The impact of response time reliability on CPR incidence and resuscitation success: a benchmark study from the German Resuscitation Registry

Inaugural-Dissertation
zur Erlangung des Doktorgrades
der Hohen Medizinischen Fakultät
der Rheinischen Friedrich-Wilhelms-Universität
Bonn

Jürgen Matthias Neukamm
aus Füssen

2013

Angefertigt mit Genehmigung der
Medizinischen Fakultät der Universität Bonn

1. Gutachter: Prof. Dr. med. Matthias Fischer

2. Gutachter: Prof. Dr. med. Christian Putensen

Tag der Mündlichen Prüfung: 10. Januar 2013

Aus der Klinik und Poliklinik für Anästhesiologie und operative Intensivmedizin der
Rheinischen Friedrich-Wilhelms-Universität Bonn
Direktor: Prof. Dr. med. A. Hoeft

Inhaltsverzeichnis

Deutsche Zusammenfassung

Einleitung

Weltweit zeigen sich große Unterschiede im Behandlungsergebnis nach präklinischer kardiopulmonaler Reanimation bei plötzlichem Herztod zwischen verschiedenen Notarzt- und Rettungsdiensten. In hoch effizienten Systemen kann bei bis zu 53 % dieser Patienten ein Spontankreislauf wieder hergestellt werden. Dagegen weisen einige andere lediglich eine Erfolgsquote von 9-12 % auf, obwohl auch hier die gültigen Reanimationsleitlinien Anwendung finden.

Im Jahre 2007 wurde von der Deutschen Gesellschaft für Anästhesiologie und Intensivmedizin das Deutsche Reanimationsregister begründet. Sieben der derzeit 84 teilnehmenden Rettungsdienste werden in dieser Studie untersucht und miteinander verglichen, der Einfluss der Einhaltung von Hilfsfristen auf die Inzidenz und den Erfolg von Reanimationsmaßnahmen wird analysiert.

Material und Methoden

Die Grundlage dieser Auswertung sind die anonymisierten Daten von sieben deutschen teilnehmenden Standorten:

Notarzt- und Rettungsdienst

- der Stadt Bonn
- des Krankenhauses „Klinik am Eichert“, Göppingen
- des Kreises Gütersloh
- der Stadt Münster
- des Kreises Tübingen
- des Kreises Rendsburg-Eckernförde
- der Region Stadt Marburg

Es wird die Strukturqualität anhand der sozioökonomischen Faktoren Einwohnerzahl und Größe des versorgten Gebietes, sowie die Vorhaltestunden mit Rettungsmitteln dargestellt. Die Prozessqualität wird anhand der Faktoren Hilfsfristerreichung, der Re-

animationsinzidenz, der Verwendung spezieller Hilfsmittel sowie der Durchführung einer präklinischen Hypothermiebehandlung untersucht. Außerdem werden folgende Patientendaten verglichen: Alter, Geschlecht, Ort und Ursache des Kreislaufstillstandes, Durchführung einer Laienreanimation.
Gemäß den Utstein-Style-Kriterien wurden bezüglich der Darstellung der Ergebnisqualität folgende Endpunkte definiert: Wiederherstellung des Spontankreislaufs, Krankenhausaufnahmerate mit Spontankreislauf, 24-Stunden-Überlebensrate und Krankenhausentlassrate.
Zudem wird die Rate an erfolgreichen Reanimationen mit dem RACA-Score, einem statistisch berechneten Vorhersagewert verglichen.
Die Daten wurden in einem Zeitraum zwischen Mai 2006 und Dezember 2009 für mindestens 12 Monate erhoben.
Zur statistischen Auswertung wurden der Chi-Quadrat-Test, der t-Test und die Bonferroni-Korrektur herangezogen. Ein Unterschied von $p<0,05$ wurde als statistisch signifikant betrachtet.

Ergebnis und Diskussion

Insgesamt wurden 2.330 Patienten in diese Studie eingeschlossen.

Bonn und Münster weisen eine hohen Bevölkerungsdichte auf. Rendsburg-Eckernförde, Marburg und Tübingen zeigen insgesamt eine ländliche Struktur mit niedriger Einwohnerdichte. Göppingen und Gütersloh haben eine gemischte Struktur.
Je nach Standort ergab sich eine Reanimationsinzidenz zwischen 36,0 und 65,1 pro 100.000 Einwohner und Jahr.
In Rendsburg-Eckernförde und Tübingen wurde der Einsatzort lediglich in 65,6 % bzw. 62,0 % innerhalb der geforderten Hilfsfrist von 8 Minuten erreicht. Die weiteren 5 Rettungsdienste erreichten dies in 70,4 % bis 95,5 % (Bonn). Dementsprechend ergaben sich mit 36,0 und 36,1 pro 100.000 Einwohner und Jahr in Rendsburg-Eckernförde und Tübingen die geringsten Reanimationsinzidenzen und mit 16,7 bzw. 14,6 pro 100.000 Einwohner und Jahr der geringste Erfolg bei der Krankenhausaufnahmerate. Der Standort Marburg kann durch eine hohe Zahl an Vorhaltestunden von Rettungsfahrzeugen (54.314 Stunden pro Jahr gegenüber nur 22.603 Stunden in

Münster) den Nachteil seiner ländlichen Bevölkerungsstruktur ausgleichen.

Alle sieben Rettungsdienste arbeiten nach dem Rendez-vous-system und führen regelmäßige Trainingsmaßnahmen durch. Für die Notärzte sind diese zum Teil auf freiwilliger Basis.
Durch Laien wurden 60,8 % der Kreislaufkollapse beobachtet, aber lediglich in 18,8 % der Fälle wurde mit Reanimationsmaßnahmen begonnen.
Männer sind mit 66,9 % etwa doppelt so häufig vom plötzlichen Herztod betroffen als Frauen, es bestehen keine Unterschiede zwischen den Standorten (p=0,64).
Ebensowenig unterscheidet sich der Ort des Kreislaufstillstandes (p=0,05), 70,8 % ereignen sich in häuslicher Umgebung.

Ebenso wie die Hilfsfristerreichung (>70 % innerhalb 8 Minuten: Bonn, Göppingen, Gütersloh, Marburg und Münster gegenüber <70 % innerhalb 8 Minuten: Rendsburg-Eckernförde und Tübingen) und die Reanimationsinzidenz unterscheiden sich die Standorte bei der Anzahl der erfolgreichen Reanimationen bezüglich der Endpunkte Spontankreislauf (p<0,001), Krankenhausaufnahme mit Spontankreislauf (p<0,001) und 24-Stunden-Überleben (p<0,001). Hingegen gibt es bei einer prozentualen Berechnung bezogen auf die Anzahl der begonnenen Reanimationen keine signifikanten Unterschiede bei den Endpunkten Spontankreislauf (p=0,32) und Krankenhausaufnahme (p=0,17).

In allen sieben Zentren war die Rate an erfolgreicher Wiederherstellung eines Spontankreislaufs höher als der Vorhersagewert (RACA-Score). An vier Standorten (Bonn, Göppingen, Rendsburg-Eckernförde und Tübingen) war der Vergleich signifikant unterschiedlich. Mit im Mittel 42,8 % vs. 32,7 % Krankenhausaufnahmerate schnitten diese sieben Rettungsdienste besser als alle weiteren Standorte des Deutschen Reanimationsregisters ab.

Diese Studie zeigt, dass eine möglichst kurze Hilfsfrist zu einer höheren Inzidenz an begonnenen Reanimationen führt, wodurch letztendlich mehr Patienten mit Spontankreislauf in eine Klinik eingeliefert werden als bei Standorte mit längeren Hilfsfristen, obwohl auch diese eine prozentual überdurchschnittliche Erfolgsrate aufweisen. Die meist

übliche prozentuale Berechnung spiegelt also nur unzureichend die Qualität eines Rettungsdienstes wieder.

Daher sollten die Anzahl und Standorte der Rettungs- und Notarztfahrzeuge möglichst auf die jeweiligen örtlichen Gegebenheiten angepasst werden, um möglichst kurze Hilfsfristen zu erreichen. Zudem könnte diese durch Einführen von GPS-Systemen und computergestützter Disposition optimiert werden.

Außerdem sollten, bei überwiegend in häuslicher Umgebung sich ereignenden Kreislaufstillständen, intensive und regelmäßige Kurse und Trainingsmaßnahmen für die öffentliche Bevölkerung eingeführt werden, insbesondere für ältere Personen.

