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CLINICAL RESEARCH
Acute coronary syndromes

ROSC after cardiac arrest—the RACA score to predict outcome after out-of-hospital cardiac arrest

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Aims

Return of spontaneous circulation (ROSC) following cardiopulmonary resuscitation from cardiac arrest (CA) depends on numerous variables. The aim of this study was to develop a score to predict the initial resuscitation outcome—the RACA (ROSC after cardiac arrest) score.

Methods and results

Based on 5471 prospectively registered out-of-hospital CAs patients between 1998 and 2008 within the German Resuscitation Registry, calculation of the RACA score was performed by multivariate logistic regression analysis with ROSC as the outcome variable. The probability of ROSC was defined as $1/(1 + e^{-X})$, where X is the weighted sum of independent factors. Additional 2218 patients documented between 2009 and 2010 were used for validation of the RACA score. The following independent variables were found to have a significant positive (+) or negative (−) impact on the probability of ROSC: male gender (−0.2); age ≥80 years (−0.2); witnessing by lay people (+0.6) and by professionals (+0.5); asystole (−1.1); location at doctor's office (+1.2), medical institution (+0.5), public place (+0.3) and nursing home (−0.3); presumable aetiology of hypoxia (+0.7), intoxication (+0.5) and trauma (−0.6); and time until professionals arrival (−0.04 per minute). In a validation cohort, observed ROSC (43.8%) did not differ from predicted ROSC (43.7%).

Conclusion

The RACA score represents a simple tool and enables comparison between observed and predicted ROSC rates based on readily available variables after CA. Thereby, the RACA score may contribute to preclinical quality assessment and may help analysing the effects of different (post)-resuscitation strategies.

Keywords Cardiac arrest • Cardiopulmonary resuscitation • Epidemiology • Resuscitation registry

Background

Outcome following cardiopulmonary resuscitation (CPR) depends on numerous underlying independent variables, which are related to the condition of the individual patient as well as to general conditions. For example, time from collapse to initiation of CPR and duration of CPR are available at admission and have been evaluated as predictors of outcome after cardiac arrest (CA).[1,2] However, both variables performed poorly as predictors due to inaccurate recall or recording of time intervals. Therefore, prediction of the

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individual prognosis may be improved by taking into account multiple independent factors for calculating an outcome scoring system.

Cardiopulmonary resuscitation registries have been collecting data of resuscitation procedures worldwide for many years.[3–8] Recommended guidelines for uniform reporting of data from out-of-hospital CA have been developed as the Utstein Style,[9,10] and the EuReCa recommendations of the European Resuscitation Council (ERC),[11] thus a basis for comparison has been created by providing clear data definitions. Since CPR registries, however, represent clinical data based on a cohort study design, the question concerning comparability of different cohorts arises. In addition, direct comparison of outcome may further be hindered by different definitions of inclusion and exclusion criteria, and thereby, investigating different subgroups of patients in different studies.

The purpose of the study was to develop a simple and generally applicable tool for predicting the initial resuscitation success indicated by return of spontaneous circulation (ROSC) by using different independent variables that are readily available after arrival of the emergency medical services (EMS) team—the ROSC after cardiac arrest (RACA) score. Thereby, the RACA score might enable comparison of different EMS systems worldwide (e.g. within the European Registry of Cardiac Arrest of the ERC), and in addition, may help analysing the effects of different resuscitation strategies and post-resuscitation interventions in patients with a comparable RACA score.

Methods

This study is a retrospective analysis of 9085 prospectively documented out-of-hospital CA patients between 1998 and 2010 within the German Resuscitation Registry (GRR),[4] where a professional pre-hospital EMS team has been requested by dispatchers. The GRR represents currently 51 emergency medical systems who record data on out-of-hospital resuscitation attempts throughout Germany, thus encompassing 4.5 Million citizens (total population of Germany counts 85 Million).

