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Clinical paper

Adherence to guidelines is associated with improved survival following in-hospital cardiac arrest



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Abstract

Background: Most resuscitation guidelines have recommendations regarding maximum delay times from collapse to calling for the rescue team and initiation of treatment following cardiac arrest. The aim of the study was to investigate the association between adherence to guidelines for cardiopulmonary resuscitation (CPR) after in-hospital cardiac arrest (IHCA) and survival with a focus on delay to treatment.

Methods: We used the Swedish Registry for CPR to study 3212 patients with a shockable rhythm and 9113 patients with non-shockable rhythm from January 1, 2008 to December 31, 2017. Adult patients older than or equal to 18 years with a witnessed IHCA where resuscitation was initiated were included. We assessed trends in adherence to guidelines and their associations with 30-day survival and neurological function. Adherence to guidelines was defined as follows: time from collapse to calling for the rescue team and CPR within 1 min for non-shockable rhythms. For shockable rhythms, adherence was defined as the time from collapse to calling for the rescue team and CPR within 1 min and defibrillation within 3 min.

Results: In patients with a shockable rhythm, the 30-day survival for those treated according to guidelines was 66.1%, as compared to 46.5% among those not treated according to guidelines on one or more parameters, adjusted odds ratio 1.84 (95% CI 1.52–2.22). Among patients with a non-shockable rhythm the 30-day survival for those treated according to guidelines was 22.8%, as compared to 16.0% among those not treated according to guidelines on one or more parameters, adjusted odds ratio 1.43 (95% CI 1.24–1.65). Neurological function (cerebral performance category 1–2) among survivors was better among patients treated in accordance with guidelines for both shockable (95.7% vs 91.1%, <0.001) and non-shockable rhythms (91.0% vs 85.5%, $p < 0.008$). Adherence to the Swedish guidelines for CPR increased slightly 2008–2017.

Abbreviations: CA, cardiac arrest; CPR, cardiopulmonary resuscitation; IHCA, in-hospital cardiac arrest; ROSC, return of spontaneous circulation; VF/pVT, ventricular fibrillation/pulseless ventricular tachycardia; PEA, pulseless electrical activity; SRC, Swedish Resuscitation Council; CAT, cardiac arrest team; ICU/CCU, intensive care unit/coronary care unit; AED, automated external defibrillator; OR, odds ratio.

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Conclusions: Adherence to guidelines was associated with increased probability of survival and improved neurological function in patients with a shockable and non-shockable rhythm, respectively. Increased adherence to guidelines could increase cardiac arrest survival.

Keywords: In-hospital cardiac arrest, Cardiopulmonary resuscitation, Chain of survival, Guidelines

Background

Survival following in-hospital cardiac arrest (IHCA) has increased in recent years¹ but remains low at 15–30%.^{1,2} Multiple factors influence the chance of survival, and some of the most crucial aspects have been summarized in the concept of the chain of survival: early recognition and call for help, early and efficient cardiopulmonary resuscitation (CPR), swift defibrillation and effective post resuscitation care.³ Most guidelines have recommendations regarding these initial and crucial steps to help clinicians take the best possible actions during cardiac arrest (CA) treatment.

The Swedish Resuscitation Council (SRC) has issued guidelines for the treatment of IHCA based on the European Resuscitation Council (ERC)/American Heart Association (AHA) guidelines.⁴ In addition to the ERC/AHA recommendations that patients found in a shockable rhythm should be defibrillated within 3 min the Swedish guidelines state that the delay from CA to calling for the cardiac arrest team (CAT) and to starting of CPR should not exceed 1 min. In 2017, calling for the rescue team and CPR was performed within 1 min and defibrillation was made within 3 min in 80–90% of IHCAs in Sweden.⁵

The associations between an early call for the rescue team, the swift initiation of CPR, immediate defibrillation and survival following CA are well established.^{6–8} However, few studies have specifically investigated whether adherence to resuscitation guidelines is associated with increased chance of survival.

The present study is based on the Swedish Registry for Cardiopulmonary Resuscitation (SRCPR). The aim of the study was to investigate whether adherence to current resuscitation guidelines was associated with an increased chance of 30-day survival, neurological function, and whether adherence increased from 2008 to 2017. Secondly, we quantify how large the potential for improvement in survival could be by comparing survival among patients treated according to guidelines versus not according to guidelines.

Methods

Study population and setting

This is a retrospective registry-based cohort study of all IHCAs registered in the SRCPR from 1 January 2008 to 31 December 2017. All of Sweden's seventy-three hospitals with CATs currently participate in the registry. By the end of 2017, 70 hospitals contributed to reporting data. The registry was designed to comply with the Utstein style of reporting IHCA research.⁹ The registry is a national quality registry and publishes an annual report presenting nationwide characteristics and trends.

