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Clinical paper

Outcome of out-of-hospital cardiac arrest over a period of 15 years in comparison to the RACA score in a physician staffed urban emergency medical service in Germany☆

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ABSTRACT

Background: Patient outcome after out of hospital cardiac arrest (OHCA) depends on the cardiopulmonary resuscitation (CPR) performance and might also be influenced by organisation of the emergency medical service (EMS) and implementation of guidelines.
Aim: To assess the rate of return of spontaneous circulation (ROSC) after cardiac arrest to the predicted rate by the ROSC after cardiac arrest (RACA) score over a 15-year period reflecting three different implemented ALS-guidelines in a physician-staffed EMS.
Methods: All adult patients with non-traumatic OHCA in the EMS of Bonn from 1996 to 2011 were included. Utstein data from three 5-years time periods (1996–2001, 2001–2006, 2006–2011) representing different ALS-guideline implementations were collected. Group comparisons were made in terms of incidence, epidemiology and short-term outcome of CPR with emphasis on changes over time and factors of importance. In each group observed ROSC rate were compared to the predicted ROSC rates (the RACA score).
Results: CPR by the ALS unit was attempted in a total of 1989 patients (735, 666, and 588 patients in the first, second and third period, respectively). Average crude incidence of CPR per 100,000 person-years decreased over time (61.3; 55.5; 49.0/100,000/years) while patients treated were significantly older (65.5 ± 16.5; 67.9 ± 15; 68.9 ± 15.7 ($p < 0.001$)). Observed ROSC rates were higher than predicted by the RACA score in all time periods, however, admittance to ICU decreased significantly from 50% in the first five-year period to 38% last five-year period ($p < 0.001$). From first to third period the proportion of arrests with first observed rhythm of VT/VF arrests did not change (29% vs. 27%, $p = 0.323$) nor there were changes in bystander CPR rates (17% vs. 17%, $p = 0.520$).
Conclusions: In a 15-years period and in the setting of a physician-staffed EMS the ROSC rates remain higher than predicted by the RACA score but the admittance to the ICU after OHCA declined significantly. This finding was accompanied by a decrease in CPR incidence and an increase in age of patients.

Introduction

Sudden out-of-hospital cardiac arrest (OHCA) is still a leading cause of death in Europe and the United States. OHCA is responsible for more than 60% of death from coronary heart disease in adults.[1] The incidence of OHCA in Europe is estimated 37–55 per 100,000 populations per year.[2–5]

In the last 20 years efforts have been made to improve the outcome of resuscitation, e.g. the implementation of early defibrillation and public access defibrillators. Since 2000 the American Heart Association (AHA) and European Resuscitation Council (ERC) regularly publish guidelines for cardiopulmonary resuscitation (CPR), to foster the adoption of consensus care for OHCA patients. The guidelines are reviewed every five years and adapted to the current state of scientific research and best clinical practice. Reports on