The GPR is divided into two different data sets:

(i) The 'preclinical care' data set originated from the Utstein-style template aiming at documentation of pre-hospital logistic issues, presumed aetiology, resuscitation therapy and patient's initial outcome including 118 variables.
(ii) The 'post-resuscitation care' data set is aimed at documentation of in-hospital post-resuscitation efforts, in particular ECG, circulatory support, and cerebral performance category and survival at both 24 h and at hospital discharge. The GRR further includes dichotomic (yes/no) questions if any diagnostic and therapeutic procedure has been performed, e.g. chest X-ray, ultrasound, computer tomography, hypothermia, and coronary intervention.[6]

Participation is voluntary. Collecting centres are staffed by emergency physicians from several medical specialties (predominantly anaesthesiology, surgery, and internal medicine) with additional training in emergency medicine. The registry is organized and funded by the German Society of Anaesthesiology and Intensive Care Medicine (DGAI). ROSC was defined as a palpable pulse for >20 s.[9,10,12] Any ROSC was considered as a positive outcome. Failure of prehospital ROSC with ongoing CPR on admission was considered as a negative outcome (no ROSC).

Inclusion criteria

Between 1998 and 2008 the 'preclinical care' data set contained 6583 out-of-hospital CA patients. Of the total, 1112 patients were excluded from further analysis because of incomplete data in terms of sex, age, presumable aetiology, witnessing, location of CA, initial ECG rhythm, bystander CPR, arrival time of EMS, and status of ROSC, leaving 5471 patients (83%) for the development of the score. For subsequent validation, 2502 patients were registered between 2009 and 2010, out of which 2218 (89%) were complete.

Patients being admitted to hospital with unclear or missing information about ROSC were excluded since they could not be assigned to a positive or negative initial resuscitation success.

Steps of development

Development and validation of the scoring system was carried out in six steps:

(i) definition of the endpoint for the prediction model (ROSC);
(ii) selection of variables (predictors) with potential prognostic relevance that are readily available at arrival of EMS at the scene (review of available publications and guidelines, reports from CPR registries, and quality analyses[5,7,8,12–24]);
(iii) definition of patient groups for which the data sets were complete (developmental data set);
(iv) univariate evaluation of selected predictors;
(v) multivariate analysis and calculation of the RACA score;
(vi) validation of the RAC score in a subsequent independent patient group (validation data set).

Variables associated with a poor outcome (steps 2 and 4) were included in a multiple logistic regression model (step 5). The time interval from collapse to arrival of the EMS team has been defined as 'EMS arrival time'. Time of collapse was defined as the time of witnessed collapse, and in case of non-witnessed CA, we used time of receiving the call at the dispatch centre.

Statistical approach

Apart from time intervals, all considered variables were binary or categorical variables. Univariate analysis was carried out using the χ^2 test for binary and categorical variables, and *t*-test for the age and time variables. All tests were two-sided, and significance was defined at $P \leq 0.05$.

Development of the RACA score was performed by a multivariate logistic regression analysis using forward stepwise selection for independent variables. The primary endpoint was ROSC that represents the earliest endpoint reflecting the 'unbiased' initial resuscitation success. In contrast, endpoints such as 'hospital discharge' and 'survival after 1 year' are clinically more relevant, but are also affected by the type, quality, and extent of post-resuscitation care that is often not standardized, and may therefore not be appropriate as a primary endpoint for scoring systems that are mainly based on preclinical data collection.[25]

The logistic model provided a linear combination of independent factors weighted by coefficients, which could be interpreted as the log-odds of the target event. The log-odds were then transformed into a probability for ROSC by using the logistic function. The odds ratios (OR) and 95% confidence intervals (95% CI) are presented for each selected variable (factors). Consequently, the probability P of ROSC can be calculated as following:

$$P(\mathrm{ROSC}) = \frac{1}{(1 + e^{-X})}$$

where X represents the linear combination of the independent factors (log-odds).

The predictive ability of the final score was assessed by receiver operating characteristic (ROC) curve analysis in the development and validation data set. Area under the ROC curves is presented with 95% confidence intervals (95% CI). Statistical analysis was done using SPSS version 17 (SPSS, Inc., Chicago, IL, USA).