The SRCPR contains variables including age, gender, witnessed status, cause of alarm, location of cardiac arrest, electrocardiogram (ECG) monitoring, time to call, time to CPR, time to defibrillation, initial rhythm, treatment characteristics and short-term outcome, as well as 30-day survival and neurologic function pre-arrest and at discharge

(measured by Cerebral Performance Categories, CPC-score). The study complies with the Declaration of Helsinki and was approved by the regional ethical board in Gothenburg, Sweden (reference no 349-16 20160516).

Validation of the SRCPR

For review and validation of the SRCPR, please refer to Supplement S1.

Inclusion criteria

'The study included all patients aged 18 years and older who suffered a witnessed IHCA, between 1 January 2008 and 31 December 2017 and in who resuscitation was started. Further requirements were complete data on initial rhythm, time to call the CAT and time to first shock'. For a review of included and excluded patients see supplemental material.

Definition of exposure groups

Patients were managed according to guidelines if the following criteria were fulfilled: time from CA to calling for the cardiac arrest team (CAT) and to the start of CPR did not exceed 1 min and the time to defibrillation did not exceed 3 min. The last criterion only applied to patients who presented with a shockable rhythm. Patients were categorized as either fulfilling or not fulfilling these criteria. Patients were divided into those presenting *with shockable rhythm or non-shockable rhythms*.

Statistical analysis

Baseline characteristics are presented using means, medians and proportions, with appropriate measurements of dispersion. Hypothesis tests were not computed for baseline features.¹⁰ We assessed trends in adherence to guidelines. This was done by examining the proportion of patients treated according to guidelines from 2008 to 2017. Similarly, we assessed the proportion of patients surviving to 30 days (2008–2017) in relation to adherence to guidelines. Logistic regression was performed for each group to evaluate annual changes in 30-day survival. Differences in survival trends, in relation to adherence to guidelines, were evaluated using an interaction term between calendar year and adherence to guidelines.

The association between guideline adherence and 30-day survival was ultimately evaluated using logistic regression, with adjustment for covariates of clinical importance or displaying varying distributions between the groups at baseline.

We constructed gradient boosting models to estimate the most important predictors of 30-day survival among patients suffering an IHCA with a shockable and non-shockable initial rhythm. The measurements of strength of an association in gradient boosting are denoted as relative influence. Gradient boosting is a machine learning technique that can be used for regression analysis. It uses machine learning techniques and overcomes some of the limitations

of conventional logistic regression models (such as linearity) and can discover nonlinear associations and high-order interactions.¹¹

We also computed odds ratios (ORs) in the entire population by imputing missing data using Multiple Imputation by Chained Equations (MICE) algorithm.¹² One data set was imputed and we compared the obtained ORs with those obtained in the complete case set. MICE is a method of dealing with missing data, and evaluates if the loss of data is likely to have affected the observed results. *p*-Values <0.05 were considered statistically significant. Standard mean difference is the difference between the means for the two groups divided by their standard deviation. Values below 0.1 (10%) are considered inconsequential.

We used R (<https://r-project.org>) for all analyses.

Missing data

For review of missing data and a comparison of cases with complete and incomplete data, please refer to Supplement S1–S7.

Results

Baseline characteristics

A total of 23,460 IHCA patients were entered on the SRCPR between 1 January 2008 and 31 December 2017, of which 12,325 patients met

the study criteria. Of these 3212 had a shockable rhythm and 9113 a non-shockable rhythm.

Shockable rhythms

There was no difference in the mean ages of patients with a shockable rhythm regardless of whether treatment was according to guidelines or not (70.6 v 71.9 years, respectively) (Table 1). The distribution of gender was similar. Those who were not treated according to guidelines were twice as frequently located in regular hospital wards, whereas those who were treated according to guidelines were more frequently located in a coronary care unit (CCU), emergency room (ER), intensive care unit (ICU), operating room (OR), or catheterization laboratory. ECG monitoring was in use among 80.8% of patients who were treated according to guidelines, as compared with 56.0% of patients who were not. Defibrillation was more common in the group treated according to guidelines. All coexisting conditions apart from previous myocardial infarction were more common in patients who were not treated according to guidelines.

Non-shockable rhythms

There was no difference in the mean ages of patients with a non-shockable rhythm regardless of whether treatment was according to guidelines or not (73.3 v 74.1 years respectively) (Table 2). The distribution of gender was similar in relation to guideline status. Patients who were not treated according to guidelines were more frequently located in regular wards. ECG monitoring was more

Table 1 – Baseline characteristics of patients with a shockable rhythm.