Abkürzungsverzeichnis

ACD	Active compression decompression
ALS	Advanced cardial life support
BLS	Basic life support
CPR	Cardio pulmonary resuscitation
DGAI	German Society for Anaesthesiology and Intensive Care Medicine (Deutsche Gesellschaft für Anästhesiologie und Intensivmedizin)
ECG	Electrocardiography
EMS	Emergency medical service
ERC	European Resuscitation Council
EU	European Union
EuReCa	European Registry of Cardiac Arrest
GRR	German Resuscitation Registry
ILCOR	International Liaison Committee on Resuscitation
LDB	Load distributing band
NA	Notarzt (Emergency physician)
NEF	Notarzteinsatzfahrzeug (ermgency vehicle, staffed with emergency physicians)
OHCA	Out of hospital cardiac arrest
PEA	Pulsless electrical activity
RA	Rettungsassistent (Paramedic)
ROSC	Return of spontaneous circulation
RS	Rettungssanitäter (Emergency medical technican)
RTR	Response time reliability
RTW	Rettungswagen (emergency vehicle staffed with paramedics, no doctors)
SD	Standard deviation
VF	Ventricular heart flutter
VT	Ventricular tachycardia

Originalarbeit

The impact of response time reliability on CPR incidence and resuscitation success: a benchmark study from the German Resuscitation Registry

Jürgen Neukamm*[1], Jan-Thorsten Gräsner*+[2], Jens- Christian Schewe[3], Martin Breil[3], Jan Bahr[4], Ulrich Heister[3], Jan Wnent[5], Andreas Bohn[6], Gilbert Heller[2], Bernd Strickmann[7], Hans Fischer[8], Clemes Kill[9], Martin Messelken[1], Berthold Bein[2], Roman Lukas[6], Patrick Meybohm[2], Jens Scholz[2] and Matthias Fischer[1]

* *Both first authors contributed equally to the study and the publication.*

+ *Corresponding author*

1) Department of Anesthesiology and Intensive Care, Klinik am Eichert, Eichertstraße 3, 73035 Göppingen, Germany
2) Department of Anesthesiology and Intensive Care Medicine, University Hospital Schleswig-Holstein, Campus Kiel, Schwanenweg 21, 24105 Kiel, Germany
3) Department of Anesthesiology and Intensive Care Medicine, University Hospital Bonn, Bonn, Germany
4) Department of Anesthesiology, Emergency Medicine and Intensive Care University Hospital Göttingen, Göttingen, Germany
5) Department of Anesthesiology and Intensive Care Medicine, University Hospital Schleswig-Holstein, Campus Lübeck, Ratzeburger Allee 160, 23538 Lübeck, Germany
6) Department of Anesthesiology and Intensive Care Medicine, University Hospital Münster, Münster, Germany; Emergency Medical Services System of the city of Münster, Germany
7) Department of Anesthesiology and Intensive Care, Klinikum Ravensberg, Halle (Westfalen), Emergency Medical Services System of the county of Gütersloh, Germany
8) Department of Anesthesiology and Intensive Care Medicine, University Hospital Tübingen, Tübingen, Germany
9) Department of Anesthesiology and Intensive Care Medicine, University Hospital Marburg, Marburg, Germany

Abstract

Introduction: Sudden cardiac arrest is one of the most frequent causes of death in the world. In highly qualified EMS systems, including well trained emergency physicians, spontaneous circulation may be restored in up to 53% of patients at least until admission to hospital. Compared with these highly qualified EMS systems, in other systems markedly lower success rates are observed. These data clearly show that there are considerable differences between EMS systems concerning treatment success following cardiac arrest and resuscitation, although in all systems international guidelines for resuscitation are used. This study compares 7 German EMS systems participating in the German Resuscitation Registry. The influence of response time reliability on CPR incidence and resuscitation success is analysed.

Material and methods: Anonymized patient data after out of hospital cardiac arrest from 2006 to 2009 of 7 EMS systems in Germany were analysed to socioeconomic factors (population, area, EMS unit hours), process quality (response time reliability, CPR incidence, special CPR measures, prehospital cooling), patient factors (age, gender, cause of cardiac arrest, bystander CPR). Endpoints were defined as ROSC, admission to hospital, 24h survival and hospital discharge rate. For statistical analyses, chi-square, t-test and Bonferroni correction were used.

Results: 2,330 prehospital CPR from 7 centres were included in this analysis. Incidence of sudden cardiac arrest differs from 36.0 to 65.1 / 100,000 inhabitants / year. We identified two EMS systems reaching the patients within 8 min in 62.0 and 65.6% while the other five EMS systems achieved 70.4 up to 95.5%. EMS systems arriving relatively later at the patients side (RTR<70%) less frequently initiate CPR and admit fewer patients alive to hospital (calculated per 100,000 inhabitants / year). Using the multi-variate RACA score to predict outcome, the percentage ROSC rate in all 7 centres were higher than predicted.

Discussion and conclusion: This study demonstrates that on the level of EMS systems, faster ones will more often initiate CPR and will increase number of patients admitted alive to hospital. Furthermore it is shown that with very different approaches, all adhering to and intensely training in the ERC guidelines 2005, superior and, according to international comparison, excellent success rates following resuscitation may be

achieved.

Keywords

Resuscitation, cardiac arrest, quality management, resuscitation registries

1. Introduction

Sudden cardiac arrest is one of the most frequent causes of death in the world. In the US and Europe about 300,000 and 450,000, respectively, suffer this fate [1; 2] of which males are markedly more frequently affected than females, the ratio is 4.1/2.7 [3]. For Germany, data of the MONICA registry show an incidence of projected 123 cases per 100,000 inhabitants per year in the age group 35-64 years [4; 5], whereas in the European Union (EU) per 100,000 inhabitants only on about 55 patients resuscitation attempts are performed [1; 6-9]. Thus, in the EU with actually about 500 million inhabitants more than 275,000 resuscitation attempts are performed annually. However, more than half of the patients suffering from sudden cardiac arrest die without any resuscitation attempt since the event occurs unwitnessed or the emergency medical service (EMS) team, due to the statutory requirements, arrives too late at the patient's site and only can declare the patient death. Out-of-hospital cardiopulmonary resuscitation (CPR) frames a huge challenge to emergency medical services since sudden cardiac death is a particularly time-critical event. Additionally, successful management requires a complex and target-oriented response of all acting persons and the entire chain of survival, from dispatch centre personnel to the hospital team.

To improve treatment effect, the International Liaison Committee on Resuscitation (ILCOR) or rather the European Resuscitation Council (ERC) publish new resuscitation guidelines regularly, actually all 5 years and lastly in October 2010 [10-17]. For these guidelines current studies are screened and evaluated by experts in a scientific process, amongst others studies concerning "telephone guided CPR" [18-20], therapeutic hypothermia [21-24] or vasopressin treatment [25-27]. Following publication of the guidelines it is essential to teach and subsequently implement them into the EMS systems.

In highly qualified EMS systems, including well trained emergency physicians, spontaneous circulation may be restored in up to 53% of patients at least until admission to hospital [1; 9; 28]. Discharge rate in these EMS-systems is reported as 14-20%, and 1-year survival rate can reach up to 12%. The 10-years survival rate of patients discharged from hospital may reach 46% [1; 9; 28; 29]. Compared with these highly qualified EMS systems, in other systems markedly lower success rates are observed, with only 9-12% of patients being admitted to hospital and only 1-3% being discharged

from hospital with good neurologic outcome [1; 8; 9; 28-30].

These data clearly show that there are considerable differences between EMS systems concerning treatment success following cardiac arrest and resuscitation, although in all systems the current international guidelines for resuscitation are used [1; 6; 8; 9; 28]. It is therefore essential to analyse the reasons for these differences. However, only few studies have been published correlating resuscitation results with known influencing factors like response times, qualification of team members, actions during resuscitation and quality management procedures.

Not at least for this purpose, the German Society for Anaesthesiology and Intensive Care Medicine (Deutsche Gesellschaft für Anästhesiologie und Intensivmedizin (DGAI)) has set up the German resuscitation registry which has been officially implemented in 2007 [31; 32].

This study compares 7 German EMS systems participating in the German Resuscitation Registry (GRR) with regard to resuscitation results and underlying structures and concepts. The influence of response time reliability (RTR) on CPR incidence and resuscitation success is analysed.

2. Materials and methods

Participating centres

EMS service of

- the city of Bonn
- the hospital „Klinik am Eichert“, Göppingen
- the county of Gütersloh
- the city of Münster
- the county of Tübingen
- the county of Rendsburg-Eckernförde
- the region of Marburg.

In all of these 7 EMS well trained emergency physicians are responsible for the resuscitation procedures at the site.

The EMS named above and the scientific advisory board of the resuscitation registry of the DGAI have approved the participation in and the accomplishment of this comparison.

(Trial Nr. 02/2011 ReaReg)

The German Resuscitation Registry

Based on national and international recommendations (MIND2, Utstein Style, European Registry of Cardiac Arrest (EuReCa), ILCOR Guidelines), the nationwide interdisciplinary resuscitation registry run by the DGAI centrally collects data from actually 84 participating centres [2; 31; 32].

The quality reports of the 7 above named participating centres have been analysed.

Inclusion criteria for the resuscitation registry

Patients in whom an out-of-hospital cardiac arrest was determined and a resuscitation attempt performed have been included, independent from the reason of out of hospital cardiac arrest (OHCA). Great value was set upon that all EMS treatment details and all corresponding data were completely transferred to the resuscitation registry, making it possible to calculate the resuscitation incidence.

Study period

The study period comprises the years 2006 to 2009. However, the single EMS systems reported periods of various lengths. The centres provided complete data sets for at least one entire calendar year.

Structural, process and results quality

According to requirements of the resuscitation registry the following structural quality data of the EMS systems were recorded:

- Population served
- Service area
- Population density
- Unit hours ALS / BLS (unit hour is defined as a fully equipped response unit on a response or waiting for a response for one hour)

With regard to process quality the following data were recorded:

- Response time reliability (RTR) (rate of first vehicle arriving within 8 min [%]).