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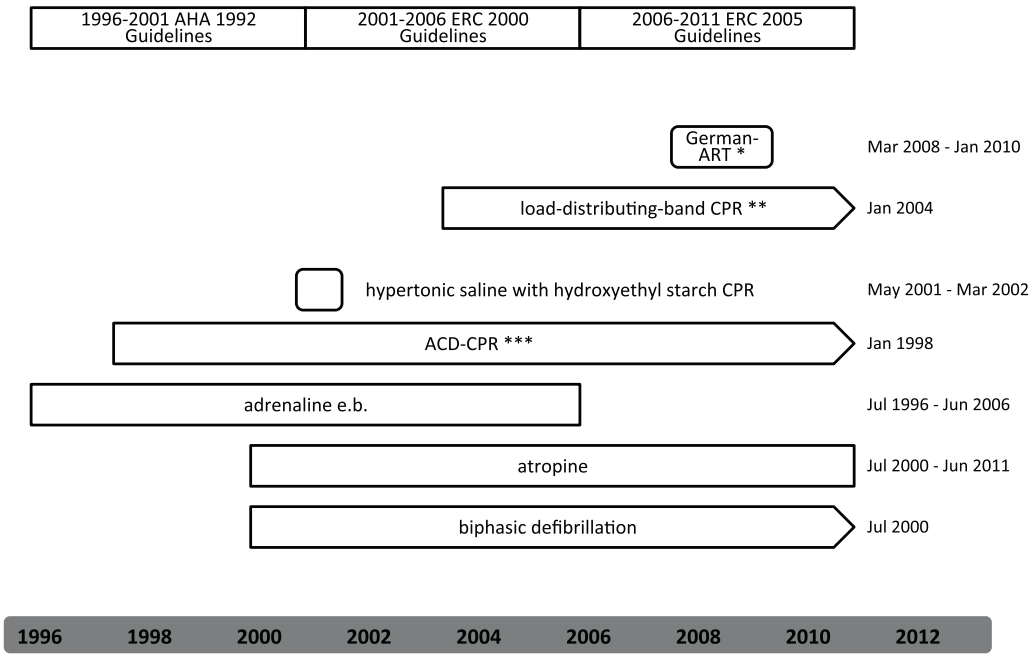

Fig. 1. Overview of different CPR guidelines and local approaches for strengthening the chain of survival or clinical trials. * German Automatic chest compression Resuscitation Trial. ** Used individually. *** Stopped during German ART.

outcomes of OHCA vary, most likely influenced by epidemiological factors as well as differences in data collection methodologies.

As elsewhere, in the emergency medical service (EMS) of the City of Bonn many efforts were made to improve the local chain of survival, e.g. keeping the EMS response time following emergency calls below 8 min, regular CPR training for the EMS staff (paramedics) and emergency physicians, and early implementation of the current CPR guidelines. Beyond implementation of guidelines other changes were made during the past years, including introduction of active-compression–decompression CPR, use of endobronchial adrenaline (epinephrine), hypertonic saline with hydroxyethyl starch and load-distributing band CPR (Fig. 1).

The EMS of Bonn CPR data have been recorded in an Utstein style[6,7] conform since 1989, providing a unique OHCA dataset in a physician staffed EMS in Germany over more than 20 years.

The aim of this retrospective study is to review the primary prehospital CPR outcome of OHCA patients over a 15-year in three distinct time periods reflecting different CPR guidelines (1996–2001, 2001–2006, 2006–2011) and to assess the short-term patient outcome in comparison to the predicted ROSC rate by the RACA in a physician-staffed EMS.[8] The RACA score was introduced as a tool to compare the initial resuscitation success by observed and predicted ROSC rate based on readily available factors.[8] It may help analysing the effects of different resuscitation strategies used over time.

Material and methods

Design

Retrospective cohort study from 1996 to 2011.

Population

Adults older than 18 years with OHCA and non-traumatic cause of cardiac arrest.

Settings

The EMS of the city of Bonn serves 320,000 residents in a service area of 141 sqkm, with a population density of 2250 persons sqkm^{-1}. The city reflects typical urban features. A total of 12 basic life support (BLS) Units and two advanced life support (ALS) units serve in a double response system. The EMS has 84,240 BLS-Unit and 17,520 ALS-unit h year^{-1}.

The EMS responds currently to 26,000 emergency calls per year, including 7600 ALS unit interventions annually. The EMS system admits the patients to 8 hospitals in the city area, and 4 hospitals in the surrounding area, all of which offer different care levels.

The BLS units are routinely staffed with one emergency medical technician and one paramedic. The ALS-units have one paramedic and one emergency physician on board. The emergency physicians of the ALS units are mostly anaesthesiologists, and have at least two years of postgraduate training, and a special emergency training course according to the German medical academy.

The EMS-staff is trained once a year in the current CPR algorithm, during a 30 h training week with certification. Over the 15 years period, new CPR algorithms were implemented between 3 and 6 months after publication. Dispatcher assisted resuscitation by laypersons was not undertaken during the study period.

