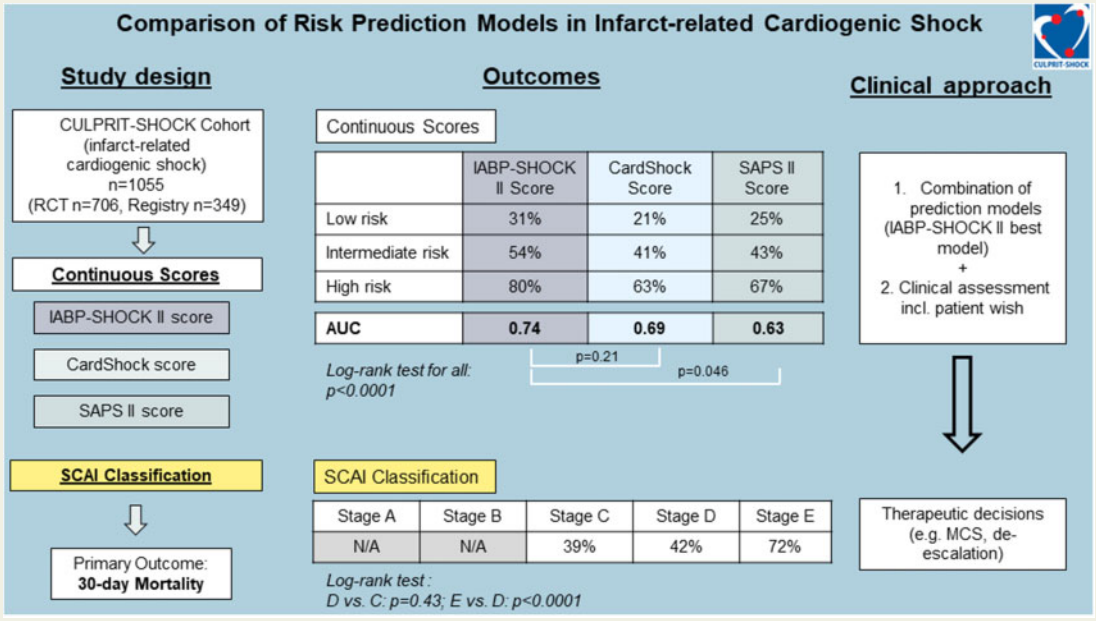
Graphical Abstract



Keywords Cardiogenic shock • Acute myocardial infarction • Outcome • Prognosis • Risk models • Scores

Introduction

During the past decades, advances in the treatment of cardiogenic shock (CS) caused by acute myocardial infarction (AMI) have led to a substantial decrease in short- and long-term mortality.[1,2] However, mortality in infarct-related CS is still high, reaching 40–50% at 30 days.[3,4] To improve treatment guidance and allow for reproducible characterization of shock severity, several prediction models for shock in general, and CS in particular have been developed. General scores, like the Simplified Acute Physiology Score (SAPS) II Score predict mortality in intensive care patients, not referring exclusively to shock.[5] Cardiac patients were excluded from the original study and so far the score has not been adequately validated in patients with CS. Exclusively for CS, the CardShock-Score and the IABP-SHOCK II Score are available. The CardShock-Score was developed in a relatively small cohort of CS patients including both AMI-CS and non-AMI-CS.[6] The IABP-SHOCK II score evolved solely from a cohort of AMI-CS patients.[7] External validation was performed for both scores showing satisfactory discrimination for AMI-CS patients but yielding heterogeneous results in non-AMI-CS patients.[8,9] Recently, the Society for Cardiovascular Angiography and Intervention (SCAI) introduced a new classification of CS applicable for both AMI-CS and non-AMI-CS.[10] Compared to the aforementioned models, the SCAI classification is not a numerical score but a classification of stages based on various clinical and haemodynamic findings. The stages were not developed using a statistical approach in an existing CS cohort but defined by expert consensus. Validation was carried out retrospectively in several CS cohorts but exact definitions of each shock stage varied considerably between the studies.[11–13] The present study aimed to externally validate and compare all of these risk prediction models in the cohort of the CULPRIT-SHOCK trial, so far the largest randomized trial in CS and the corresponding registry.