Response time interval was defined from call reception in the dispatch centre until arrival of the first ambulance on scene and was calculated using the time stamps of dispatch technology

- Rate of EMS-CPR started within 8 min [%]
- Rate of dispatch under triage (no ALS-unit (emergency Physician staffed) for the first alert)
- Rate of special CPR measures (ACD-CPR, LDB-CPR, CPR-feedback)
- Medical director and quality assurance programme
- Rate of prehospital cooling to achive therapeutic prehospital hypothermia

According to Utstein recommendations and requirements of the resuscitation registry the following data regarding patients and circumstances of cardiac arrests were collected:

- Cause of cardiac arrest
- Age
- Gender
- Witnessed by bystander or EMS personnel
- Bystander CPR performed
- Location of cardiac arrest
- First ECG rhythm

According to Utstein recommendations and requirements of the resuscitation registry the following data regarding the resuscitation outcome were recorded:

- Return of spontaneous circulation (ROSC)
- Admitted to hospital with spontaneous circulation
- 24 hours survival
- Hospital discharge rate

Resuscitation procedures were performed according to the 2005 ILCOR guidelines. If not already initiated by bystanders or first responders, the resuscitation attempt was started or continued by the first team arriving at the site (BLS or ALS unit).

The survival rates of the 7 participating centres have been compared with the total sample recorded in the GRR. Besides this, for each of the 7 centres the actual ROSC rate has been compared with the predicted rate. The latter is calculated using the RACA score [33] which includes the following factors:

- Age
- Gender
- Cause of cardiac arrest
- Location of cardiac arrest
- First ECG rhythm
- Bystander CPR
- Time of EMS arrival

Statistics and analysis

Data have been processed using Excel XP (Microsoft Corporation, Redmond, Washington, USA). Distributions are reported in absolute numbers and percentages. Statistical analyses have been performed using chi-square and t-test, respectively, considering a difference of $p < 0.05$ as statistically significant. Bonferroni correction has been used to neutralise the alpha error in connection with multiple paired comparisons. Results are partially described with 95% confidence interval. The analysis of numeric variables is specified with means and standard deviations using the statistical package SPSS (Version 14.0, SPSS Inc., Chicago Illinois, USA).

Calculation of incidences refers to 100,000 inhabitants of the respective centre per year.

Ethic committee vote

Design and publication of this study were approved by the scientific committee of the GRR in compliance with current publication guidelines. Patient informed consent was waived by the ethics committee of the University of Cologne, Faculty of Medicine (Kerpener Str. 62, 50937 Cologne, Germany) while analysis of anonymous data collection for quality management was not considered to be approved.

3. Results

Socio-demographic characteristics (table 1)

The centres Bonn and Münster represent big-city population structures with a high population density, whereas Rendsburg-Eckernförde, Marburg and Tübingen belong to rural areas with a low population density. Göppingen and Gütersloh have both urban and rural areas within their EMS region.

Different time periods, varying between 12 (Marburg) and 44 months (Göppingen), were analysed. The study period was from May 1, 2006 to December 31, 2009, there were 2,330 resuscitation attempts started.

In Tübingen and Rendsburg-Eckernförde only 62.0% and 65.6%, respectively, of the patients were reached by the EMS within 8 minutes after alerting, whereas in the other centres 70.4 to 95.5% of the patients were treated by the EMS within this period of time. In the big-city areas of Bonn and Münster about 90% of the patients could be reached by the first ambulance within 8 minutes after alerting. This is much faster compared to the other 5 systems ($p<0.001$). Accordingly, in Bonn and Münster resuscitation attempts were started the earliest (67.9% and 64.2% within 8 minutes after alerting, $p<0.001$).

The calculated incidence of sudden cardiac death followed by resuscitation attempt was between 36.0 and 65.1 per 100,000 inhabitants and year. In two regions (Rendsburg-Eckernförde and Tübingen) the CPR incidence amounted to 36.0 and 36.1, respectively, in the other regions with shorter response intervals to 54.0 resuscitation attempts per 100,000 inhabitants and year ($p<0.001$).

Cardiac arrest was witnessed in about 60% of patients; most rarely in Tübingen (49.4%), most often in Marburg (67.7%; $p<0.001$). In most cases the witnesses were lay people or bystanders (38.4% in Tübingen up to 59.7% in Rendsburg-Eckernförde; $p<0.001$), less often EMS personell was present at the scene when the cardiac arrest occurred (6.1% in Rendsburg-Eckernförde up to 12.5% in Göppingen; $p=0.09$). In contrast the rate of bystander CPR is low. Only in a few cases lay people have started CPR before EMS arrival, even when they had witnessed the collapse. The rate was between 1.3% in Tübingen and 28.6% in Münster ($p<0.001$).

Men more frequently suffer from cardiac arrest than women. In mean 66.9% of the patients were male, and there were only minor differences between the centres (64.4% - 71.9%; $p=0.64$). Mean age of patients from the different centres was comparable (67.1 ±

17.2), with patients being slightly younger in Rendsburg-Eckernförde (65.2 ± 16.5 years) and slightly older in Göppingen (68.9 ± 16.1 years). There were small differences between the centres regarding the patients with age over 65 years ($p<0.05$).
Regarding the site of cardiac arrest there were small differences between centres. Most collapses occurred in domestic environments (68.0% - 77.6%; $p=0.05$), in public 15.9% - 22.0% ($p=0.37$), and 5.9% - 14.5% at other sites ($p<0.01$).

Description of the EMS-Systems, medical treatment and special measures (table 2)

In all participating centres the two tired system has been established with BLS- and ALS-units (emergency physician staffed) meeting at the site of the emergency. The availability of EMS teams results from the time during which units are held available. The highest amount of unit hours per 100,000 inhabitants and year have been reported from Marburg (54,314 unit hours) and the lowest from Göppingen (6,732 unit hours).
It is essential that the staff of dispatch centres will identify cardiac arrest victims correctly, to send out BLS- and ALS units immediately. The fact that an ALS-unit has to be requested later by the BLS-unit after arrival at scene means a deficit in identifying cardiac arrest (under triage by dispatch centre). The rate of under triage was different, between 17.9% in Münster and 3.8% in Tübingen ($p<0.001$).
In some centres additional CPR-devices are used besides the normal equipment. In Bonn for example in 15.4% of all cases a mechanical resuscitation was performed with help of a load distributing band (LDB-CPR). In Münster a CPR feedback system was used in 90.3% of the patients. ACD-CPR was not available in Gütresloh and Rendsburg-Eckernförde, whereas the other centres used this system, most frequently in Göppingen (42.6%).
All centres have implemented regular CPR trainings, with differences concerning intervals and intensity. For emergency physicians the training partly is on a voluntary basis.
The recommended induction of mild hypothermia following resuscitation and ROSC was performed most frequently in Bonn (72.0%) and Münster (64.0%), markedly less often in Tübingen (7.9%) and Rendsburg-Eckernförde (only 1.0%; $p<0.001$).

Clinical outcome (table 3, figure 1)

Table 3 shows the survival rates following sudden cardiac arrest and resuscitation for the seven EMS systems, calculated by two different methods. On the one hand, for all patients and the respective Utstein sub-groups the survival rate has been calculated in percent, on the other hand the absolute numbers of the survivors per 100.000 inhabitants and year have been reported. The frequency of ROSC and hospital admission with ROSC could be determined for all centres, the 24-hours survival completely for Bonn, Göppingen, Gütersloh, Marburg, Münster and Tübingen, but not for Rendsburg-Eckernförde. Discharge rates have been completely recorded only in Göppingen, Gütersloh and Marburg.

Overall 2,330 patients were resuscitated in the 7 EMS systems; in 46.7% spontaneous circulation could be restored. 42.8% of the patients were admitted to a hospital with ROSC; 30.7% survived 24 hours, and 15.4% could be discharged alive.

Survival rates differed between the centres. Any ROSC could be obtained in 42.6% (Tübingen) and 53.1% (Rendsburg-Eckernförde) ($p=0.32$). Between 39.8% (Gütersloh) and 47.1% (Göppingen) were admitted to hospital with ROSC ($p=0.17$). Survival after 24 hours varied from 15.1% (Münster) to 30.3% (Göppingen) ($p<0.001$). Discharge rates were between 13.8% and 16.6% ($p=0.50$).

Quality of EMS care should not be measured only by using the *“percentage admission to hospital rate”* since a selection bias might influence this rate in both directions. Therefore, in this study the quality of preclinical care has been additionally described by the *“admission rate related to the population served”*.

Regarding the CPR incidence the EMS systems differ significantly. In two of the seven systems the CPR incidence is below 38 per 100.000 population per year, and in these two systems the rate of patients admitted to hospital is significantly lower than in the other centres ($p<0.001$). In Tübingen and Rendsburg-Eckernförde only 14.6 and 16.7 patients per 100,000 population per year, respectively, are admitted to hospital following cardiac arrest, whereas in the other five systems between 22.5 (Bonn) and 27.4 (Marburg) patients per 100,000 population per year survived the event to hospital admission ($p<0.001$).

The quality of EMS care may furthermore be described using the real ROSC rate and

the predicted ROSC rate (RACA-Score [33]). The predicted ROSC rate was on average 41.9% with a minimum of 37.1% in Tübingen and a maximum of 45.5% in Marburg. In all seven centres the ROSC rate was higher than predicted by RACA score. In four centres (Bonn, Göppingen, Rendsburg-Eckernförde and Tübingen) the ROSC rate was significantly higher than predicted.

An outcome analysis for sub-groups according to the initially recorded cardiac rhythm may further specify the comparison of the centres, eliminating an important influencing factor.

For example the sub-group of patients with a collapse of cardiac origin found in a shockable initial rhythm (23.9% of all patients) admission rate was 65.7% and thus considerably higher than in patients with asystole (25.3%) or pulseless electrical activity (40.4%) (incidence 7.9 vs. 3.3 vs. 1.8 / 100,000 inhabitants / year).