Inclusion criteria

All patients older than 18 years suffering from presumed non-traumatic OHCA, who received resuscitation attempts by the ALS-Unit (physician staffed) between 1996 and 2011. Not included were patients with definite signs of death, already declared dead on arrival without any attempts of CPR and patients that received no treatment from the ALS unit due to *"do not attempt resuscitation"* orders.

Definition of the data set

The data set is accordance with the data set "preclinical Care"[9] of the national registry of CPR in Germany.[10] The data set originates

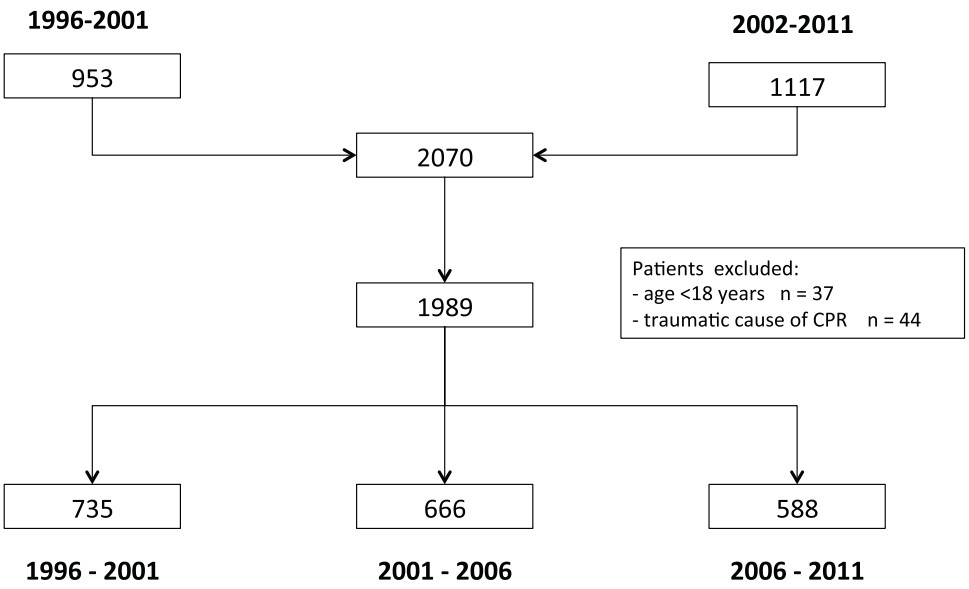

Fig. 2.

from the Utstein style templates used to document resuscitation efforts, and in particular used to record pre-hospital logistic issues, diagnosis, resuscitation therapy and patients initial outcome.

The primary endpoints of this study are ROSC (defined as palpable pulse >20 s) and admittance to hospital. An ongoing CPR was counted, according to the Utstein definition, as a negative outcome.[6,7]

Data management/collection

For this study we only included complete available datasets from one ALS-unit covering the entire 15 years period, corresponding to services to a population of 240,000 inhabitants and have been constant over the study period.

From 1996 to 2001 the CPR datasets were recorded in an Utstein style conform, self-designed local database (*old data*). These datasets were transformed into the current format, used by the national German resuscitation registry. Only complete datasets (93%) were transformed.

Since 2001 as part of a standard operating procedure (SOP) the physician performing the CPR has been required to record the dataset of the CPR. In the years 2001 to 2007 the CPRs of the ALS-Unit were recorded using a paper based document, designed by the national CPR Register. For this study these data sets were transformed in the online database. After 2007 the CPR data are recorded trough an online platform.

The data were divided into tree time periods: January 1996–June 2001 (period 1), July 2001–June 2006 (period 2), and July 2006–June 2011 (period 3), corresponding to the 5 year renewal and implementation of the ERC guidelines into the local EMS. The time periods were chosen according to the five years renewal of the ERC guidelines and implementation of these guidelines into the local EMS.