	Non-adherence to guidelines	Adherence to guidelines	<i>p</i>	SMD
<i>n</i>	970	2242		
Age (mean (SD))	71.93 (12.26)	70.61 (12.51)	0.006	0.106
Gender = female (%)	312 (32.2)	680 (30.3)	0.321	0.040
Location (%)			<0.001	0.609
Regular ward	419 (43.2)	469 (20.9)		
CCU	162 (16.7)	763 (34.0)		
Catheterization laboratory	79 (8.1)	317 (14.1)		
ER	119 (12.3)	331 (14.8)		
ICU	82 (8.5)	215 (9.6)		
OR	14 (1.4)	20 (0.9)		
Other ward	47 (4.8)	48 (2.1)		
Outpatient ward, lab, radiology	48 (4.9)	79 (3.5)		
ECG monitoring (%)	543 (56.3)	1812 (81.4)	<0.001	0.563
Non-academic hospital (%)	571 (58.9)	1459 (65.1)	0.001	0.128
No CPR before CAT arrival (%)	77 (8.3)	96 (4.3)	<0.001	0.163
Not defibrillated (%)	37 (3.8)	1 (0.0)	<0.001	0.277
Heart failure (%)	393 (44.6)	850 (40.4)	0.039	0.084
Diabetes (%)	260 (28.1)	549 (25.1)	0.096	0.067
Respiratory insufficiency (%)	134 (14.6)	278 (12.9)	0.222	0.050
Myocardial infarction (%)	299 (33.3)	715 (33.5)	0.916	0.006
Cancer (%)	152 (16.7)	264 (12.1)	0.001	0.129
Stroke (%)	103 (11.2)	207 (9.5)	0.170	0.056
Minutes to CPR (median [IQR])	1.00 [0.00, 2.00]	0.00 [0.00, 0.00]	<0.001	0.529
Minutes to call (median [IQR])	2.00 [1.00, 2.00]	0.00 [0.00, 1.00]	<0.001	0.530
Minutes to defibrillation (median [IQR])	4.00 [2.00, 6.00]	1.00 [1.00, 2.00]	<0.001	0.077

SMD: the standardized mean difference is the difference between the means for the two groups divided by their standard deviation. Values below 0.1 (10%) are considered inconsequential (i.e., no difference between the groups). CCU: cardiac care unit; ED: emergency department; ICU: intensive care unit; OR: operation room; CPR: cardiopulmonary resuscitation; CAT: cardiac arrest team.

Table 2 – Baseline characteristics of patients with a non-shockable rhythm.

	Non-adherence to guidelines	Adherence to guidelines	<i>p</i>	SMD
<i>n</i>	2131	6982		
Age (mean (sd))	74.05 (12.82)	73.31 (13.03)	0.021	0.058
Gender = female (%)	898 (42.1)	2872 (41.1)	0.424	0.020
Location (%)			<0.001	0.405
Regular ward	1319 (61.9)	3193 (45.7)		
Catheterization laboratory	74 (3.5)	341 (4.9)		
CCU	231 (10.8)	1337 (19.1)		
ER	159 (7.5)	904 (12.9)		
ICU	108 (5.1)	581 (8.3)		
OR	40 (1.9)	147 (2.1)		
Other ward	77 (3.6)	129 (1.8)		
Outpatient ward, lab, radiology	123 (5.8)	350 (5.0)		
ECG monitored (%)	813 (38.6)	3892 (56.2)	<0.001	0.357
Non-academic hospital (%)	1235 (58.0)	4526 (64.8)	<0.001	0.141
No CPR before alarm-group arrival (%)	205 (9.8)	360 (5.2)	<0.001	0.175
Not defibrillated (%)	1835 (87.2)	6069 (87.9)	0.365	0.023
Heart failure (%)	672 (34.2)	2197 (34.0)	0.890	0.004
Diabetes (%)	535 (25.9)	1904 (27.9)	0.074	0.046
Respiratory insufficiency (%)	523 (25.7)	1582 (23.6)	0.054	0.049
Myocardial infarction (%)	446 (22.2)	1502 (22.6)	0.680	0.011
Cancer (%)	465 (22.7)	1344 (20.0)	0.008	0.066
Stroke (%)	295 (14.4)	823 (12.1)	0.008	0.066
Minutes to CPR (median [IQR])	1.00 [0.00, 2.00]	0.00 [0.00, 0.00]	<0.001	0.152
Minutes to call (median [IQR])	2.00 [2.00, 3.00]	0.00 [0.00, 1.00]	<0.001	0.162

SMD: the standardized mean difference is the difference between the means for the two groups divided by their standard deviation. Values below 0.1 (10%) are considered inconsequential (i.e., no difference between the groups). CCU: cardiac care unit; ED: emergency department; ICU: intensive care unit; OR: operation room; CPR: cardiopulmonary resuscitation; CAT: cardiac arrest team.