Differences between EMS systems can generally also be found in the sub-group analysis. Following collapse of cardiac origin and shockable rhythm, in Marburg 72.7% were admitted, but only 57.9% in Tübingen (p=0.28). In Göppingen, 55.3% of the patients were alive 24 hours after the event, but only 26.3% in Münster und Rendsburg-Eckernförde (p<0.001).

Comparison of two groups of EMS systems, grouped by "response time reliability < or > than 70% within 8 min" (table 4, figure 2)

For comparisons regarding RTR the five EMS systems of Bonn, Göppingen, Gütersloh, Marburg and Münster (group 1), where more than 70% of patients are reached by the first unit within 8 minutes, were contrasted by the systems of Tübingen and Rendsburg-Eckernförde (group 2), where less than 70% of the patients are reached within 8 minutes (RTR group 1: 82.7±10 vs. group 2: 63.8±1.8 [%], p<0.05).

In faster EMS systems with RTR > 70% (group 1) CPR incidence was significantly higher than in group 2 (58.3±4.3 vs. 36.1±0.1 [1/100,000 / year]; p<0.01) and more patients with ROSC were admitted to hospital (24.9±2.1 vs. 15.7±1.5 [1/100,000/year]; p<0.01). On the other hand these two groups did not differ in *"percentage CPR success rates"* (ROSC rate: 46.5±1.9 vs. 47.8±7.4 [%], p=0.73) (admitted to hospital rate: 42.9±3.3 vs. 43.5±4.2 [%], p=0.97). In both groups the predicted ROSC (RACA score) (42.8±2.3 vs. 39.8±3.7 [%], p=0.41) is significantly lower.

Comparing all seven participating centres with the population of all EMS systems included in the German resuscitation registry revealed that the seven centres more frequently reached the site of arrest within 8 minutes (80.0% vs. 73.6%; p<0.001), accomplished a higher ROSC rate (46.7% vs. 37.9%; p<0.001) and could admit more patients alive to the hospital (42.8% vs. 32.7%; p<0.001).

4. Discussion

For sudden cardiac arrest in Germany, this study for the first time demonstrates a relation between the response time reliability, CPR incidence, and resuscitation success (table 3 and 4, figure 1 and 2). Out of those seven EMS systems voluntarily participating both in the GRR and this study two systems could be identified in which the response time reliability, CPR incidence, and resuscitation success were lower than in the other five centres. Our study clearly shows that a lower CPR incidence could not be compensated by a higher *"percentage resuscitation rate"* to reach the same number of patients admitted to hospital. It is noticeable that EMS systems with the lowest CPR incidence have shown to have the longest response intervals.

The rate of patients admitted to the hospital with ROSC is an indicator for the quality of care by the EMS-Systems. Interestingly, the *"percentage admission to hospital rate"*, which is usually used to compare systems, did not differ between both groups and thus seems to be a weak indicator for the performance of EMS systems (figure 2).

In addition, the response time reliability (RTR) seems to be a particularly important influencing factor. It affects, on the one hand, the frequency of resuscitation attempts by an EMS system, on the other hand the resuscitation success related to the population served. In this study the time interval between call and arrival of the first ambulance was used to calculate, consistent for all centres, the response time reliability in resuscitation missions. The rate of patients reached within 8 minutes was determined. This corresponds largely to the national standard for response intervals in the United Kingdom, whereas in Germany, due to different State Laws on EMS, there is no nationwide standard. According to the heterogeneous legal requirements the best response time reliability could be found in the most densely populated areas (Bonn, Münster), with 90% of the patients being reached by the first ambulance within 8

minutes after the call. It is remarkable that also in the very rural EMS system of Marburg with the second lowest population density, 79.8% of the patients could be reached within 8 minutes. This success is explained by a high provision of EMS vehicles and unit hours. A high RTR regularly shortens the interval without treatment, so professional resuscitation attempts may be initiated earlier. This leads to improved admission rates and survival, as described by Hollenberg et al. who compared the resuscitation success rates of Gothenburg and Stockholm (admission rate 30% vs. 16%) [36]. Vukmir et al. have shown that more patients survive when it was possible to initiate resuscitation attempts within 8 minutes (56 vs. 32 patients) [37]. Our study supports the demand for a standardised response interval for the first arriving vehicle, and a reliability of 80%, meaning that regularly 80% of the patients should be reached within 8 minutes.

Because regional differing state laws in Germany response intervals are defined differently, and health funds provide financial means only to reach the respective standard. Thus, a German EMS system can realise a response interval standard only within a given legislative and financial framework. To compare the quality of EMS care under these conditions, further indicators have to be looked at. The survival rate following cardiac arrest is, besides other factors, influenced by techniques and quality of BLS [38; 39], ALS [40-43] and post resuscitation care [44-47]. Therefore, in our study the quality of EMS care was analysed by additionally describing *“percentage survival rates”* – ROSC and admission to hospital – of the total population, of sub-groups defined beforehand, and in comparison with a predictive value (RACA-Score) [33]. Table 4 shows that both groups of EMS systems could achieve higher ROSC rates than predicted by the RACA score but did not differ regarding the *“percentage survival rates”*. This means that (1) all seven EMS centres belong to the best performing systems in the German resuscitation registry, and that (2) a lower CPR incidence does not lead to a positive selection of “good risks”. The first statement is additionally supported by a comparison with the admission rates from the resuscitation registry since all seven centres perform better than the other participants of the DGAI resucitation registry, with on average 42.8% vs. 32.7% of patients being admitted to a hospital.

There might be various reasons for those superior resuscitation results of the seven participating EMS systems. It is well known that both a collapse in public and a

witnessed collapse improve the chances of surviving an OHCA [9]. However, in this respect there are no differences between the seven centres and the total GRR (witnessed: 60.2% vs. 61.6%; collapse in public: 18.3% vs. 18.2%). The results can neither be explained with the rate of bystander CPR being 18.8% in the seven centres and 18.5% in the total registry. Altogether, it is remarkable, that in Germany bystanders too rarely initiated CPR before EMS arrival even when they had witnessed the collapse. The positive influence of bystander CPR on the survival rate has been demonstrated frequently [48-50]. Previous studies have shown similar set-ups in German and European systems [9; 51]. One reason for the low rate of bystander CPR in Germany may be that more than 70% of the events occur at home and that usually elderly people are affected, living alone or with an also elderly partner who is unable to perform BLS spontaneously. As a consequence the approach of telephone guided CPR should urgently be intensified in these EMS systems and in Germany.

The comparatively high survival rates in the seven analysed centres may be explained with the higher rate of patients found in a shockable rhythm (rate of VF/VT 28.4% vs. 23.1% in the registry; $p<0.001$). Therapeutic hypothermia following ROSC was induced in 46.2% of the patients in the seven centres, but only in 13.7% of all patients in the registry ($p<0.001$).

Special effort in all seven centres observed was made in respect of CPR training in general and particularly to BLS. This is reflected by the fact that in three centres special supporting devices are intensely trained and used: Bonn has established LDB-CPR [39; 52], in Göppingen ACD-CPR in connection with an impedance valve is applied [53], and in Münster, after precedent intense training and continuous scientific evaluation, a CPR feedback system [34; 35], is regularly used. In this study, there is no evidence provided that using above named supporting devices will attain success. However, as the figures of the remaining participating centres show: Excellent results are possible by only applying committed manual CPR.

5. Limitations

The relationship between response time reliability, CPR incidence, and admission rate in

this study including seven EMS systems is obvious, but needs to be examined in more detail on the basis of a greater number of included centres.

6. Conclusions

This study demonstrates that on the level of EMS systems, faster ones will more often initiate CPR and will increase number of patients admitteld alive to hospital. Furthermore it is shown that with very different approaches, all adhering to and intensely training in the ERC guidelines 2005, superior and, according to international comparison, excellent success rates following resuscitation may be achieved. The three EMS systems where the discharge rate related to 100,000 inhabitants and year could be calculated (Göppingen, Gütersloh, Marburg) are, with results between 6.8 and 10.7 discharged patients, taking a top position in Europe (table 3).

Despite these internationally compared excellent results some potential improvements for the centres could be identified:

- Change of location of ambulance and emergency physicians stations, implementation of GPS and computer-aided dispatch should be uses to improve the rate of calls reached within the standardised response interval
- Shorten the time interval between arrival and onset of CPR
- Forceful training in BLS, especially when mechanical devices are implemented or used
- Special CPR training for elderly citizens
- Awareness raising and training of the population regarding the importance of bystander CPR
- Implementation of a structured interview of emergency calls an telephone guided CPR instructions by the dispatch centre
- Implementation or consistent use of a standard operating procedure concerning therapeutic hypothermia, starting in the preclinical phase.