The RACA sore was calculated as published elsewhere.[8] RACA score is a multivariate logistic regression model and provide the probability of ROSC. The score is developed as a general applicable tool to predict the initial resuscitation success using different independent variables (age, gender, aetiology of CA, witnessing by lay people or professionals, location of CA, initial rhythm, bystander CPR)[8,11] that are easy to assess after arrival of the EMS. Mean observed ROSC (95% confidence interval) is compared with predicted ROSC (RACA). The RACA score can be used as an instrument to compare different EMS systems, and my help to assess effects of different resuscitation strategies.[8]

Statistical analysis

Data were processed using EXCEL XP (Microsoft Corporation, Redmond, Washington, USA), and statistic analyses used IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.

Category Data were analysed with a chi-square test, and linear by linear trend for association over periods. Values for parametric data are given as means with standard deviations. Continuous data were analysed using a one-way ANOVA. p-Values ≤ 0.05 were considered statistically significant. Response time is given in minutes and seconds.

For comparison of observed ROSC and predicted ROSC (RACA) the 95% confidence interval of observed ROSC rate and the calculated mean of predicted ROSC was used. A statistical significance ($p < 0.05$) is given, if the predicted ROSC rate is not within the 95% confidence interval (95% CI) of the observed ROSC rate.

Ethic committee vote

This study is in compliance with the active guidelines and approved by the scientific committee of the German Resuscitation Registry (GRR). Furthermore, as a retrospective analysis of clinical routine data this study is in accordance with county code of medical ethics and was additionally approved by the local ethics committee (reference number 115/15).

Results

During the study period from 1996 to 2011 a total of 2070 patients received ALS treatment for out of hospital cardiac arrest. Of these cases 1989 met the inclusion criteria and were eligible for statistical analysis (Fig. 2).

Below, the results for three time periods observed (period 1: 1996–2001; period 2: 2001–2006; period 3: 2006–2011) are given in order.

Table 1
Demographic characteristics and overall outcome.

Time periods	1996–2011		1996–2001		2001–2006		2006–2011		*p*-Value
Served population	240,000		240,000		240,000		240,000		
CPR incidence [1/Y/100,000]	**55.3**		**61.3**		**55.5**		**49.0**		
ROSC at any time* incidence [1/Y/100,000]	**24.8**				**26.9**		**22.8**		
Admitted to ICU incidence [1/Y/100,000]	**25.3**		**30.8**		**26.4**		**18.5**		
	n		***n***		***n***		***n***		
ALS Initiated	**1989**		**735**		**666**		**588**		
Age (mean)/(±SD)	**67.4**	**±15.7**	**65.5**	**±16.5**	**67.9**	**±15**	**68.9**	**±15.7**	<0.001
Gender (%male)	1275	**64%**	452	**61%**	446	**67%**	377	**64%**	0.269
Cardiac origin	1399	**70%**	587	**80%**	429	**64%**	383	**65%**	<0.001
Location									
Home	1256	**64%**	413	**56%**	429	**64%**	414	**70%**	<0.001
Public	377	**19%**	149	**20%**	123	**18%**	105	**18%**	0.256
Other/unknown	356	**17%**	173	**24%**	114	**17%**	69	**12%**	<0.001
Initial rhythm									
VT/VF	518	**26%**	210	**28.57%**	152	**22.82%**	156	**26.53%**	0.323
PEA/asystole	1188	**60%**	375	**51%**	429	**64%**	384	**65%**	<0.001
Other/unknown	283	**14%**	150	**20%**	85	**13%**	48	**8%**	<0.001
Witnessed arrest only EMS	126	**7%**	10	**1%**	53	**8%**	63	**11%**	<0.001
Witnessed arrest (all)	1051	**53%**	406	**55%**	282	**42%**	363	**62%**	0.055
Bystander CPR	294	**15%**	128	**17%**	68	**10%**	98	**17%**	0.520
Response time (RT)									
RT < 8 min		**89.1%**		**89.2%**		**91.3%**		**86.9%**	
RT Interval mean ± SD***	**5:25**	**±2:39**	**5:08**	**±2:46**	**5:13**	**±2:24**	**5:55**	**±2:48**	<0.001**
RACA/ROSC									
RACA		**44.3%**		**45.6%**		**43.1%**		**44.1%**	0.009
ROSC at any time*	596	**47%**			323	**48%**	273	**46%**	0.315
Admitted to ICU	909	**45%**	370	**50%**	317	**48%**	222	**38%**	<0.001
Transport with ongoing CPR****	201	**10%**	75	**10%**	46	**7%**	80	**14%**	0.069