Methods

Study design and overview

The present analysis was performed in patients enrolled in the CULPRIT-SHOCK trial, the design and main results of which have been published previously.[4,14,15] In brief, the CULPRIT-SHOCK trial was a multi-centre international randomized study in patients with infarct-related CS and multi-vessel coronary artery disease comparing immediate multi-vessel percutaneous coronary intervention (PCI) against PCI of the culprit lesion only (with the option of staged revascularization at a later time point). Between 2013 and 2017, 706 patients were enrolled at 83 European centres and randomized in a 1:1 fashion. Cardiogenic shock was defined as systolic blood pressure <90 mmHg for >30 min or the use of catecholamine therapy to maintain a systolic pressure >90 mmHg, clinical signs of pulmonary congestion, and signs of impaired organ perfusion with at least one of the following manifestations: altered mental status; cold, clammy skin, and extremities; oliguria with urine output <30 mL/h; and serum lactate >2.0 mmol/L. Further eligibility criteria included planned early revascularization by means of PCI, multi-vessel coronary artery disease, and an identifiable culprit lesion. Exclusion criteria were

cardiopulmonary resuscitation >30 min, no intrinsic heart action, an assumed severe deficit in cerebral function with fixed dilated pupils, an indication for primary urgent coronary artery bypass grafting (CABG), single-vessel coronary artery disease, mechanical cause of CS, onset of shock more than 12 h before randomization, age >90 years, shock of non-cardiac cause, massive pulmonary embolism, known severe renal insufficiency (creatinine clearance <30 mL/min), and other severe concomitant diseases associated with a life expectancy of less than 6 months. With regards to a composite primary endpoint of all-cause mortality or severe renal failure leading to renal replacement therapy within 30 days after randomization, PCI of the culprit lesion only was superior to immediate multi-vessel PCI.

Patients with infarct-related CS not eligible for randomization were included in the CULPRIT-SHOCK registry. For the present sub-study, all patients from the randomized trial and registry were included, giving a total of 1055 patients. Informed consent was obtained for all patients.

Calculation of continuous scores

The SAPS II score was calculated for each patient by the individual study centre on a daily basis. For the present study, only the score on the day of study inclusion was used, which corresponded in most cases with the day of admission and in general with the day of cardiac catheterization and PCI.

The CardShock score and IABP-SHOCK II score were calculated post hoc using their individual items from the database (see Supplementary material online, *Tables S1* and *S2*). Patients with one or more missing items required to calculate the individual score were not included into the respective analyses.

SCAI classification

Patients were retrospectively assigned to one of the SCAI classification groups (A = at risk; B = hypotension; C = hypoperfusion; D = deteriorating; E = extremis). Adapted definitions for each group for the present cohort are shown in Supplementary material online, *Table S3*. Groups were further stratified by the 'A-modifier' as set out in the original classification, indicating the presence of cardiac arrest. In the present analysis, this was defined as resuscitation up to 24 h prior to study inclusion or during index cardiac catheterization.

Statistical analysis

Categorical variables are presented as absolute numbers and percentages, continuous data as median with interquartile range to account for non-normal distribution in most cases. For categorical variables, comparisons between patients with and without death until Day 30 were performed using χ^2 or Fisher's exact test when the expected number of patients in one cell was less than five. For continuous variables, Wilcoxon rank-sum tests were performed.

To assess and compare discrimination of each continuous score (SAPS II score, CardShock score, and IABP-SHOCK II score), receiver operating characteristic (ROC) curves were constructed. Additionally, the area under the curve (AUC) for each score was calculated. For patients in whom the determination of all three continuous scores was possible, AUCs were compared by using a contrast matrix to take differences of the areas under the empirical ROC curves.[16] Calibration in this subset of patients was assessed by Hosmer–Lemeshow Goodness-of-Fit test.

Kaplan–Meier curves with comparison of survival times using log-rank test were computed for the pre-defined risk groups by definition of the respective classification. In case of the SAPS-II score, patients were classified into three risk groups by tertiles as stratification by risk groups was not part of the original score.