7. Key messages

- Later arrival of the first EMS-unit on scene decreases the incidence of CPR, the number of patients that reached ROSC and that could be admitted to hospital.
- Change of location of ambulance and emergency physicians stations, implementation of GPS and computer-aided dispatch should be used to improve the rate of OHCA victims reached within the standardised response interval
- Intensive training of EMS is necessary, especially if advanced technique is used during CPR
- Basic life support training should be forced for general public and special groups of elder people to reduce no flow-time unless EMS handover CPR

8. List of abbreviations

ACD	Active compression decompression
ALS	Advanced cardial life support
BLS	Basic life support
CPR	Cardio pulmonary resuscitation
DGAI	German Society for Anaesthesiology and Intensive Care Medicine (Deutsche Gesellschaft für Anästhesiologie und Intensivmedizin)
ECG	Electrocardiography
EMS	Emergency medical service
ERC	European Resuscitation Council
EU	European Union
EuReCa	European Registry of Cardiac Arrest
GRR	German Resuscitation Registry
ILCOR	International Liaison Committee on Resuscitation
LDB	Load distributing band
NA	Notarzt (Emergency physician)
NEF	Notarzteinsatzfahrzeug (Emergency vehicle, staffed with emergency physicians)
OHCA	Out of hospital cardiac arrest
PEA	Pulsless electrical activity

RA	Rettungsassistent (Paramedic)
ROSC	Return of spontaneous circulation
RS	Rettungssanitäter (Emergency medical technican)
RTR	Response time reliability
RTW	Rettungswagen (Emergency vehicle staffed with paramedics, no doctors)
SD	Standard deviation
VF	Ventricular heart flutter
VT	Ventricular tachycardia

9. Competing interests

JTG, JW, MM and MF are members of the steering committee of the German Resuscitation Registry. All authors declare that there are no competing interests.

10. Authors' contributions

JN and JTG have made substantial contributions to conception and design, and drafted the manuscript. MF conceived of the study, and participated in its design and coordination and helped to draft the manuscript. JCS, MB, UH, JW, AB, GH, BS, HF, CK, RL and MM were responsible for data collection and quality control in the participating centers and helped to revise the manuscript. JB, BB and MF have been involved in the final revising the manuscript critically.

11. Acknowledgements

The authors are indebted to all active participants of the GRR who registered patients. Further, the authors would like to thank all professionals EP and EMT involved in pre-hospital emergency medical care and intensive care of the emergency physician-staffed emergency medical systems.

12. References

1. Berdowski J, Berg RA, Tijssen JG, Koster RW. Global incidences of out-of-hospital cardiac arrest and survival rates: Systematic review of 67 prospective studies. Resuscitation 2010; 81(11): 1479-1487.

2. Gräsner JT, Herlitz J, Koster RW, Rosell-Ortiz F, Stamatakis L, Bossaert L. Quality management in resuscitation - Towards a European Cardiac Arrest Registry (EuReCa). Resuscitation 2011; 82(8): 989-994.

3. Zheng ZJ, Croft JB, Giles WH, Mensah GA. Sudden cardiac death in the United States, 1989 to 1998. Circulation 2001; 104(18): 2158-2163.

4. Lowel H, Meisinger C, Heier M, Hormann A, Kuch B, Gostomzyk J, Koenig W. Sex specific trends of sudden cardiac death and acute myocardial infarction: results of the population-based KORA/MONICA-Augsburg register 1985 to 1998. Dtsch Med Wochenschr 2002; 127(44): 2311-2316.

5. Willich SN, Lowel H, Lewis M, Hormann A, Arntz HR, Keil U. Weekly variation of acute myocardial infarction: increased Monday risk in the working population. Circulation 1994; 90(1): 87-93.

6. Atwood C, Eisenberg MS, Herlitz J, Rea TD. Incidence of EMS-treated out-of-hospital cardiac arrest in Europe. Resuscitation 2005; 67(1): 75-80.

7. Messelken M, Kehrberger E, Dirks B, Fischer M. The quality of emergency medical care in baden-wurttemberg (Germany): four years in focus. Dtsch Arztebl Int 2010; 107(30): 523-530.

8. Fischer M, Krep H, Wierich D, Heister U, Hoeft A, Edwards S, Castrillo-Riesgo LG, Krafft T. Comparison of the emergency medical services systems of Birmingham and Bonn: process efficacy and cost effectiveness. Anasthesiol

Intensivmed Notfallmed Schmerzther 2003; 38(10): 630-642.

9. Fischer M, Fischer NJ, Schuttler J. One-year survival after out-of-hospital cardiac arrest in Bonn city: outcome report according to the 'Utstein style'. Resuscitation 1997; 33(3): 233-243.

10. Lippert FK, Raffay V, Georgiou M, Steen PA, Bossaert L. European Resuscitation Council Guidelines for Resuscitation 2010 Section 10. The ethics of resuscitation and end-of-life decisions. Resuscitation 2010; 81(10): 1445-1451.

11. Soar J, Monsieurs KG, Ballance JH, Barelli A, Biarent D, Greif R, Handley AJ, Lockey AS, Richmond S, Ringsted C et al. European Resuscitation Council Guidelines for Resuscitation 2010 Section 9. Principles of education in resuscitation. Resuscitation 2010; 81(10): 1434-1444.

12. Richmond S, Wyllie J. European Resuscitation Council Guidelines for Resuscitation 2010 Section 7. Resuscitation of babies at birth. Resuscitation 2010; 81(10): 1389-1399.

13. Biarent D, Bingham R, Eich C, Lopez-Herce J, Maconochie I, Rodriguez-Nunez A, Rajka T, Zideman D. European Resuscitation Council Guidelines for Resuscitation 2010 Section 6. Paediatric life support. Resuscitation 2010; 81(10): 1364-1388.

14. Arntz HR, Bossaert LL, Danchin N, Nikolaou NI. European Resuscitation Council Guidelines for Resuscitation 2010 Section 5. Initial management of acute coronary syndromes. Resuscitation 2010; 81(10): 1353-1363.

15. Deakin CD, Nolan JP, Soar J, Sunde K, Koster RW, Smith GB, Perkins GD. European Resuscitation Council Guidelines for Resuscitation 2010 Section 4. Adult advanced life support. Resuscitation 2010; 81(10): 1305-1352.

16. Deakin CD, Nolan JP, Sunde K, Koster RW. European Resuscitation Council Guidelines for Resuscitation 2010 Section 3. Electrical therapies: Automated external defibrillators, defibrillation, cardioversion and pacing. Resuscitation 2010; 81(10): 1293-1304.

17. Nolan JP, Soar J, Zideman DA, Biarent D, Bossaert LL, Deakin C, Koster RW, Wyllie J, Bottiger B. European Resuscitation Council Guidelines for Resuscitation 2010 Section 1. Executive summary. Resuscitation 2010; 81(10): 1219-1276.

18. Ghuysen A, Collas D, Stipulante S, Donneau AF, Hartstein G, Hosmans T, Vantroyen B, D'Orio V. Dispatcher-assisted telephone cardiopulmonary resuscitation using a French-language compression-only protocol in volunteers with or without prior life support training: A randomized trial. Resuscitation 2011; 82(1): 57-63.

19. Hupfl M, Selig HF, Nagele P. Chest-compression-only versus standard cardiopulmonary resuscitation: a meta-analysis. Lancet 2010; 376(9752): 1552-1557.

20. Bobrow BJ, Spaite DW, Berg RA, Stolz U, Sanders AB, Kern KB, Vadeboncoeur TF, Clark LL, Gallagher JV, Stapczynski JS et al. Chest compression-only CPR by lay rescuers and survival from out-of-hospital cardiac arrest. Jama 2010; 304(13): 1447-1454.

21. Szumita PM, Baroletti S, Avery KR, Massaro AF, Hou PC, Pierce CD, Henderson GV, Stone PH, Scirica BM. Implementation of a Hospital-wide Protocol for Induced Hypothermia Following Successfully Resuscitated Cardiac Arrest. Crit Pathw Cardiol 2010; 9(4): 216-220.

22. Gaieski DF, Band RA, Abella BS, Neumar RW, Fuchs BD, Kolansky DM, Merchant RM, Carr BG, Becker LB, Maguire C et al. Early goal-directed hemodynamic optimization combined with therapeutic hypothermia in comatose

survivors of out-of-hospital cardiac arrest. Resuscitation 2009; 80(4): 418-424.

23. Friberg H, Nielsen N. Hypothermia after Cardiac Arrest: Lessons Learned from National Registries. J Neurotrauma 2009; 26(3): 365-9.

24. Nolan JP, Neumar RW, Adrie C, Aibiki M, Berg RA, Bbttiger BW, Callaway C, Clark RS, Geocadin RG, Jauch EC et al. Post-cardiac arrest syndrome: Epidemiology, pathophysiology, treatment, and prognostication: A scientific statement from the International Liaison Committee on Resuscitation; the American Heart Association Emergency Cardiovascular Care Committee; the Council on Cardiovascular Surgery and Anesthesia; the Council on Cardiopulmonary, Perioperative, and Critical Care; the Council on Clinical Cardiology; the Council on Stroke (Part 1). Int Emerg Nurs 2009; 17(4): 203-225.

25. Duncan JM, Meaney P, Simpson P, Berg RA, Nadkarni V, Schexnayder S. Vasopressin for in-hospital pediatric cardiac arrest: results from the American Heart Association National Registry of Cardiopulmonary Resuscitation. Pediatr Crit Care Med 2009; 10(2): 191-195.

26. Mentzelopoulos SD, Zakynthinos SG, Tzoufi M, Katsios N, Papastylianou A, Gkisioti S, Stathopoulos A, Kollintza A, Stamataki E, Roussos C. Vasopressin, epinephrine, and corticosteroids for in-hospital cardiac arrest. Arch Intern Med 2009; 169(1): 15-24.

27. Gueugniaud PY, David JS, Chanzy E, Hubert H, Dubien PY, Mauriaucourt P, Braganca C, Billeres X, Clotteau-Lambert MP, Fuster P et al. Vasopressin and epinephrine vs. epinephrine alone in cardiopulmonary resuscitation. N Engl J Med 2008; 359(1): 21-30.