Results

Basic descriptive data of both the development and validation cohorts are presented in Supplementary material online, *Table S1*.

Prognostic factors—univariate analysis

Results of the univariate analysis are presented in *Table 1*. Patients with ROSC were on average only 0.2 years younger than patients without ROSC (64.9 vs. 65.1 years; $P = 0.73$). Analysis of age subgroups revealed that age ≥80 years was significantly associated with a decreased chance of ROSC [age ≥80 years (39%) compared with patients <80 years (44%; $P = 0.003$)]. The longer the time of EMS arrival was, the worse the chance of achieving any ROSC (*Figure 1*). Time until EMS arrival was significantly longer in patients without ROSC (9.0 ± 9.8 min) as compared with patients with ROSC (6.6 ± 8.6 min; $P < 0.001$).

Table 1 Frequency of return of spontaneous circulation for different subgroups of patients

	Prevalence *n* (%)	ROSC rate *n* (%)	*P*-value
Age (years)			
<40	447 (8.7)	185 (39.0)	<0.001
40–49	437 (8.0)	193 (44.2)	
50–59	735 (13.4)	336 (45.7)	
60–69	1200 (21.9)	538 (44.8)	
70–79	1519 (27.8)	675 (44.4)	
80–89	965 (17.6)	385 (39.9)	
90+	141 (2.6)	49 (34.8)	
Gender			
Males	3711 (67.8)	1583 (42.7)	0.28
Females	1760 (32.2)	778 (44.2)	
Aetiology			
Cardial	4513 (82.5)	1941 (43.0)	<0.001
Trauma	136 (2.5)	38 (27.9)	
Hypoxia	374 (6.8)	198 (52.9)	
Intoxication	102 (1.9)	42 (41.2)	
Other	346 (6.3)	142 (41.0)	
Witnessed			
None	2221 (40.6)	733 (33.0)	<0.001
Lay people	2750 (50.3)	1351 (49.1)	
Professionals	500 (9.1)	277 (55.4)	
Location			
At home	3141 (57.4)	1271 (40.5)	<0.001
Nursing home	234 (4.3)	81 (34.6)	
Work place	114 (2.1)	51 (44.7)	
Doctor's office	87 (1.6)	65 (74.7)	
Public place	973 (17.8)	523 (53.8)	
Medical institution	99 (1.8)	53 (53.5)	
Other place	823 (15.0)	317 (38.5)	
Initial ECG			
VF	1544 (28.2)	956 (61.9)	<0.001
PEA	626 (11.4)	244 (39.0)	
Asystole	2583 (46.4)	745 (29.4)	
Others	763 (13.9)	416 (54.5)	
Bystander CPR			
No	4673 (85.4)	1938 (41.5)	<0.001
Yes	798 (14.6)	423 (53.0)	

Multivariate analysis

During the stepwise multivariate development of the RACA score, all conditions recommended in the Utstein style were included. Age was considered as categorical variable while time until EMS arrival was included as a continuous measurement. For each categorical variable one condition was defined as standard category (e.g. the condition 'female gender' was defined as standard within the category of 'sex'), which did not receive a specific coefficient in the model but was defined as a reference for the other conditions (e.g. 'female gender' was considered as the standard category vs. 'male gender' with a negative coefficient) of the respective variable. The following conditions have been defined as 'standard category': female gender, age <80 years, cardiac aetiology, non-witnessed CA, location at home and work place, ventrical fibrillation (VF) as first ECG rhythm, and no bystander CPR. Multivariate logistic regression analysis confirmed significant association with ROSC (*Table 2*). Negative regression coefficients were associated with worse chance of ROSC, while positive regression coefficients indicated a better chance of ROSC. The AUC was 0.710 (0.697–0.724).

The RACA score was then derived from the multivariate logistic regression by rounding the regression coefficients to one decimal. The final score is presented in *Table 3*. The X value calculated for each patient by the presented equation was then transformed into calculation of the probability of ROSC by using the logistic function. This function is symmetrically around zero, where $X = 0$ corresponds to a 50% chance of ROSC, and X values above or below zero correspond to an increased or decreased chance, respectively (see Supplementary material online, *Figure S1*).