Table 3 – 30-Day survival and CPC-score among patients with a shockable rhythm.

	Non-adherence to guidelines	Adherence to guidelines	<i>p</i>	SMD
<i>n</i>	970	2242		
Survived = yes (%)	451 (46.5)	1483 (66.1)	<0.001	0.404
CPC 1 (%)	296 (75.1)	1112 (85.0)	<0.001	
CPC 2	63 (16.0)	140 (10.7)		
CPC 3	27 (6.9)	44 (3.4)		
CPC 4	5 (1.3)	10 (0.8)		
CPC 5	3 (0.8)	3 (0.2)		

SMD: the standardized mean difference is the difference between the means for the two groups divided by their standard deviation. Values below 0.1 (10%) are considered inconsequential (i.e., no difference between the groups). CPC: cerebral performance category.

Table 4 – 30-Day survival and CPC-score among patients with a non-shockable rhythm.

	Non-adherence to guidelines	Adherence to guidelines	<i>p</i>	SMD
<i>n</i>	2131	6982		
Survived = yes (%)	341 (16.0)	1590 (22.8)	<0.001	0.172
CPC 1 (%)	191 (67.5)	974 (74.3)	<0.008	
CPC 2	51 (18.0)	219 (16.7)		
CPC 3	32 (11.3)	97 (7.4)		
CPC 4	9 (3.2)	15 (1.1)		
CPC 5	0 (0.0)	6 (0.5)		

SMD: the standardized mean difference is the difference between the means for the two groups divided by their standard deviation. Values below 0.1 (10%) are considered inconsequential (i.e., no difference between the groups). CPC: cerebral performance category.

Table 5 – Comparison of adjusted ORs for 30-day survival between complete cases and cases with imputed data.

Initial rhythm	Variable	Complete cases			Imputed data		
		OR	LL	UL	OR	LL	UL
Shockable	Overall	<1.838	1.524	2.217	1.732	1.496	2.004
Shockable	Men	1.686	1.344	2.115	1.606	1.345	1.917
Shockable	Women	2.245	1.594	3.17	1.988	1.532	2.582
Shockable	Age <65 years	1.333	0.886	1.995	1.204	0.884	1.632
Shockable	Age 65 years or older	2.022	1.632	2.507	1.923	1.625	2.276
Non-shockable	Overall	1.427	1.237	1.651	1.334	1.182	1.507
Non-shockable	Men	1.417	1.176	1.714	1.348	1.151	1.583
Non-shockable	Women	1.449	1.159	1.822	1.323	1.097	1.601
Non-shockable	Age <65 years	1.208	0.925	1.586	1.204	0.96	1.514
Non-shockable	Age 65 years or older	1.53	1.289	1.823	1.394	1.208	1.613

UL = upper limit, LL = lower limit. The adjusted odds ratio (95% CI) for 30-day survival among patients treated according to guidelines among shockable and non-shockable rhythms stratified by sex and age, complete cases and imputed data. ORs obtained in the imputed data set were in line with those obtained in the complete data set.

common in patients treated according to guidelines (55.7% vs 38.2%). There were no marked differences in coexisting conditions in relation to guideline status

Adherence to guidelines and 30-day survival

The over-all 30-day survival rate was 31.4% ($n=12,325$). Among survivors > 90% had a CPC-score of 1–2. In patients with a shockable rhythm, comparing treatment according to guidelines to without, 30-

day survival was 66.1% v 46.5% (OR 1.88, 95% CI 1.56–2.26). In patients with a non-shockable rhythm, comparing treatment according to guidelines to without, 30-day survival was 22.8% v 16.0% (OR 1.43, 95% CI 1.25–1.67). Neurological function (CPC 1–2) among survivors was better among patients treated in accordance with guidelines for both shockable (95.7% vs 91.1%) and non-shockable rhythms (91.0% vs 85.5%) (Tables 3 and 4). Stratification of patients showed that, among patients with a shockable rhythm, women and patients >65 years had the greatest benefit of treatment in