28. Herlitz J, Bahr J, Fischer M, Kuisma M, Lexow K, Thorgeirsson G. Resuscitation in Europe: a tale of five European regions. Resuscitation 1999; 41(2): 121-131.

29. Holler NG, Mantoni T, Nielsen SL, Lippert F, Rasmussen LS. Long-term survival after out-of-hospital cardiac arrest. Resuscitation 2007; 75(1): 23-28.

30. Gräsner JT, Meybohm P, Caliebe A, Böttiger BW, Wnent J, Messelken M, Jantzen T, Zeng T, Strickmann B, Bohn A et al. Postresuscitation care with mild therapeutic hypothermia and coronary intervention after out-of-hospital cardiopulmonary resuscitation: a prospective registry analysis. Crit Care 2011; 15(1): R61.

31. Gräsner JT, Meybohm P, Fischer M, Bein B, Wnent J, Franz R, Zander J, Lemke H, Bahr J, Jantzen T et al. A national resuscitation registry of out-of-hospital cardiac arrest in Germany-a pilot study. Resuscitation 2009; 80(2): 199-203.

32. Gräsner JT, Messelken M, Fischer M, Jantzen T, Bahr J, Bottiger BW, Dorges V, Franz R, Gries A, Krieter H et al. [The DGAI CPR registry - the datasets "hospital care" and "long-term process"]. Anasthesiol Intensivmed Notfallmed Schmerzther 2008; 43(10): 706-709.

33. Gräsner JT, Meybohm P, Lefering R, Wnent J, Bahr J, Messelken M, Jantzen T, Franz R, Scholz J, Schleppers A et al. ROSC after cardiac arrest--the RACA score to predict outcome after out-of-hospital cardiac arrest. Eur Heart J 2011; 32(13): 1649-1656.

34. Yeung J, Meeks R, Edelson D, Gao F, Soar J, Perkins GD. The use of CPR feedback/prompt devices during training and CPR performance: A systematic review. Resuscitation 2009; 80(7): 743-751.

35. Abella BS, Edelson DP, Kim S, Retzer E, Myklebust H, Barry AM, O'Hearn N, Hoek TL, Becker LB. CPR quality improvement during in-hospital cardiac arrest using a real-time audiovisual feedback system. Resuscitation 2007; 73(1): 54-61.

36. Hollenberg J, Bang A, Lindqvist J, Herlitz J, Nordlander R, Svensson L, Rosenqvist M. Difference in survival after out-of-hospital cardiac arrest between

the two largest cities in sweden. A matter of time? J Intern Med. 2005; 257: 247-254.

37. Vukmir RB. Survival from prehospital cardiac arrest is critically dependent upon response time. Resuscitation. 2006; 69: 229-234.

38. Kramer-Johansen J, Myklebust H, Wik L, Fellows B, Svensson L, Sorebo H, Steen PA. Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: A prospective interventional study. Resuscitation. 2006; 71: 283-292.

39. Ong ME, Ornato JP, Edwards DP, Dhindsa HS, Best AM, Ines CS, Hickey S, Clark B, Williams DC, Powell RG, Overton JL, Peberdy MA. Use of an automated, load-distributing band chest compression device for out-of-hospital cardiac arrest resuscitation. JAMA. 2006; 295: 2629-2637.

40. Fischer M, Kamp J, Garcia-Castrillo Riesgo L, Robertson-Steel I, Overton J, Ziemann A, Krafft T. Comparing emergency medical service systems-a project of the european emergency data (eed) project. Resuscitation. 2011; 82: 285-293.

41. Olasveengen TM, Sunde K, Brunborg C, Thowsen J, Steen PA, Wik L. Intravenous drug administration during out-of-hospital cardiac arrest: A randomized trial. JAMA. 2009; 302: 2222-2229.

42. Lund-Kordahl I, Olasveengen TM, Lorem T, Samdal M, Wik L, Sunde K. Improving outcome after out-of-hospital cardiac arrest by strengthening weak links of the local chain of survival; quality of advanced life support and post-resuscitation care. Resuscitation. 2010; 81: 422-426.

43. Dickinson ET, Schneider RM, Verdile VP. The impact of prehospital physicians on out-of-hospital nonasystolic cardiac arrest. Prehosp Emerg Care. 1997; 1: 132-135.

44. Sunde K, Pytte M, Jacobsen D, Mangschau A, Jensen LP, Smedsrud C, Draegni T, Steen PA. Implementation of a standardised treatment protocol for post resuscitation care after out-of-hospital cardiac arrest. Resuscitation. 2007 Apr; 73(1): 29-39. Epub 2007 Jan 25.

45. Gräsner JT, Meybohm P, Caliebe A, Böttiger BW, Wnent J, Messelken M, Jantzen T, Zeng T, Strickmann B, Bohn A, Fischer H, Scholz J, Fischer M, Grr GR. Postresuscitation care with mild therapeutic hypothermia and coronary intervention after out-of-hospital cardiopulmonary resuscitation: A prospective registry analysis. Crit Care. 2011; 15: R61.

46. Holzer M, Mullner M, Sterz F, Robak O, Kliegel A, Losert H, Sodeck G, Uray T, Zeiner A, Laggner AN. Efficacy and safety of endovascular cooling after cardiac arrest: Cohort study and bayesian approach. Stroke. 2006; 37: 1792-1797.

47. Holzer M, Bernard SA, Hachimi-Idrissi S, Roine RO, Sterz F, Mullner M. Hypothermia for neuroprotection after cardiac arrest: Systematic review and individual patient data meta-analysis. Crit Care Med. 2005; 33: 414-418.

48. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Hiraide A. Bystander-initiated rescue breathing for out-of-hospital cardiac arrests of noncardiac origin. Circulation. 2010; 122: 293-299.

49. Nordberg P, Hollenberg J, Herlitz J, Rosenqvist M, Svensson L. Aspects on the increase in bystander cpr in sweden and its association with outcome. Resuscitation. 2009; 80: 329-333.

50. Sekimoto M, Noguchi Y, Rahman M, Hira K, Fukui M, Enzan K, Inaba H, Fukui T. Estimating the effect of bystander-initiated cardiopulmonary resuscitation in japan. Resuscitation. 2001; 50: 153-160.

51. Steinmetz J, Barnung S, Nielsen SL, Risom M, Rasmussen LS. Improved survival after an out-of-hospital cardiac arrest using new guidelines. Acta Anaesthesiol Scand. 2008; 52: 908-913.

52. Krep H, Mamier M, Breil M, Heister U, Fischer M, Hoeft A. Out-of-hospital cardiopulmonary resuscitation with the autopulse system: A prospective observational study with a new load-distributing band chest compression device. Resuscitation. 2007; 73: 86-95.

53. Wolcke BB, Mauer DK, Schoefmann MF, Teichmann H, Provo TA, Lindner KH, Dick WF, Aeppli D, Lurie KG. Comparison of standard cardiopulmonary resuscitation versus the combination of active compression-decompression cardiopulmonary resuscitation and an inspiratory impedance threshold device for out-of-hospital cardiac arrest. Circulation. 2003; 108: 2201-2205.

Socio-demographic charcteristics	Bonn	Göppingen	Gütersloh	Marburg	Münster	Rendsburg-Eckernförde	Tübingen	p value	total / average
Served population [n]	315,000	192,000	319,732	251,800	280,199	272,488	218,692		1,849,911
Service area [sqkm]	141.0	354.0	864.0	1262.6	302.9	2185.9	519.2		5629.6
Population density [1/sqkm]	2234.0	542.4	370.1	199.4	925.0	124.7	421.2		328.6
timeframe	01.01.07-31.12.09	01.05.06-31.12.09	01.11.07-31.12.09	01.01.08-31.12.08	01.06.07-31.12.09	01.01.06-31.12.07	01.01.07-31.12.09		
CPR attempted [n]	533	399	410	164	391	196	237		2,330
CPR incidence [1/Y/100,000 I]	56.4	56.6	59.2	65.1	54.0	36.0	36.1	**<0.001**	50.6
Rate of first vehicle reached emergency patient within 8 minutes(%)	95.5	70.4	77.9	79.8	90.0	65.6	62.0	**<0.001**	80.0
Rate of CPR started within 8 minutes(%)	67.9	60.6	57.6	57.9	64.2	56.0	53.0	**<0.001**	60.3
Wittnessed [%]	64.2	58.1	58.3	67.7	59.6	65.8	49.4	**<0.001**	60.2
wittnessed by Bystander [%]	53.8	45.6	47.1	58.5	53.2	59.7	38.4	**<0.001**	50.4
CPR performed by bystander [%]	23.3	10.0	20.2	17.1	28.6	24.0	1.3	**<0.001**	18.8
wittnessed and CPR performed by EMS [%]	10.3	12.5	11.2	9.1	6.4	6.1	11.0	**0.09**	9.8
Male [%]	64.4	66.9	66.1	68.3	68.0	71.9	66.7	**0.64**	66.9
AGE [mean]	66.9	68.9	67.9	65.9	67.4	65.2	65.3		67.1
AGE [median]	70.6	73.0	70.9	69.4	70.2	68.6	70.0		70.2
AGE [SD]	17.7	16.1	16.6	16.6	17.0	16.5	19.8		17.2
> 65 years [%]	65.5	71.4	67.3	57.9	63.4	62.2	66.2	**<0.05**	
Location of cardiac arrest									
Home [%]	70.5	68.2	77.6	71.3	68.0	69.4	69.2	**0.05**	70.8
Public [%]	17.4	17.3	16.6	15.9	22.0	20.9	18.1	**0.37**	18.3
Others [%]	12.0	14.5	5.9	12.8	10.0	9.7	12.7	**<0.01**	10.9