The primary outcome for all analyses was 30-day all-cause mortality. For explorative analyses, Kaplan–Meier curves were also computed to compare 1-year mortality.

A two-sided *P*-value of 0.05 was considered statistically significant for all tests. Statistical analyses were performed using SAS version 9.4 (Statistical Analysis Software, Cary, NC, USA).

Results

Patient characteristics

Baseline and procedural characteristics are displayed in *Table 1*. A total of 1055 patients were included into the analysis. In 31 (2.9%) patients, no information on 30-day mortality was available. The median age was 68 years with a substantially higher proportion of male patients and an overall high cardiovascular risk profile. More than half of the patients experienced resuscitation within 24 h before study inclusion. About two thirds had ST-segment elevation myocardial infarction (STEMI) and the left anterior descending (LAD) was the vessel most commonly related to infarction. The majority of patients received mechanical ventilation and catecholamine treatment. Mechanical circulatory support (MCS) was implemented in one-third with intra-aortic balloon pump (IABP) as the device most frequently used. Overall mortality was 46.2% at 30 days and non-surviving patients were more likely to have diabetes, atrial fibrillation, altered mental status on admission, STEMI, the LAD as culprit vessel, multivessel disease, and unsuccessful PCI defined as thrombolysis in myocardial infarction (TIMI) flow <3 after PCI. Further, the rates of mechanical ventilation, catecholamine therapy and MCS were all higher in fatal cases, who also had higher levels of lactate, creatinine and glucose on admission.

Risk prediction models

SAPS I, IABP-SHOCK II, and CardShock Score

The Kaplan–Meier curves for the continuous scores SAPS II, IABP-SHOCK II, and CardShock are displayed in *Figure 1A–C*, respectively. The SAPS II score was available in a total of 807 patients, the IABP-SHOCK II score in 438 patients and the CardShock-Score in 231 patients. By design, categorizing the SAPS II score by tertiles resulted in a balanced distribution between the groups. With respect to the IABP-SHOCK II score, the majority of patients were categorized to the low or intermediate risk groups in which mortality at 30 days was 31% and 54%, respectively and reached 80% in the high risk group. In case of the CardShock score, mortality at 30 days was lower in all three risk groups compared to the IABP-SHOCK II score (21% for low risk, 41% for intermediate risk and 63% for high risk). On survival time analyses, the difference between the risk groups was significant for all three scores ($P < 0.0001$ by log-rank test). On explorative analyses these differences remained significant at 1-year follow-up (Supplementary material online, *Figures S1* and *S2*). Individual ROC curves for the three scores are displayed in Supplementary material online, *Figure S3*. In 161 patients, all three continuous scores were available. Baseline and procedural characteristics for these patients are displayed in Supplementary material online, *Table S4*. Mortality until 30 days did not differ between patients with all scores available and those without (47.2% vs. 47.6%, $P = 0.92$). ROC curve analyses patients are displayed in *Figure 1D*. Discrimination between patients