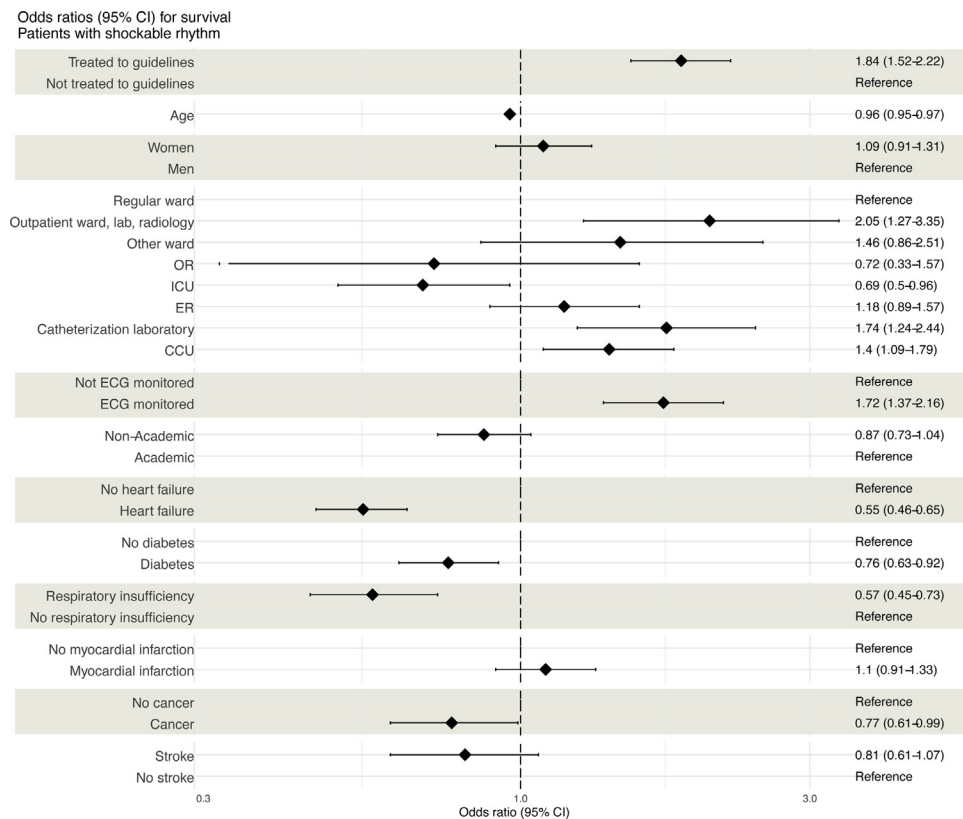


Figure 1 – (A) Forest plot with the adjusted ORs for 30-day survival among patients with a shockable rhythm for multiple variables including age, sex, ward type, monitoring, academic vs non-academic hospital and multiple comorbidities. (B) Forest plot with the adjusted ORs for 30-day survival among patients with a non-shockable rhythm for multiple variables including age, sex, ward type, monitoring, academic vs non-academic hospital and multiple comorbidities.

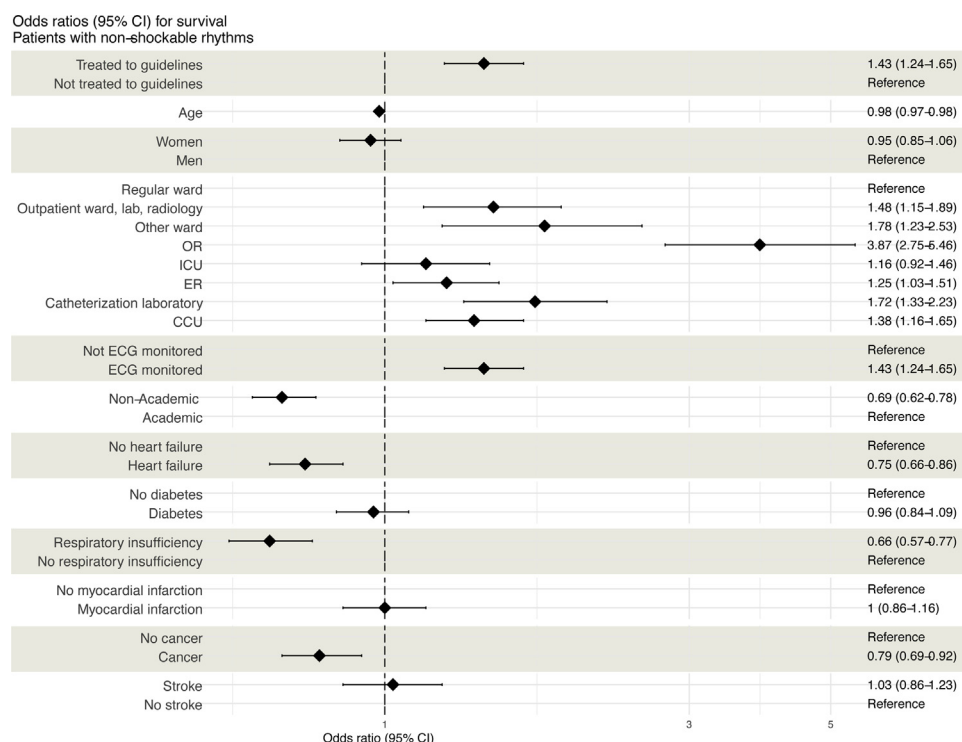


Figure 1 – (continued).