CPR: cardiopulmonary resuscitation; ROSC: return of spontaneous circulation; ALS: advanced life support; ICU: intensive care unit; VT: ventricular tachycardia; VF: ventricular fibrillation; PEA: pulseless electrical activity; EMS: emergency medical service; RACA: ROSC after cardiac arrest.
* ROSC at any time was not recorded in the first period.
** *p*-Value for RT interval mean.
*** mm:ss.
**** Considered as negative outcome an are not included in ROSC or admitted to ICU.

Demographics and patients characteristics

An overview of the results is given in Utstein Style in Table 1. The crude incidence of CPR patients decreased over time (61.3; 55.5; 49.0/100,000 people year^{-1}). The age of patients with OCHA increased over the years from an average of 65.5, 67.9 to 68.9 ($p < 0.001$, Table 1). The mean response time of the ALS unit increased from 5:08 min, 5:13 min to 5:55 min ($p < 0.001$), respectively, but remained within legal requirements (< 8 min). The number of patients with witnessed cardiac arrest increased not significantly from 55.3%, 42.3%, 61.7% ($p = 0.055$). Over the different time periods, there were more patients receiving CPR at home by the ALS/EMS team: 56%, 64%, 70% ($p = <0.001$). The incidence of VT/VF as initial rhythm remained almost unchanged: 29%, 23%, 27% ($p = 0.323$), whereas PEA and asystole increased significantly (51%, 64%, 65%, $p < 0.001$). However, this was accompanied by a significant decrease in unknown/other rhythm (20%, 13%, 8%, $p < 0.001$) which might have affected this finding.

Outcome

Pre-hospital ROSC rates were not available for patients documented in the old database (period 1). The overall ROSC rate did not change in second and third period: 48%, 46% ($p = 0.315$). The proportion of patients admitted to ICU was 50%, 47% and 38%, respectively and decreased significantly over time ($p = <0.001$). The calculated RACA score for the three periods decreased significantly (45.6%, 43.7% to 44% ($p = 0.009$)) (Table 1) and observed ROSC rates were constantly higher than predicted (Fig. 3). Nevertheless, in period 1 ROSC rate was only recorded at ICU admittance and data on pre-hospital ROSC rate were lacking. In order to make a comparison for the entire period, we used "ROSC at ICU admittance" in period 1 equally to the "ROSC rate for all cases" for comparison to the RACA score.

Sub-group

In a sub-group analysis of OHCA of presumed cardiac aetiology for ROSC and admittance to ICU similar changes were observed. For details on subgroup analysis please refer to Table 2. There was a none significant trend to a decreased admittance to ICU in patients with witnessed cardiac arrest and initial VT/VF: 72%, 82% and 67%, respectively.

Interestingly, the number of patients of presumed cardiac aetiology for all rhythms transported with ongoing CPR increased: 9.8%, 7.2% and 14% ($p < 0.05$).

Discussion

The most important finding of our study is that the observed ROSC rates are higher than reported in many other studies and are above the predicted ROSC rates by the RACA score.[8,12–14] However, even though the ROSC rates remained higher than predicted, the number of patients admitted to ICU after OHCA declined significantly ($p < 0.001$) within the 15 years study period (1996–2011). The underlying reason for this finding can only be speculated upon. As elsewhere, in the EMS of Bonn efforts were made to strengthen the chain of survival and thus improve the care for OHCA patients.