Table 1: Socio demographic characteristics of the centres
Service area and population served by the EMS systems
Unit hours: A fully equipped response unit on a response or waiting for a response for one hour
p-value calculated by χ^2 test (significant = $p<0.05$)

Description of the EMS-Systems		Bonn	Göppingen	Gütersloh	Marburg	Münster	Rendsburg-Eckernförde	Tübingen	p value	average
Provider		City of Bonn / Fire Department	Emergency medical services, district of Göppingen, Klinik am Eichert Göppingen	Emergency medical services, district of Gütersloh	Emergency medical services, district of Marburg	City of Münster / Fire Department	Emergency medical services, district of Rendsburg-Eckernförde	Emergency medical services, DRK and ASB Tübingen		All
Vehicles	Two-tired-system	yes	yes	yes	yes	yes	yes	yes		
Emergency-Phiysician Unit	Unit hours [1/Y/100,000 I]	5,561.9	6,463.5	10,959.2	10,436.9	6,252.7	6,429.6	8,011.3	**<0.001**	7,773.9
EMS-Unit	Unit hours [1/Y/100,000 I]	26,807.6	18,250.0	25,923.0	43,876.9	16,350.5	32,148.2	24,033.8	**<0.001**	26,964.8
Emercency physician unit + EMS-Unit	Unit hours [1/Y/100,000 I]	32,369.5	24,713.5	36,882.1	54,313.7	22,603.2	38,577.8	32,045.1	**<0.001**	34,738.6
Emercency physician unit + EMS-Unit	Unit hours / Y / area [h/skm]	723.1	134.0	136.5	108.3	209.1	48.1	135.0	**<0.001**	114.2
Quality assurance	Training programme	RA + RS 30 h/Y	RA + RS 30 h/Y NA 12h/Y	RA + RS: 30 h/Y NA 8 h/Y	RA + RS 38h/Y NA 8h/Y	RA + RS: 30 h/Y NA 4 h/Y	RA + RS 30 h/Y	RA + RS: 30 h/Y NA 12 h/Y		
	emergency physician additional requested by ambulance	9.0	11.5	8.8	11.6	17.9	8.7	3.8	**<0.001**	10.5
Equipment	LDB-CPR [%]	15.4	0.0	0.0	0.0	0.3	0.0	0.0	**<0.001**	3.6
	ACD-CPR [%]	4.5	42.6	0.0	5.5	7.2	0.0	6.8	**<0.001**	10.6
	Feedback-system [%]	0.0	0.0	0.0	1.8	90.3	0.0	0.0	**<0.001**	15.3
Pre-hospital cooling	Cooling of ROSC-patients [%]	72.0	50.3	40.2	33.3	64.0	1.0	7.9	**<0.001**	46.2

Table 2: Description of the EMS-Systems
EMS = Emergency medical service
NEF (Notarzteinsatzfahrzeug): emergency vehicle, including an emergency physician
RTW (Rettungswagen): emergency vehicle, without an emergency physician
RA: Rettungsassistent = PM: Paramedic
RS: Rettungssanitäter = EMT: Emergency medical technician
NA: Notarzt = Emergency physician
LDB: load distributing band; ACD: active compression decompression
p-value calculated by χ^2 test (significant = $p<0.05$)

Clinical outcome	Bonn			Göppingen			Gütersloh			Marburg			Münster			Rendsburg-Eckernförde			Tübingen			p value (1/Y/100.000 I)	p value (%)
	[n]	[1/Y/100,000 I]	%	[n]	[1/Y/100,000 I]	%	[n]	[1/Y/100,000 I]	%	[n]	[1/Y/100,000 I]	%	[n]	[1/Y/100,000 I]	%	[n]	[1/Y/100,000 I]	%	[n]	[1/Y/100,000 I]	%		
All (cardiac and non-cardiac)	533	56.4	100.0	399	56.6	100.0	410	59.2	100.0	164	65.1	100.0	391	54.0	100.0	196	36.0	100.0	237	36.1	100.0	**<0.001**	
any ROSC	250	26.5	46.9	191	27.1	47.9	179	25.8	43.7	75	29.8	45.7	189	26.1	48.3	104	19.1	53.1	101	15.4	42.6	**<0.001**	**0.32**
any ROSC CI 95%			41,9 / 51,5			43,5 / 55,2			38,7 / 52,1			41,4 / 61,4			44,0 / 56,4			45,7 / 63,8			37,4 / 54,3		
RACA Score			41.8			39.7			42.4			45.5			44.7			42.4			37.1		
difference significant			y			y			n			n			n			y			y		
admitted to hospital	213	22.5	40.0	188	26.7	47.1	163	23.5	39.8	69	27.4	42.1	178	24.6	45.5	91	16.7	46.4	96	14.6	40.5	**<0.001**	**0.17**
24 hours survival	141	14.9	26.5	121	17.2	30.3	109	15.7	26.6	40	15.9	24.4	59	8.1	15.1	n.d.			56	8.5	23.6	**<0.001**	**<0.001**
discharged alive	n.d.			56	7.8	13.8	68	9.8	16.6	27	10.7	16.5	n.d.			n.d.			n.d.			**0.30**	**0.50**
First rhythm VF/VT (all)	141	14.9	26.5	105	14.9	26.3	99	14.3	24.1	55	21.8	33.5	119	16.4	30.4	78	14.3	39.8	64	9.8	27.0	**<0.01**	**<0.01**
VF / VT (cardiac)	125	13.2	23.5	94	13.3	23.6	79	11.4	19.3	44	17.5	26.8	95	13.1	24.3	63	11.6	32.1	57	8.7	24.1	**<0.05**	**<0.05**
any ROSC	88	9.3	70.4	68	9.6	72.3	53	7.6	67.1	33	13.1	75.0	70	9.7	73.7	47	8.6	74.6	34	5.2	59.6	**<0.01**	**0.51**
admitted to hospital	77	8.1	61.6	68	9.6	72.3	47	6.8	59.5	32	12.7	72.7	66	9.1	69.5	43	7.9	68.3	33	5.0	57.9	**<0.01**	**0.28**
24 hours survival	58	6.1	46.4	52	7.4	55.3	38	5.5	48.1	n.d.			25	3.4	26.3	5	3.4	26.3	23	3.5	40.4	**<0.001**	**<0.001**
Asystoly (cardiac)	133	14.1	25.0	128	18.2	32.1	94	13.6	22.9	33	13.1	20.1	91	12.6	23.3	52	9.6	26.5	62	9.5	26.2	**<0.001**	**<0.05**
any ROSC	43	4.6	32.3	42	6.0	32.8	24	3.5	25.5	9	3.6	27.3	26	3.6	28.6	16	2.9	30.8	15	2.3	24.2	**<0.05**	**0.82**
admitted to hospital	31	3.3	23.3	42	6.0	32.8	22	3.2	23.4	8	3.2	24.2	23	3.2	25.3	11	2.0	21.2	13	2.0	21.0	**<0.01**	**0.49**
24 hours survival	18	1.9	13.5	23	3.3	18.0	12	1.7	12.8	n.d.			9	1.2	9.9	1	0.2	1.9	6	0.9	9.7	**<0.01**	**0.07**
PEA (cardiac)	73	7.7	13.7	49	7.0	12.3	30	4.3	7.3	12	4.8	7.3	15	2.1	3.8	3	0.6	1.5	21	3.2	8.9	**<0.001**	**<0.001**
any ROSC	32	3.4	43.8	23	3.3	46.9	11	1.6	36.7	5	2.0	41.7	7	1.0	46.7	3	0.6	100.0	11	1.7	52.4	**<0.001**	**0.92**
admitted to hospital	26	2.8	35.6	22	3.1	44.9	11	1.6	36.7	3	1.2	25.0	6	0.8	40.0	3	0.6	100.0	11	1.7	52.4	**<0.01**	**0.60**
24 hours survival	18	1.9	24.7	6	0.9	12.2	6	0.9	20.0	n.d.			2	0.3	13.3	n.d.			5	0.8	23.8	**<0.05**	**0.48**

Table 3: Clinical outcome
RACA Score: predicted value of ROSC; VF = ventricular heart flutter; VT = ventricular tachycardia; PEA = pulseless electrical activity
p-value (1/Y/100,000 I): Comparison of the number of patients in one year per 100,000 Inhabitants of the centre
p-value (%): Comparison of the number of grouped patients regarding to the number of all treated patients
p-value calculated by χ^2 test (significant = $p<0.05$)

Provider	Bonn, Göppingen, Gütersloh, Marburg, Münster	Rendsburg-Eckernförde, Tübingen	p-value	All 7 Providers	all other centres in German resuscitation registry
					01.01.2006 - 31.12.2009
All Patients (cardiac + non cardiac) [n]	1,897	433	0.13	2,330	4,624
time alert to first vehicle stopped, patients within 8 min [%]	82.7± 10.0	63.8± 1.8	<0.05	80.0	73.6
CPR incidence [1 / Y / 100.000 I]	58.3± 4.3	36.1± 0.1	<0.01	50.6	n.d.
ROSC [1 / Y / 100.000 I]	27.1± 1.6	17.3± 2.6	0.07	23.7	n.d.
admitted to hospital [1 / Y / 100.000 I]	24.9± 2.1	15.7± 1.5	<0.01	21.7	n.d.
ROSC [%]	46.5± 1.9	47,8 ± 7,4	0.73	46.7	37.9
RACA Score [%]	42.8± 2.3	39.8 ± 3.7	0.41	41.9	n.d.
admitted to hospital [%]	42.9± 3.3	43.5± 4.2	0.97	42.8	32.7