accordance with guidelines (adjusted OR 2.25 (CI 1.59–3.17 and 2.02 (CI 1.63–2.51), respectively). For non-shockable rhythms, again women and patients >65 years had the greatest benefit of treatment in accordance with guidelines (adjusted OR 1.45 (CI 1.16–1.82 and 1.53 (CI 1.29–1.82)) but the relative benefit was smaller compared to shockable rhythms (Table 5a and b). ORs obtained in the imputed data set were in line with those obtained in the complete case data set (Table 5).

Independent predictors of survival

After adjusting for covariates, multiple factors including age, comorbidities, location of cardiac arrest and hospital type were associated with survival (Fig. 1A and B). The relative influence of the most important predictors of survival is shown in Supplement Figs. S8a and b.

Trends in adherence to guidelines and survival

Adherence to guidelines increased from 68.5% in 2008 to 69.7% in 2017 for patients with shockable rhythms. For patients with non-shockable rhythms adherence to guidelines increased from 73.1% in 2008 to 78.6% in 2017. Please see Fig. 2A–D.

Patients with a shockable rhythm: The linear trend indicated an annual 0.73% increase in the probability of survival among patients who were treated according to guidelines. The corresponding figure for patients not treated according to guidelines was 0.81%.

Patients with a non-shockable rhythm: The linear trend indicated an annual 0.45% increase in the probability of survival among patients who were treated according to guidelines. The corresponding figure for patients not treated according to guidelines was 1.51%.

Discussion

In this large population-based study of IHCA in Sweden, we found that adherence to current resuscitation guidelines was associated with an increased chance of 30-day survival and improved neurological function. We also found that adherence to guidelines increased slightly in the study period 2008–2017.

Adherence to guidelines and survival

Our results show that adherence to guidelines increased the probability of survival at 30 days and neurological function among all patients, regardless of initial rhythm. Adherence to guidelines was the single most important modifiable factor (among patients with a shockable rhythm) and second most important factor (among patients with a non-shockable rhythm) as shown in the relative importance plots. Although other factors can influence outcome (for example age, comorbidities, location) they may not be amenable to being influenced. However, adherence to guidelines along with monitoring of patients is modifiable factors and thereby has a potential for improvement. It is worth noting that survival increased among all patients but the absolute difference between patients treated and not treated according to guidelines remained substantial over time. The mechanism behind the general increase in survival seen over time, regardless of adherence to guidelines, remains unknown. It is possible that several factors including quality of chest compressions, improved attitude towards CPR and selection of cases for successful resuscitation contribute. In this study, it is important to stress that changes in survival over time was not the major target to address.