Table 1 Baseline and procedural characteristics

Characteristics	All (*n* = 1055)	Death at 30 days (*n* = 487)	Alive at 30 days (*n* = 537)	*P*-value
Age (years), median (IQR)	68 (59–77)	73 (64–80)	64 (56–74)	<0.001
Male sex, *n* (%)	778/1038 (75.0)	349/482 (72.4)	410/535 (76.6)	0.12
Hypertension, *n* (%)	602/1001 (54.4)	266/456 (58.3)	327/529 (61.8)	0.27
Diabetes mellitus, *n* (%)	302/1001 (30.2)	157/455 (34.5)	140/528 (26.5)	0.007
Previous myocardial infarction, *n* (%)	167/1005 (16.6)	167/1005 (15.7)	92/529 (17.4)	0.48
Previous CABG surgery, *n* (%)	20/1010 (5.0)	23/463 (5.0)	27/529 (4.9)	0.92
Atrial fibrillation, *n* (%)	117/1007 (11.6)	64/461 (13.9)	23/529 (9.8)	0.05
Previous stroke, *n* (%)	76/1008 (7.5)	42/462 (9.1)	33/528 (6.3)	0.09
Chronic dialysis, *n* (%)	14/1008 (1.4)	10/462 (2.2)	3/529 (0.6)	0.03
Resuscitation within 24 h before randomization, *n* (%)	550/1015 (54.2)	261/468 (55.8)	279/529 (52.6)	0.31
Altered mental status on admission, *n* (%)	676/1012 (66.8)	342/467 (73.2)	323/528 (61.2)	<0.001
ST-segment elevation, *n* (%)	647/989 (65.4)	282/454 (62.1)	353/518 (68.1)	0.05
Mean arterial pressure on admission (mmHg), median (IQR)	76 (63–93), *n* = 867	72 (60–90), *n* = 389	78 (65–94), *n* = 462	<0.001
Arterial lactate pre PCI (mmol/L), median (IQR)	5.2 (2.7–8.6), *n* = 609	6.5 (3.5–10.0), *n* = 293	4.2 (2.3–6.9), *n* = 310	<0.001
Creatinine on admission (µmol/L), median (IQR)	111 (90–143), *n* = 964	123 (98–164), *n* = 434	103 (85–126), *n* = 516	<0.001
Glucose on admission (mmol/L), median (IQR)	12.1 (8.6–17.1), *n* = 735	13.1 (9.5–18.4), *n* = 335	11.1 (8.0–15.6), *n* = 388	<0.001
Left ventricular ejection fraction in acute setting (%), median (IQR)	32 (25–40), *n* = 374	30 (20–40), *n* = 173	37 (26–45), *n* = 196	<0.001
No. of affected vessels, *n* (%)				0.003
1	139/1031 (13.5)	50/479 (10.4)	83/533 (15.6)	
2	319/1031 (30.9)	140/479 (29.2)	173/533 (32.5)	
3	573/1031 (55.6)	289/479 (60.3)	277/533 (52.0)	
Vessel related to the infarction, *n* (%)				0.019
Left anterior descending artery	443/1028 (43.1)	227/477 (47.6)	205/532 (38.5)	
Left circumflex artery	199/1028 (19.4)	90/477 (18.9)	106/532 (19.9)	
Right coronary artery	292/1028 (28.4)	109/477 (22.9)	179/532 (33.6)	
Left main artery	82/1028 (8.0)	44/477 (9.2)	37/532 (7.0)	
Bypass graft	12/1028 (1.2)	7/477 (1.5)	5/532 (0.9)	
TIMI-flow post-PCI <3, *n* (%)	168/1022 (16.4)	118/475 (24.8)	47/530(8.9)	<0.001
Immediate PCI of additional lesions, *n* (%)	466/1036 (45.0)	236/484 (48.8)	224/534 (41.9)	0.03
Mechanical circulatory support, *n* (%)				
Any	312/1055 (29.6)	174/487 (35.7)	132/537 (24.6)	<0.001
Impella® 2.5	44/312 (14.1)	33/174 (19.0)	11/132 (8.3)	0.009
Impella® CP	68/312 (21.8)	38/174 (21.8)	29/132 (22.0)	0.96
Extracorporeal membrane oxygenation	95/312 (30.4)	66/174 (37.9)	27/132 (20.5)	<0.001
Intra-aortic balloon pump	129/312 (41.3)	58/174 (33.3)	68/132 (51.5)	0.001
Other	6/312 (1.9)	2/174 (1.2)	4/132 (3.0)	0.41
Mild induced hypothermia, *n* (%)	326/1031 (31.6)	154/483 (31.9)	167/532 (31.4)	0.87
Mechanical ventilation, *n* (%)	819/1011 (81.0)	430/469 (91.7)	378/527 (71.7)	<0.001
Catecholamine therapy, *n* (%)	907/1011 (89.7)	452/469 (96.4)	444/527 (84.3)	<0.001

CABG, coronary artery bypass grafting; IQR, interquartile range; PCI, percutaneous coronary intervention; TIMI, thrombolysis in myocardial infarction.

surviving and not surviving 30 days was highest with the IABP-SHOCK II score [area under the curve (AUC) = 0.74], followed by the CardShock score, showing only modest discrimination (AUC = 0.69) and the SAPS II score, giving poor discrimination (AUC 0.63). When comparing AUCs, the difference between IABP-SHOCK II and SAPS II score reached significance ($P = 0.046$), whereas IABP-SHOCK II and CardShock ($P = 0.21$) and SAPS II and CardShock ($P = 0.37$) did not differ significantly. All of the three scores revealed satisfying calibration by Hosmer–Lemeshow test ($P = 0.20$, $P = 0.16$, and $P = 0.35$, respectively).