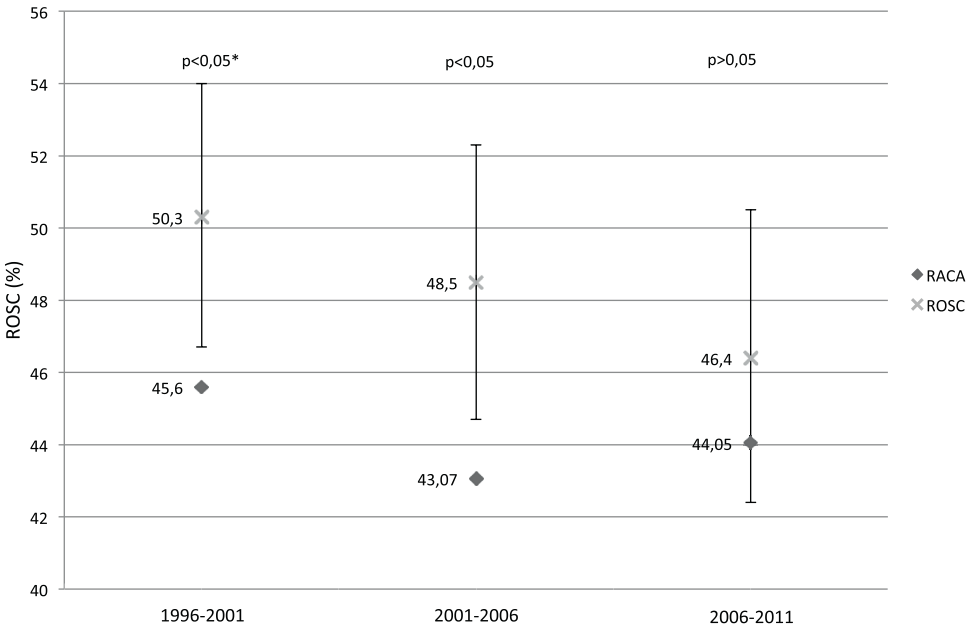

Fig. 3. Observed ROSC vs. predicted ROSC (RACA). Mean observed ROSC (95% confidence interval) is compared with predicte ROSC (RACA). In all time periods the observed. ROSC was higher than the predicted ROSC. In time period 1 and 2 observed ROSC was significant higher. * In period 1 data on pre-hospital ROSC rate were lacking. We used "ROSC at ICU admittance" in period 1 equally to the "ROSC rate at all" for comparison to the RACA score.

This included complete implementation of CPR guidelines and additionally, annual, intensive CPR training of the EMS staff. Additionally, CPR techniques mentioned in the literature but not yet recommended in the different CPR guidelines, such as ACD-CPR, endobronchial adrenaline, hypertonic saline with hydroxyethyl starch and load-distributing band CPR were temporally introduced into the daily routine (Fig. 1). This might have influenced CPR performance and created a possible *Hawthorne Effect* as clinical trials in the EMS could also have affected CPR performance. Nevertheless, this study was not designed to explain the observed findings in the context to these therapeutic approaches.

With focus on this short term outcome of OHCA, our findings are not in line with recent studies from Australia, New Zealand, Denmark and the USA in which an increased survival/ROSC rate from OHCA, after implementation of new CPR Guidelines were reported.[15–20] However, one study from Taiwan reported no alteration of ROSC rates after implementation of the 2005 Guidelines.[21] Nevertheless, these EMS were mainly paramedic based system and not physician staffed. Furthermore, even the improved outcome in the intervention period observed in these studies, is still below reported ROSC rates in our study. Depending on the results of the different studies the ROSC rate for the EMS of the city of Bonn is 10–20% higher. The urban setting of the city of Bonn with short response intervals to emergency calls might have had an important influence on this result. The relationship between the response time reliability, CPR incidence and resuscitation success rate for sudden cardiac arrest has been shown in a different study, comparing response intervals of the EMS of Bonn with other German EMS.[11]