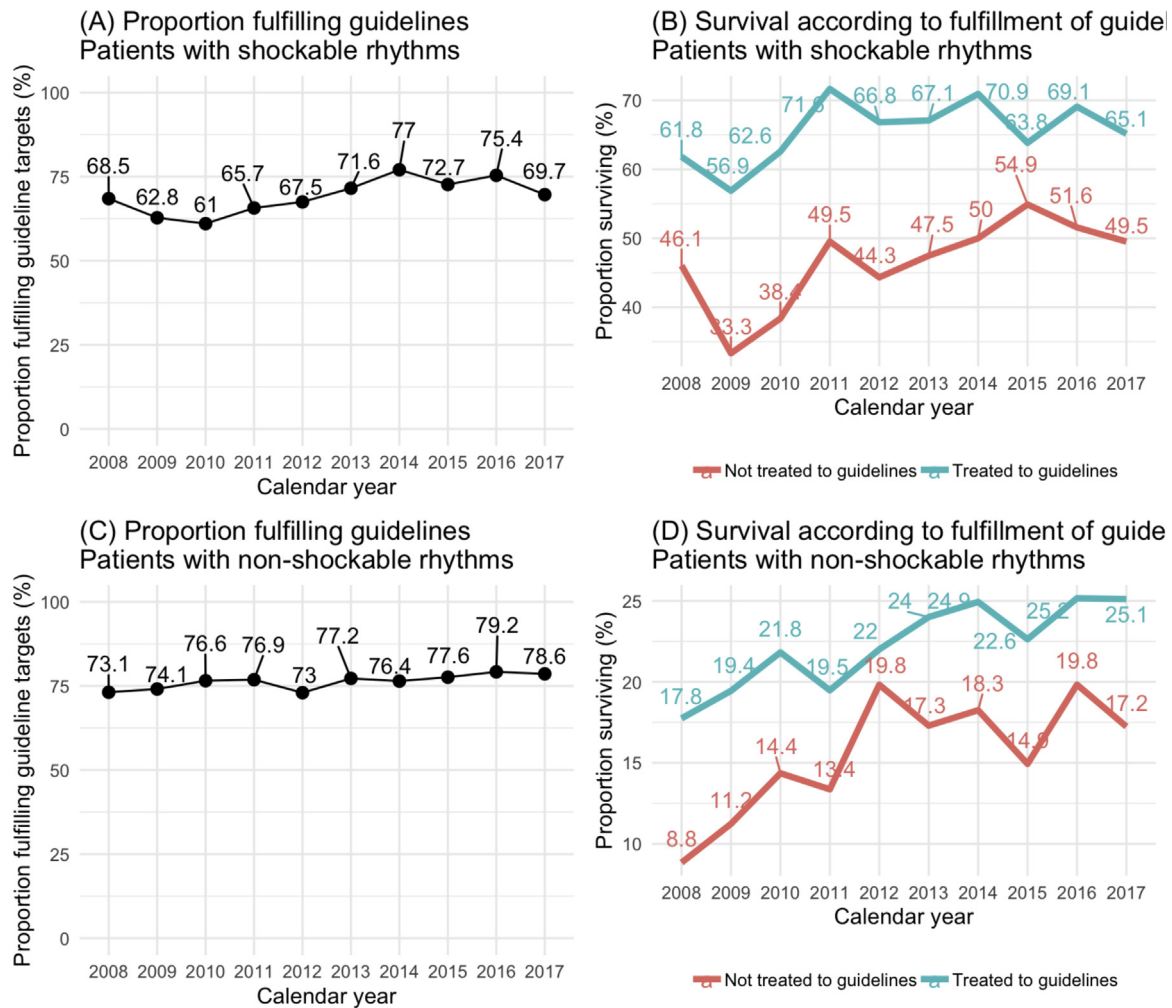


Figure 2 – Adherence to guidelines and survival. (A and C) The proportion of patients treated according to guidelines over time (2008–2017) for shockable (A) and non-shockable (C) rhythms. (B and D) The survival rate over time (2008–2017) for shockable and non-shockable rhythms comparing patients treated according to guidelines with those not treated according to guidelines.

Patients treated according to guidelines constitute 70–75% of all patients and they had a mean 30-day survival rate that was 19.1 and 6.8 percentage points higher than that of patients not treated according to guidelines for shockable and non-shockable rhythms, respectively. It is incorrect to assume that moving patients from the “not treated to guidelines” category to the “treated to guidelines” category would increase their chance of survival by 6.7–19.1%, but the absolute difference between the two groups indicate that there are substantial gains to be made by increasing adherence. McEvoy et al.¹³ showed that adherence to the 2005 ACLS protocol was associated with an increased chance of ROSC, while divergence from protocol (wrong action, wrong timing or omission) was significantly associated with a reduced chance of ROSC. In a similar study Honarmand et al.¹⁴ studied 160 resuscitation events following IHCA and found that a larger number of deviations from ACLS guidelines was associated with a reduced chance of ROSC but there was no association with survival to hospital discharge. Anderson et al.¹⁵ showed that, on a hospital level, greater adherence to prespecified process of care measures was associated with survival rate and

neurologic outcome. Interestingly, our results showed that it was the patients with a shockable rhythm that benefited the most from adherence to guidelines (OR for survival 1.88 v 1.43). This may reflect the fact that some of the patients were possibly defibrillated within less than 2 min, for example those in the CCU or cath lab. It has previously been shown that survival decreases significantly when the time from collapse to defibrillation exceeds 2 min.⁸