SCAI classification

All patients were retrospectively classified into one of the SCAI shock stages. Per definition, only shock Stages C to E were

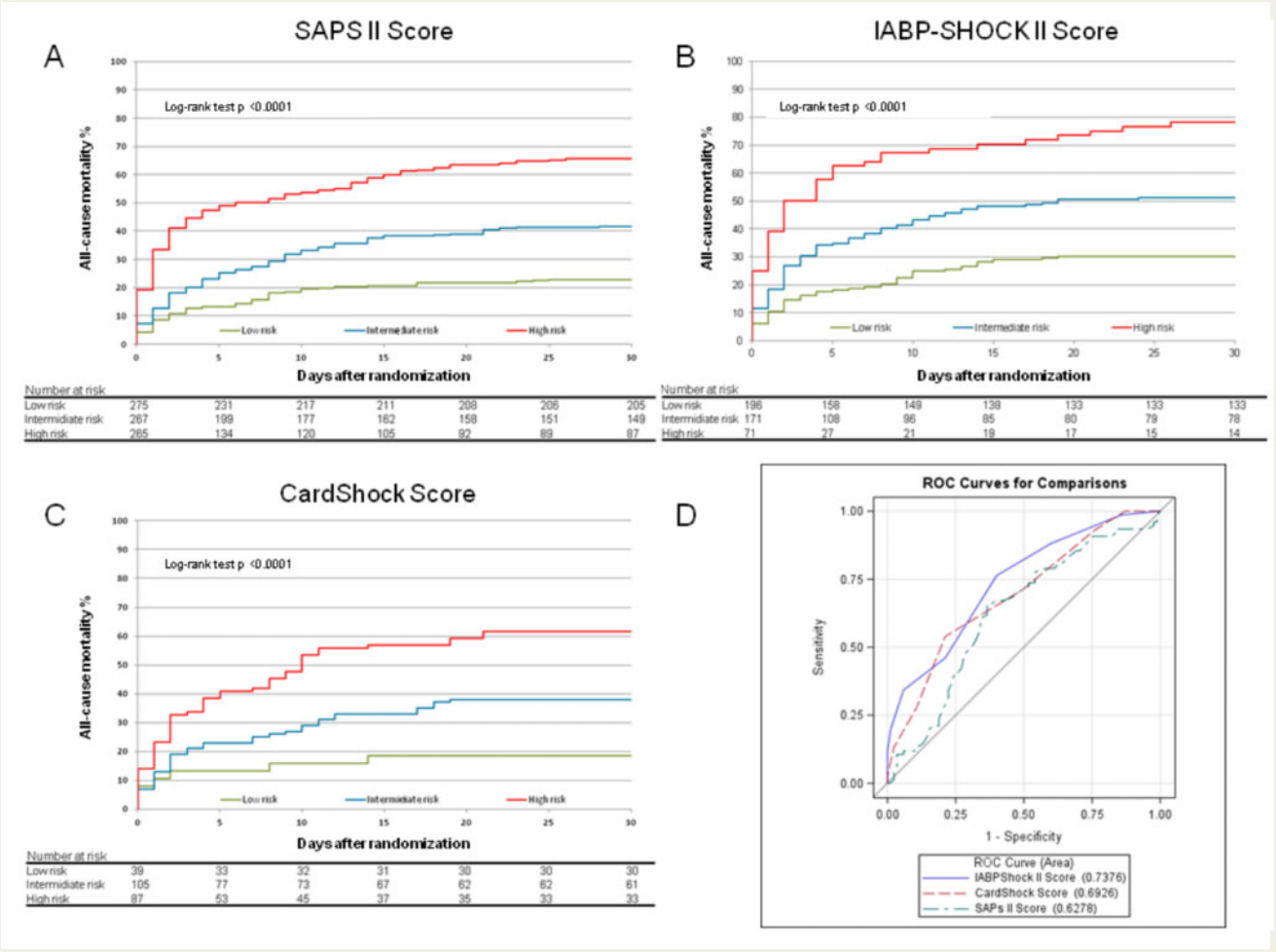


Figure 1 Survival probabilities according to SAPS II Score (*A*). IABP-SHOCK II Score (*B*), CardShock Score (*C*), and respective ROC curve analyses (*D*). SAPS II score ranges from 0 to 163 points, Tertiles = low risk: 2 to 41 points, intermediate risk: 42 to 65 points, high risk: 66 to 135 points. ROC curves (*D*) were computed in a total of 161 patients with all three scores available. $P = 0.21$ for comparison of AUCs between IABP-SHOCK II and CardShock score. $P = 0.046$ for comparison of AUCs between IABP-SHOCK II and CardShock score. IABP-SHOCK, Intra-Aortic Balloon Counterpulsation in Acute Myocardial Infarction Complicated by Cardiogenic Shock; ROC, Receiver operating characteristic; SAPS, Simplified Acute Physiology Score.

represented in this cohort. Most patients were assigned to Group C (40%), followed by E (32%), and D (27%). Mortality was highest in Group E with 72%. Mortality at 30 days did not differ considerably between Groups C and D (39% and 42%, respectively, $P = 0.43$ for log-rank test). Kaplan–Meier curves are displayed in *Figure 2A*. Cardiac arrest (the 'A-modifier') affected a total of 647 patients (61%) including about half of the patients in Groups C and D and 75% in Group E. When accounting for the 'A-Modifier', mortality was significantly higher in groups C and D in case of cardiac arrest [$P = 0.042$ for Group C, $P = 0.015$ for Group D for log-rank comparison (with vs. without cardiac arrest)] (*Figure 2B*). In Group E, poor outcome was nearly equal between patients with or without cardiac arrest ($P = 0.49$ for log-rank comparison).

Discussion

The main findings of the present analysis are (i) Overall mortality in infarct-related CS is still high with 46.2% at 30 days in the present cohort. (ii) When comparing continuous scores to predict short-term mortality in AMI-CS patients, the IABP-SHOCK II score had better discrimination than both the CardShock score and the SAPS II score, although only the latter reached statistical significance. All three scores showed good calibration. (iii) The SCAI classification as categorical prediction model displayed good prognostic assessment for the highest risk group (Stage E), but relatively poor discrimination between Stages C and D with respect to 30 day-mortality.

To predict prognosis in AMI-CS remains an important objective in order to guide therapeutic strategies, especially in view of the