Validation data set

Using the validation data set ($n = 2218$ patients), predicted ROSC by the RACA score was 43.7%, while the observed ROSC rate was 43.8 % (972 of 2218 patients). The AUC was 0.731 (0.710–0.751).

Quality management

The potential role of the RACA score in quality management of the resuscitation process is the comparison of observed and predicted ROSC rates for specific subgroups of patients, which differ in terms of institutions, hospitals, education level of the EMS system, and complications. The average expected ROSC rate served as a benchmark in these comparisons. For example, we found a significant negative impact of EMS performance by low-level centre A (observed vs. predicted ROSC: 38 vs. 43%; $P < 0.01$) and negative impact of difficulties in airway management (29 vs. 43%; $P < 0.01$), a significant positive impact of EMS performance by high-level centre B (47 vs. 43%; $P < 0.01$), and a neutral impact by the specialty of the emergency physician (*Table 4*). To further illustrate the value of the RACA score, comparison between observed and predicted ROSC rates for 15 participating EMS centres (each had >100 registered CPR attempts) is displayed in *Figure 2*.

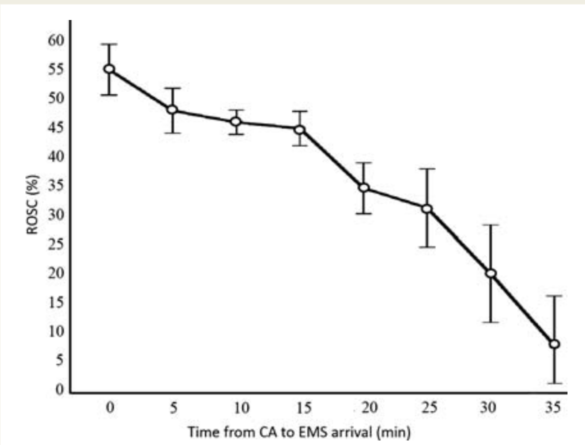

Figure 1 Relationship between time from cardiac arrest (CA) to emergency medical services (EMS) arrival and observed return of spontaneous circulation (ROSC). Return of spontaneous circulation is presented as percentage with 95% confidence interval.

Discussion

Outcome prediction scores have often been presented for estimation of individual prognosis after successful CPR. Eisenberg *et al.*[26] firstly presented a so-called ACLS score predicting the initial resuscitation outcome using readily available variables after arrival at the scene. Nevertheless, this score failed in practical use. The newly developed RACA score, however, is a simple score that is not aimed to predict initial patient's outcome to withhold any drug or CPR attempts in patients with poor baseline conditions, but the RACA score was rather developed to serve as an instrument for adjusting different conditions when ROSC of different patients or different studies is proposed to be compared. Further, the RACA score may provide some help regarding quality assessment of preclinical processes that may enable comparison between different EMS systems, educational levels, technical equipments, and therapeutic interventions.

Validation of the RACA score showed excellent results with an observed ROSC rate of 43.8% and a predicted ROSC rate of 43.7%, while the AUC of ROC was 0.731 (0.710–0.751). Unfortunately extensive laboratory values are not available at the pre-hospital scene routinely, but prediction may much be improved