Table 4: Comparison of two groups of EMS-Systems
Comparison of two groups of EMS-Systems, grouped by “response time reliability within 8 minutes (achieved or not achieved in 70%)”
unweighted means ± SD
p-value calculated by t- test (significant = $p<0.05$)

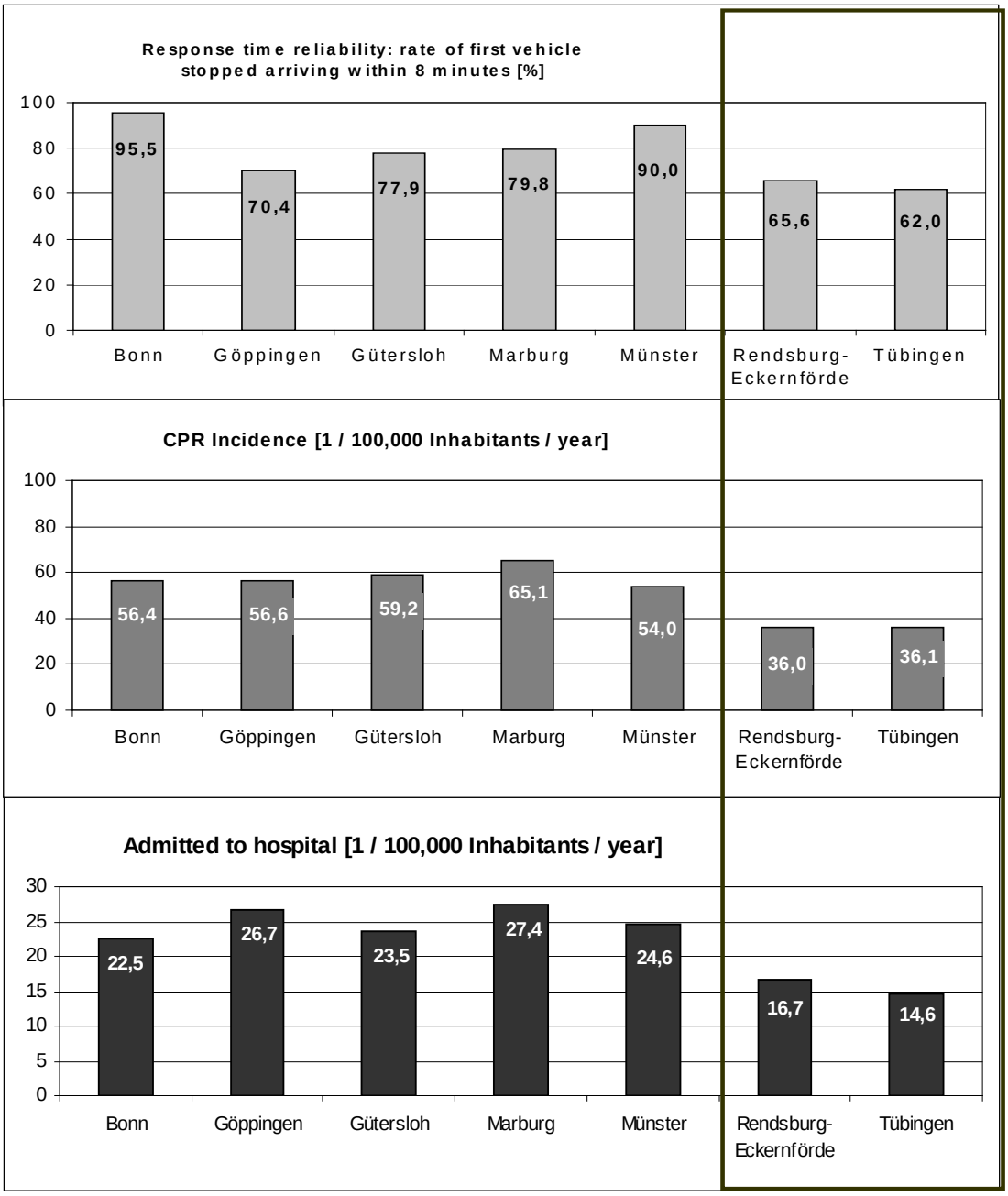

Figure 1:
Response time reliability: rate of first vehicle stopped within 8 minutes [%]
CPR incidence [1 / 100,000 Inhabitants / year]
Patients admitted to hospital [1 / 100,000 Inhabitants / year]

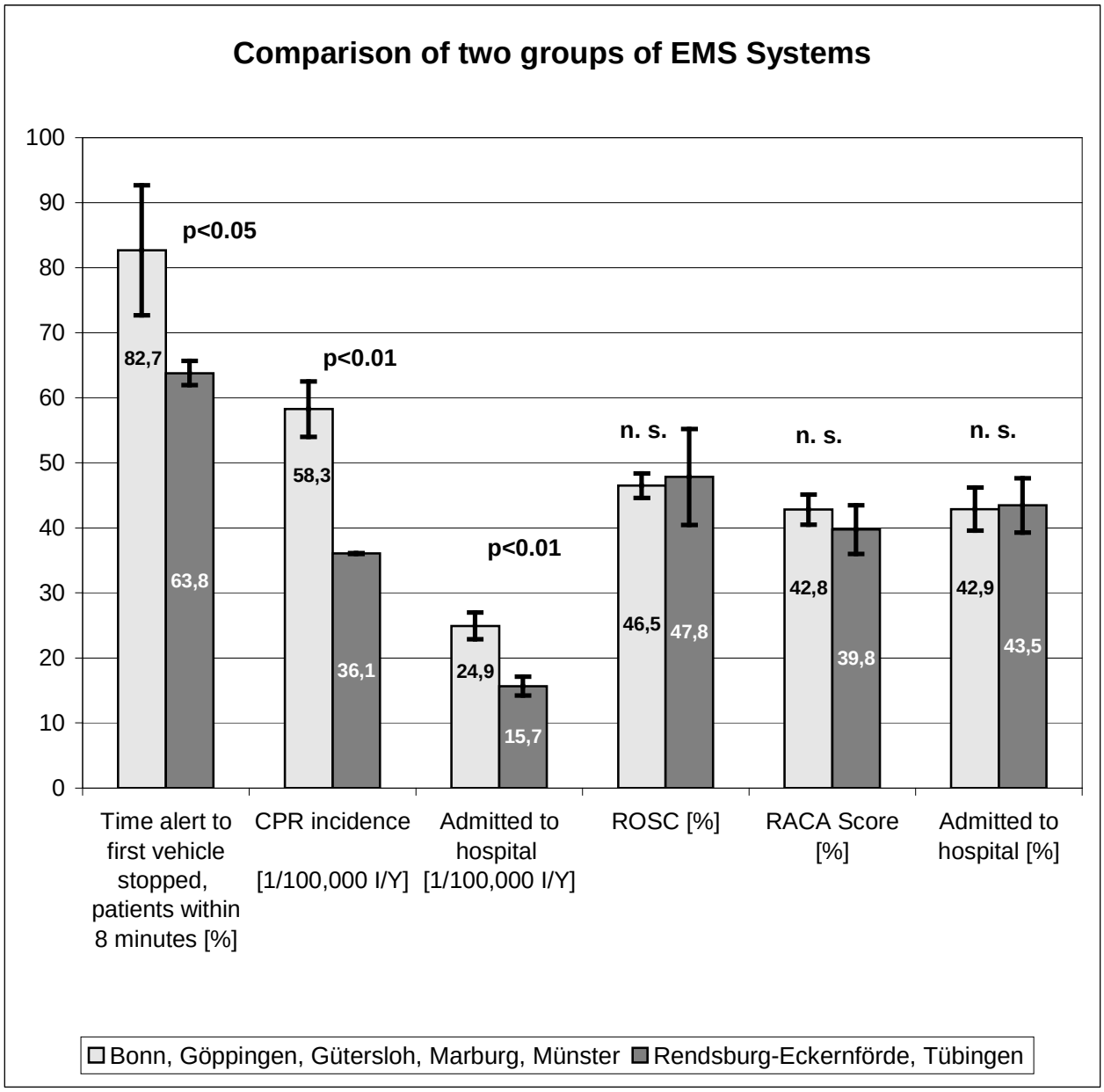

Figure 2: Comparison of two groups of EMS-Systems
grouped by “response time reliability within 8 minutes (achived or not achieved in 70%)”
unweighted means ± SD
p-value calculated by t- test (significant = $p<0.05$)
n. s.: not significant

Danksagung

Besonders bedanke ich mich bei meinem Doktorvater, Herrn Prof. Dr. med. Matthias Fischer, für die Überlassung dieses Themas und die hervorragende Betreuung bei der Erstellung dieser Arbeit. Trotz seiner anspruchsvollen Aufgabe als Chefarzt der Klinik für Anästhesiologie, operative Intensivmedizin und Schmerztherapie an der Klinik am Eichert in Göppingen hatte er stets ein offenes Ohr und stand mir mit Rat und Tat in teils tagelangen Sitzungen zur Seite.

Ebenso bedanke ich mich bei Herrn Dr. med. Jan-Thorsten Gräsner, der ebenfalls zum Gelingen dieser Arbeit beigetragen hat.