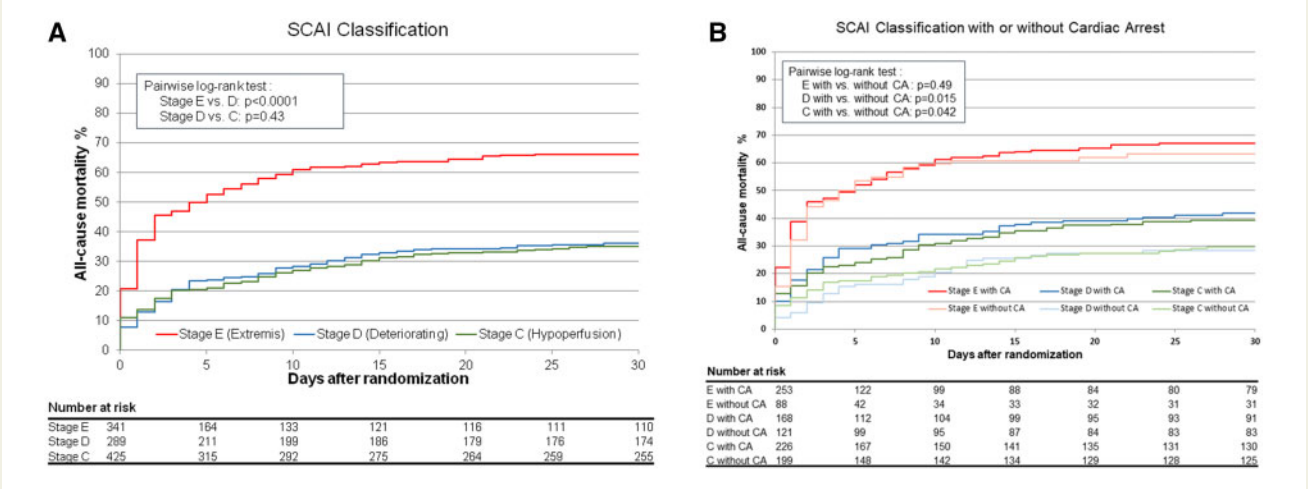


Figure 2 (*A*) Survival probabilities according to SCAI Classification. SCAI, Society for Cardiovascular Angiography and Intervention. (*A*) Survival probabilities according to SCAI Classification with and without cardiac arrest. CA, cardiac arrest; SCAI, Society for Cardiovascular Angiography and Intervention.

increasingly frequent use of active MCS. In the setting of a predicted very poor prognosis, these tools might also help to direct joint decisions on withdrawal of highly invasive or aggressive medical therapy to allow best supportive care. Conversely, highly invasive strategies including MCS may inappropriate in patients with a predicted good prognosis.

Assessment of disease severity and prognosis of mortality by scoring systems is well established in intensive care medicine. The SAPS II score was developed three decades ago in a cohort of >13 000 intensive care patients in 12 different countries.[5] The score includes age, type of admission and primarily physiological variables, giving good reproducibility. However, patients from coronary care units or post-cardiac surgery were excluded from the development cohort and so adequate validation in AMI patients is still not available. Recently, several analyses evaluated the prognostic value of the SAPS II score to predict weaning failure of veno-arterial extracorporeal membrane oxygenation (ECMO). These small studies found conflicting results, but showed rather poor discrimination particularly in AMI-CS and cardiac arrest.[17–19] This correlates with the present analysis, which also showed poor discrimination in patients with AMI-CS. In addition to poor calibration and insufficient validation, disadvantages of the SAPS II score also include a relatively large number of variables and the inclusion of laboratory markers not available as point of care testing. The Acute Physiology And Chronic Health Evaluation (APACHE) II is in widespread use in the prognostic assessment of ICU patients aiming to predict in-hospital mortality. However, recent analyses showed poor calibration of the score in CS patients.[8]

The IABP-SHOCK II score and the CardShock score were developed exclusively in CS. With a total of 7 variables the CardShock score appears easier to apply compared to SAPS II. External validation however showed considerably lower discrimination by AUC analyses than in the development cohort (0.85 in the development cohort vs. 0.71 in the validation cohort).[6] For the IABP-SHOCK II score, which is more easily applicable with only 6 dichotomized variables, c-statistics were lower during development (AUC = 0.74) compared to CardShock, but internal and external validations were more stable than for the CardShock score.[7] Recent external validations of both CS scores showed comparably good discrimination performances (AUC between 0.73 and 0.76) for infarct-related CS.[8,9] In the present analysis however, the IABP-SHOCK II score had better predictive utility than the CardShock score. This might be explained by a considerably smaller and more heterogeneous development cohort of the CardShock score compared to the IABP-SHOCK II score and some variables of the CardShock score are liable to a higher level of subjectivity. These include confusion at presentation and acute left ventricular ejection fraction. A total of 81% of the patients in the present cohort were on mechanical ventilation, so mental status is altered by sedation. Also, in patients without mechanical ventilation mental status might be affected by medication and, foremost, is subject to physician judgement. Echocardiographic assessment of left ventricular function is subjective, affected by dosage of inotropic support and often limited by difficult examination conditions (e.g. supine position, ventilated or agitated patients). External validation cohorts like the Red-Shock cohort revealing a better AUC for the CardShock score also differed compared to our cohort as revascularization was performed in only 88% of AMI-CS cases and patients with mechanical complications of AMI were not excluded.