Table 2 Results of multivariate logistic regression analysis

Variable	Condition	Regression coefficient	SE	*P*-values	OR (95% CI)
Sex	Male	−0.17	0.54	0.01	0.85 (0.75–0.96)
Age	≥80 years	−0.19	0.08	0.02	0.83 (0.72–0.97)
Aetiology	Trauma	−0.56	0.21	0.01	0.57 (0.38–0.85)
	Hypoxia	+0.68	0.12	<0.001	1.98 (1.57–2.48)
	Intoxication	+0.45	0.22	0.04	1.57 (1.02–2.40)
Witnessed	Lay people	+0.62	0.07	<0.001	1.86 (1.64–2.12)
	Professional	+0.49	0.11	<0.001	1.63 (1.31–2.02)
Location at	Nursing home	−0.27	0.16	0.079	0.76 (0.56–1.03)
	Doctor's office	+1.17	0.26	<0.001	3.23 (1.93–5.40)
	Public place	+0.34	0.08	<0.001	1.40 (1.20–1.64)
	Medical institution	+0.52	0.22	0.016	1.69 (1.10–2.58)
Initial ECG	PEA	−0.82	0.1	<0.001	0.44 (0.36–0.53)
	Asystole	−1.08	0.65	<0.001	0.34 (0.30–0.39)
Bystander CPR	Yes	+0.23	0.09	0.008	1.26 (1.06–1.49)
EMS arrival time	Per minute	−0.04	0.01	<0.001	0.96 (0.95–0.97)
Constant		0.29	0.09	0.001	1.34

Multivariate logistic regression analysis was performed to investigate the influence of different variables on chance of return of spontaneous circulation (ROSC). Independent variables that were associated with a positive coefficient increase the chance of ROSC, while negative coefficients decrease the chance of ROSC. Standard category were female gender, age <80 years, cardiac aetiology, non-witnessed cardiac arrest, location at home and work place, VF as first ECG rhythm, and no bystander CPR. SE, standard error; ECG, electrocardiogram; PEA, pulseless electrical activity; CPR, cardiopulmonary resuscitation; EMS, emergency medical services.

by adding laboratory parameters, e.g. serum concentration of creatinine and lactate as demonstrated by Adrie *et al.*[27] The success of CPR is further determined by initial unknown factors (e.g. medical history) and by the quality of EMS performance. The later, however, was not considered in the development of RACA since it was just developed to evaluate these differences. Quality assessment with registries requires adjustment of outcome data for valid comparisons since conditions may vary from one EMS system to another one.

The German Society for Trauma Surgery has recently reported a specific prognostic score system based on the German trauma register—the so-called 'trauma score'—that allows estimation of trauma severity and the comparison between observed and predicted therapeutic success in trauma care.[28,29] According to the analysis of the 'trauma score', the RACA score now enable the comparison of observed and predicted ROSC rates. The standardization may further allow comparative analyses even in the case of primarily not comparable patient groups (i.e. different individual EMS centres and different EMS systems worldwide). For illustration of the potential role of the RACA score in quality management, we compared the observed and predicted ROSC rates in terms of individual EMS centres, difficulties in preclinical airway management, and different specialties of the emergency physician. In EMS teams operating on a high-quality level, the observed ROSC rate was significantly higher than the predicted ROSC rate. Contrarily, the observed ROSC rate was lower than the predicted ROSC rate in individual EMS centres with low-level performance, where further analyses of the EMS structure and process quality are urgently needed. We further found a significant negative impact for difficulties in airway management, which are often seen in the preclinical situation since out-of-hospital tracheal intubation is challenging.[30] In addition, much controversy exists about who can provide the best medical care for critically ill patients in the prehospital setting.[31] Comparing the observed and predicted ROSC rate, we found no influence by the specialty of the emergency physician.

Table 3 Equation of the ROSC after cardiac arrest score

$X=$
0.3 (constant)
$+ (-0.2 \times \text{male})$
$+ (-0.2 \times \text{age} \geq 80 \text{ years})$
$+ (-0.6 \times \text{trauma}) + (0.7 \times \text{hypoxia}) + (0.5 \times \text{intoxication})$
$+ (0.6 \times \text{witnessed by lay people}) + (0.5 \times \text{witnessed by professionals})$
$+ (-0.3 \times \text{nursing home}) + (1.2 \times \text{doctor's office}) + (0.3 \times \text{public place}) + (0.5 \times \text{medical institution})$
$+ (-0.8 \times \text{PEA}) + (-1.1 \times \text{asystole})$
$+ (0.2 \times \text{bystander CPR})$
$+ (-0.04 \times \text{minutes until EMS arrival})$
Probability of ROSC $= 1/(1 + e^{-X})$

Equation of the RACA (ROSC after cardiac arrest) score. Score value *X* will be transformed into a probability of return of spontaneous circulation (ROSC) by logistic function. PEA, pulseless electrical activity; CPR, cardiopulmonary resuscitation; EMS, emergency medical services.