Barriers to adherence to guidelines

What are the barriers to detect all CAs immediately, calling for help and initiating CPR within 1 min and defibrillation within 3 min? In theory, the identification of the deteriorating patient at increased risk of CA should reduce the risk of CA and different track-and-trigger systems have been suggested, but to date they have failed to prospectively show a survival benefit.¹⁶ The time from collapse to the recognition of CA, calling for the rescue team and witnessed status has previously been shown to be independently associated with survival.² In the present study, only witnessed IHCAs were included in the analysis. ECG-

monitored IHCA should by definition be recognized immediately and the time to call should be minimized. The number of staff and their individual and collective knowledge of cardiac arrest care vary between wards and hospitals and this could explain some of the variation seen in delays from collapse to action. This is further emphasized by the fact that survival decreases outside office hours possibly due to less staff on the hospital wards. It has previously been shown that CAs on specific wards with high levels of expertise in the CA field, such as the CCU, have an increased chance of survival.² Our results show that adherence to guidelines was generally better on high-resource wards such as the ICU/CCU/cath lab as compared to regular wards. To our knowledge, this has not been reported before. It has been shown previously⁵ that the time intervals from collapse to 1) calling for the rescue team, 2) starting CPR and 3) defibrillation was significantly longer in general wards compared with the ICU/CCU/cath lab/OR. Surprisingly, adherence to guidelines was lower at academic hospitals compared with non-academic hospitals, perhaps reflecting logistical barriers to initiation of treatment. Even so, survival was higher among patients treated at academic hospitals with a non-shockable rhythm (and not statistically different for patients with a shockable rhythm).

When it comes to the barriers to initiating CPR, the patients location (in a patient room vs an elevator) and position, a lack of adequate equipment (CPR board), a lack of education are a few of the reasons why CPR might not be initiated immediately.

Defibrillation is the appropriate treatment in patients with a shockable rhythm, but in 20% of cases there is a delay of more than 3 min.⁵ A lack of AEDs at strategic locations inside the hospital and inadequate training in how to operate an AED are two possible explanations of this shortcoming.

Trends in adherence 2008–2017

Adherence to guidelines was slightly higher for patients with a non-shockable rhythm (mean 76.3%) compared with shockable rhythms (mean 69.2%), adherence to guidelines increased slightly in 2008–2017. Previous studies have shown that ACLS training improves hospital employees' theoretical knowledge of CPR,¹⁷ improves practical skills when assessed in CA simulation training¹⁸ and the presence of ACLS-trained instructors is associated with an increased chance of ROSC and 1-year survival.¹⁹ Although never shown, it is possible that improved ACLS training increases the likelihood of adherence to CPR guidelines, and this would support continued emphasis on CPR training.

Limitations

Patients found in a shockable rhythm in the CCU, ICU and the cath lab are sometimes successfully defibrillated without calling for the rescue team. We therefore assume that there may be under-reporting of IHCA and an underestimation of the importance of adherence to guidelines since many CAs in above locations are successfully resuscitated.

The patient cohort was divided according to the initial rhythm. The registry does not contain information on rhythm change during resuscitation, a factor known to have an effect on outcome.

Furthermore, the current study only investigated the effect of guidelines compliance specifically delays in time to call, start of CPR and defibrillation. Other factors, e.g., quality of chest compressions, which also influence outcomes were not addressed.

Finally, it is likely that there is some variation in the accuracy of the estimated time intervals from collapse to calling for the rescue team, the initiation of CPR and to some degree to defibrillation, and this should be acknowledged.

Conclusion

Increased adherence to guidelines has the potential to further improve IHCA survival as demonstrated by the substantial difference in survival rates between patients treated and not treated according to guidelines and the independent association with 30-day survival and improved neurological function. Continued focus on CPR education and the retention of acquired skills are suggested as means of achieving further improvements. Considering the large amount of resources spent on developing national and international guidelines, more evaluation of their impact on quality of care and survival is needed.

Authors' contributions

Fredrik Hessulf: Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing.

Johan Herlitz: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Validation, Visualization, Writing – review & editing.

Araz Rawshani: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Validation, Visualization, Writing – review & editing.

Solveig Aune: Conceptualization, Methodology, Visualization, Writing – review & editing.

Johan Israelsson: Methodology, Visualization, Writing – review & editing.

Marie-Louise Södersved-Källestedt: Methodology, Visualization, Writing – review & editing.

Per Nordberg: Methodology, Visualization, Writing – review & editing.

Peter Lundgren: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Validation, Visualization, Writing – review & editing.

Johan Engdahl: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Validation, Visualization, Writing – review & editing.

Ethical approval and consent to participate

The study was approved by the regional ethical board in Gothenburg, Sweden, which waived the need for informed consent due to the retrospective design of the study.

Availability of data and material

The data sets used and/or analyzed during the current study will be available from the corresponding author in response to reasonable requests.

Conflict of interest

The authors declare that there are no conflicts of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:10.1016/j.resuscitation.2020.07.009.

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