When analysing the pre-defined risk groups in each score, the between group differences in mortality were highly significant for both scores. For the CardShock score, and comparing the original derivation cohort with the present cohort, short-term survival of the present cohort was considerably higher for the low-risk group (21% vs. 9%) and lower for the high-risk group (63% vs. 77%). In case of the IABP-SHOCK II score, mortality of the risk groups was similar between the original derivation cohort and the present cohort. These findings were similar in an external validation of both scores using the Red-Shock cohort.[9]

The SCAI classification is the most recent approach for a standardized categorization of CS patients.[10] While the classification originally comprises Stages A–E, only patients in Stages C–E were met in the

present CS cohort. Direct comparison with the above-mentioned scores was not possible as the SCAI classification serves as a non-metric prognostic model. However, while short-term survival in Stage E as the highest risk group is comparable to the outcome of the high-risk groups of the IABP-SHOCK II score and the CardShock score, survival in stages C and D equalled and were comparable with those of the low-risk group of the IABP-SHOCK II score. As a major difference compared to other scores, the SCAI classification was not developed on the basis of an existing cohort, but was established on clinical and hemodynamic considerations of an expert commission. In the first subsequent retrospective validation, a very good gradation of mortality according to the different stages was shown.[11] However, an individual adaptation of the respective stage definitions was used especially in Stages D and E. This affected characterizations that were not defined in sufficient detail in the original classification but also strictly defined criteria like levels of lactate. In the following retrospective validations, the classification definition was also individually modified.[11–13,20] This makes an objective allocation to the respective stages difficult.

Further, in contrast to the first validations, a recent study showed also poor discrimination between stage C and D with mortality rates of Stages C–E being comparable to the present analysis.[13] The authors highlighted that assignment of patients to stage E during re-evaluation after 24 h, correlated very well with a very poor outcome, regardless of the initial stage. In this case, mortality surpassed that of Stage E on initial assessment. The possible strength of the classification might therefore lie more in a time-dependent assessment of CS, especially in stage D ('deteriorating'), which by definition contains a temporal component. These findings were recently confirmed by a prospective single-centre validation of the classification where improvement of SCAI stage on 24 h reassessment was associated with an improvement in survival, whereas similar or worsening SCAI stage predicted a very high mortality.[21] However, predictive discrimination regarding in-hospital mortality between SCAI Stages D and E on admission was limited in this first prospective validation. Therefore, risk stratification using the SCAI classification at a very early stage of hospitalization needs further refinement and validation before implementation in clinical and trial settings.

A worse outcome in case of the presence of cardiac arrest is well known.[22] Recent findings on the impact of cardiac arrest ('A-modifier') on outcome for the individual SCAI stages[11,23] were confirmed by the present analysis for Stages C and D but not for Stage E.

Limitations

Several limitations should be mentioned. First, due to missing items, above all, left ventricular ejection fraction in the acute setting, the number of patients in whom all continuous scores were available was limited. Therefore, selection bias cannot be excluded. Further, classification according to SCAI stages was performed again by adjusted and subjective criteria. However, the original classification does not allow discrimination between stages C, D, and E using variables of an existing data set alone as for example haemodynamic or laboratory parameters especially for Stage D are not defined in detail. Prospective classification by clinicians might therefore differ from the results in the present analysis. For comparison 30-day mortality was used as primary outcome. The CardShock- and SAPS II score were initially validated for in-hospital-mortality. However, only a total of 10 patients of the entire study population and only one patient in the cohort for comparison of continuous scores experienced in-hospital death after 30 days. Last, as the randomized CULPRIT-SHOCK trial revealed a significant difference between groups with respect to the primary endpoint of 30-day all-cause mortality and severe renal failure leading to renal-replacement therapy, a bias might have been introduced to the risk prediction analyses, analysing patients irrespective of the treatment group.

Conclusion

Despite the continuous efforts to provide objective prognostic models to guide treatment in AMI-CS, none of the models examined can yield 100% accuracy in predicting short-term mortality. However, the information gained can be used as a piece of the puzzle for choosing the appropriate therapy strategy. Next to the implementation in clinical practice, risk models should serve as tool to define patient selection in future CS trials, especially in the setting of evaluating the use of MCS. According to the results of the present analysis, the IABP-SHOCK II score appears to be the most suitable for this purpose. For the future, the integration of artificial intelligence in individual risk prediction may be an auspicious approach.

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