Assessment of specific independent factors

Selection of the independent factors was performed considering available literature.[5,7,8,13,15–24] Engdahl *et al.*[29] described the relevance of the factors 'witnessing CA', 'presumed aetiology', 'initial ECG', and the effect of the 'no-flow time'. Herlitz *et al.* additionally focused on age and sex.[8,17,32] We were able to confirm these results, thus our formula contains a negative coefficient of −0.2 for male patients and of −0.2 for patients ≥80 years old. Patients having CA from cardiac aetiology represented the biggest group within the study population. Since intoxication and hypoxia are less common but both situations may involve

Table 4 Quality management—examples for ROSC after cardiac arrest practical use

Factor	Patients (*n*)	Observed ROSC (95% CI; %)	Predicted ROSC (%)	Impact
EMS performance				
Low level (centre A)	514	38.1 (33.9–42.3)	42.6	Negative[a]
High level (centre B)	424	47.4 (42.7–52.3)	42.6	Positive[a]
Difficulties				
Airway management	52	28.8 (18.4–39.2)	43.0	Negative[a]
Specialty				
Anaesthesiologist	2.368	44.5 (42.5–46.5)	43.0	Neutral
Surgeon	316	46.5 (41.5–52.0)	45.1	Neutral
Internal medicine	2809	42.6 (40.8–44.5)	42.4	Neutral

The table demonstrates the potential role of the RACA score in quality management of the resuscitation process. By comparing the observed and predicted ROSC, we found a significant negative impact of low-level emergency medical services (EMS) performance (EMS centre A) and difficulties in airway management. High-level EMS performance from another EMS centre B resulted in a significant better observed ROSC rate, and a significant positive impact comparing observed and predicted ROSC. Comparing different specialty of emergency physicians, we found a neutral impact.
[a]Statistical significant ($P < 0.05$), if the predicted ROSC rate is not within the 95% confidence interval (95% CI) of the observed ROSC rate.

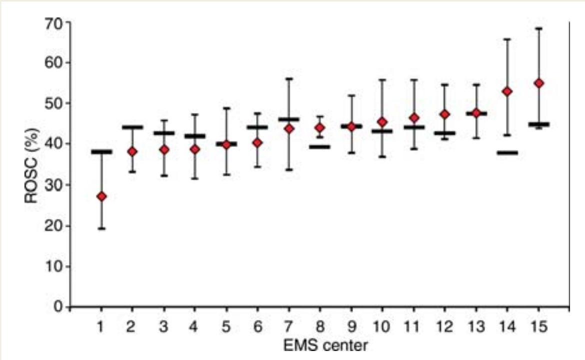

Figure 2 Overview of 15 individual emergency medical services (EMS) centres with more than 100 registered CPR attempts with the observed and predicted return of spontaneous circulation (ROSC) rate, respectively. Mean observed return of spontaneous circulation (95% confidence interval) is compared with predicted return of spontaneous circulation rate (black bar). While the predicted return of spontaneous circulation rate tended to be higher than the observed return of spontaneous circulation rate in centres 1 and 2 (lower EMS performance), the predicted return of spontaneous circulation rate was lower than the observed return of spontaneous circulation rates in centres 8, 14, and 15, respectively.