The variability of the outcome of OHCA cases in different studies in global comparison may also be affected by the definition of OHCA used. Different definitions of OHCA could, for example, include patients who died outside of a hospital, only patients who die suddenly, only those attended by EMS staff or those for whom

Table 2

Sub-group's time periods	1996–2011		1996–2001		2001–2006		2006–2011		*p*-Value
Cardiac origin, all rhythm									
CPR incidence [1/Y/100,000]	1399	38.9	587	48.9	429	35.8	383	31.9	
ROSC at any time*	415	51.0%			226	52.7%	189	49%	0.343
Admitted to ICU	691	48.7%	310	52.8%	222	51.7%	159	42%	<0.001
Transport with ongoing CPR**	142	10.3%	58	9.9%	31	7.2%	53	14%	0.017
Cardiac origin, VT/VF									
CPR incidence [1/Y/100,000]	161	13.4	205	17.1	139	11.6	138	11.5	
ROSC at any time*	212	76.5%			110	79.1%	102	73.9%	0.305
Admitted to ICU	340	70.9%	140	68.3%	110	79.1%	90	65.2%	0.743
Transport with ongoing CPR**	47	9.8%	20	9.8%	10	7.2%	17	12.3%	0.515
Cardiac origin, VT/VF, witnessed arrest									
CPR incidence [1/Y/100,000]	114	9.5	154	12.8	80	6.7	109	9.1	
ROSC at any time*	150	79.8%			66	82.5%	84	77.1%	0.362
Admitted to ICU	250	73.9%	111	72.1%	66	82.5%	73	67.0%	0.466
Transport with ongoing CPR**	36	9.9%	17	11.0%	4	5.0%	15	13.8%	0.580

CPR: cardiopulmonary resuscitation; ROSC: return of spontaneous circulation; ICU: intensive care unit; VT: ventricular tachycardia; VF: ventricular fibrillation.

* ROSC at any time was not recorded in the first period.

** considered as negative outcome an are not included in ROSC or admitted to ICU.

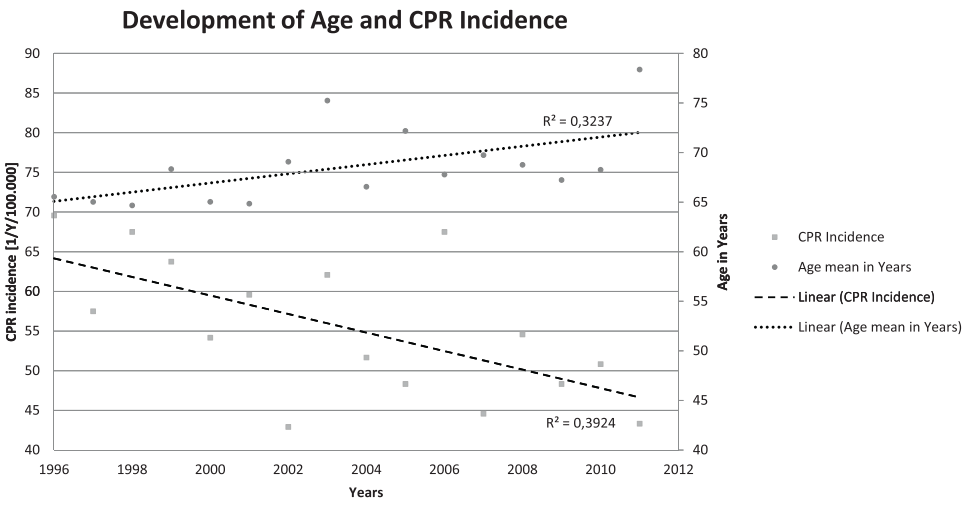

Fig. 4.

resuscitation efforts were made by the EMS.[5] The latter definition was used in our study.