reversible causes, which can often easily be treated by immediate application of specific antidotes or successful airway management, these events lead to significantly higher ROSC rates and a positive coefficient (intoxication +0.5; hypoxia +0.7). In contrast, CA by trauma was associated with a negative coefficient of −0.6. Faucher *et al*. have recently confirmed the negative impact of trauma aetiology and reported an initial ROSC rate of only 25%.[30] In terms of witnessing CA, we found a positive effect on the initial resuscitation success if CA was witnessed by lay people (+0.6) or by professionals (+0.5), since the presence of a witness may lead to a more rapid emergency call and, if applicable, to an earlier initiation of CPR attempts.[31] Out-of-hospital CA most frequently occurred at private home that has also been confirmed in other studies.[2,33,34] The location 'nursing home' was associated with an independent negative factor of −0.3. CA at public places showed a positive factor of +0.3.The location 'doctor's office' had the strongest positive factor with +1.2. However, only a very small group of patients (2%) took advantage at this location. Comparable, a very small amount of patients (2%) received CPR attempts by a pre-hospital EMS team in any medical institutions (e.g. rehabilitation institution or ambulatory eye clinic) where an in-hospital emergency team is not provided routinely. In these institutions, an emergency call for a pre-hospital EMS team was done, and therefore type of CA was defined as out-of-hospital CA, although the location was a medical institution, but without any in-hospital EMS support. Nevertheless, we found a positive factor of +0.5 in these kinds of medical institutions.

In our study, we further confirmed the widely accepted effect of the initial ECG rhythm on resuscitation outcome. VF has been shown to be the most favourite ECG wave form during CA, since there is a specific therapy, such as defibrillation, and also some residual myocardial activity.[13,16,33] In contrast, asystole represented the strongest negative prognostic factor (−1.1) followed by PEA (−0.8).

Bystander CPR showed an independent positive effect of +0.2, which may be improved by additional factors (e.g. witnessing). The rate of bystander CPR was reasonably low in our study (14%)[35] and hence far away from Sweden (26%),[7,18,32] Poland (24%),[36] and Slovenia (23%)[37] In addition to the low rate of bystander CPR, the poor quality of bystander CPR, in particular when chest compressions and breathing may be performed alternatively, can further be assumed as a main reason why the positive impact of bystander CPR was only +0.2.

Regarding the time interval until arrival of professional EMS team, we found an independent regression coefficient of −0.04 per minute from collapse/call until EMS team arrival. Thus, our model confirmed the results of previous publications[7,33] that EMS arrival time clearly affects the probability of ROSC.

Limitations

Exclusions due to incomplete data sets are widely accepted within huge registries, thus, the respective exclusion rate of the present analysis of 17% is in an acceptable range. A limitation of the present study is that it included only cases with complete data for all required variables. Although the ROSC rate in cases with partial missing data is similar, a selection bias could not be excluded. The use of the RACA score for comparing EMS systems would, however, require a maximum number of cases with valid data, and therefore strategies for imputing single missing values are worth to develop in future. In following data set, RACA variables will be recommended as core variables. Compared with other registries, e.g. trauma registries,[38,39] where MTOS data or TARN-UK showed about 30% missing data about the initial respiratory rate, the missing rate between 11 and 17% seems reasonably acceptable in the present study. Further, the preselection of potential predictive factors in a multivariate analysis approach might have missed some potential variables. The most important factors known from the literature, however, have been included. In addition, we only included those factors which are readily available at the time of EMS arrival. Adding further demographic variables, patients-related factors, e.g. pre-existing diseases, pre-medications, or laboratory variables may further improve our model. These variables, however, have not been recorded within the GRR, and therefore, could not be included into the model.

Conclusions

Initial resuscitation success can accurately be predicted after out-of-hospital CA using factors that are readily available following arrival at the scene. The RACA score represents a simple tool for calculating the probability of ROSC, and enables direct comparison between observed and predicted ROSC. This standardization allows comparative analyses even in the case of primarily not comparable patient groups (i.e. different individual EMS centres and different EMS systems worldwide), and in addition, may help analysing the effects of different resuscitation strategies and post-resuscitation interventions in patients with a comparable RACA score. In EMS teams operating on a high quality level, the observed ROSC rate may be higher than the predicted ROSC rate; the same should be true for a therapeutic intervention and medical treatment having positive effects. Contrarily, where the observed ROSC rate is reasonably lower than the predicted ROSC rate, further analyses of the EMS structure and process quality may be useful to identify reasons for that low performance.

Supplementary material

Supplementary material is available at *European Heart Journal* online.

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Appendix

GPR Study Group

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