Since ROSC following CA depends on numerous variables, the ROSC after cardiac arrest (RACA) score was developed as a tool, to predict the initial resuscitation outcome.[8] This benchmark tool enables a comparison of the observed and predicted ROSC rates based on local settings. Applying this score to our patients, we observed higher ROSC rates than predicted by the RACA score (Fig. 3) for each period. However, not only the ROSC rate, but also the RACA score decreased over time. This lower RACA score reflects changes in OHCA patients' age which makes establishing ROSC more challenging, and not only rely on CPR performance but also on the population group itself. In this regard, our population group showed a higher age (Fig. 4) over time, lower incidence of cardiac origin and less VT/VF as initial rhythm (Table 1). Even if we cannot report on comorbidities of the patients since individual data on medical histories were not available, one can assume that improved preventative measures taken in the last decade have had an influence on the onset and incidence of CPR and thus there were not only fewer patients with OHCA but these patient are nowadays also older (Fig. 4).[22,23] Data on general population for the county of Nordrhein-Westfalen from the Federal Statistical Office report a tendency of lower mortality of cardiac origin within the study period, whereas the general mortality rate remained unchanged.[24] This trend could underline how better medical measure such as improved medical procedures, treatment strategies and medications might influence the long term CPR incidence.

The lower incidence of CPR might also be influenced by local policies on whether or not to start a resuscitation attempt. In this context, we cannot give any data, but it is the impression in daily clinical routine of the authors, that over the past 15 years as a result the increased number of patient advance directives explicitly stating that no resuscitation attempts should be undertaken, fewer CPR attempts occurred thus lowering CPR incidence.

The observed longer response time intervals could have an impact on initial shockable rhythms, as also reported elsewhere.[15,19,25] This has also been found in our subgroup analysis (Table 2), which is considered to be the easiest to compare due to their homogeneity.[15]

It is remarkable, that from period 1 to period 3 the rate of patients transported with ongoing CPR increased and is higher than one could expect in relation to current guidelines, in which a transport of a patient without ROSC is only recommended for certain circumstances. One reason for these observed high rates of transported patients could be due to the urban setting of the city Bonn with a high hospital density and short distances for transportation. Furthermore, within the study period the use of mechanical CPR devices (load distributing band-CPR, Fig. 1) was established and the devices were widely used, which may have had also an impact on transport decision of the attending EMS physician. Even if in the admitting hospitals the availability of PCI and the willingness to perform PCI under ongoing CPR increased over the past 15 years, our observations show that this was not accompanied by higher rates of ICU admittance. However, due to missing data, our study is unable to report any further details on this subgroup of patients, mainly because of missing hospital data. Although we did not see any improvement in ROSC rates of OHCA patients in EMS of the city Bonn under the influence of the different CPR guidelines implemented in the three 5-years-periods, the overall patient outcome was better than predicted by the RACA score over the entire 15 years period and is indicative of a high performing EMS.[8] As this excellent performance was seen through all three time periods and even prior to the implementation of the first ERC Guidelines in the year 2000, we believe that intense CPR training and implementation are the main underlying factors leading to improved CPR outcomes.

Limitations

First of all, this was an observational retrospective study and thus we can only identify association rather than causation. We report on a single centre experience with all known limitations of this condition, however, in terms of EMS organisation, study populations served and the urban setting, there are little other variables apart from CPR guideline changes. In this study, we cannot report on any quality measurements of CPR attempts, such as compression depth or rate or ventilation, which might have an influence on CPR outcome. Furthermore, it is assumed that the CPR's performed were as closely to guidelines as possible. As data on long term outcome were not recorded, we focused on the pre-hospital EMS treatment and can not report any data on hospital outcomes.

In the observed period there were a couple of resuscitation trials conducted in the EMS of the city of Bonn (e.g. hypertonic saline with hydroxyethyl starch and load-distributing band CPR) which may have affected the performance and outcome of CPR attempts.

Conclusion

In our EMS we continually observed CPR outcomes that were better than predicted by the RACA-Score, but did not find any positive influence on primary CPR outcomes in the three different time

periods. Even if, the ROSC rates remained on a high level, the admittance to ICU decreased significantly over a period of 15 years.

Conflict of interest statement

None of the authors has any conflicts to declare.

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