Clinical paper

Changes over time in 30-day survival and the incidence of shockable rhythms after in-hospital cardiac arrest - A population-based registry study of nearly 24,000 cases

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Abstract

Objective: To determine changes over time in 30-day survival and the incidence of shockable rhythms after in-hospital cardiac arrest, from a countrywide perspective.

Methods: Patient information from the Swedish Registry for Cardiopulmonary Resuscitation was analysed in relation to monitoring level of ward and initial rhythm. The primary outcome was defined as survival at 30 days. Changes in survival and incidence of shockable rhythms were reported per year from 2008 to 2018. Also, epidemiological data were compared between two time periods, 2008 – 2013 and 2014 – 2018.

Results: In all, 23,196 unique patients (38.6% female) were included in the study. The mean age was 72.6 (SD 13.2) years. Adjusted trends indicated an overall increase in 30-day survival from 24.7% in 2008 to 32.5% in 2018, (on monitoring wards from 32.5% to 43.1% and on non-monitoring wards from 17.6% to 23.1%). The proportion of patients found in shockable rhythms decreased overall from 31.6% in 2008 to 23.6% in 2018, (on monitoring wards from 42.5% to 35.8 % and on non-monitoring wards from 20.1% to 12.9%). Among the patients found in shockable rhythms, the proportion of patients defibrillated before the arrival of cardiac arrest team increased from 71.0% to 80.9%.

Conclusions: In an 11-year perspective, resuscitation in in-hospital cardiac arrest in Sweden was characterised by an overall increase in the adjusted 30-day survival, despite a decrease in shockable rhythms. An increased proportion, among the patients found in a shockable rhythm, who were defibrillated before the arrival of a cardiac arrest team may have contributed to the finding.

Keywords: In-hospital cardiac arrest, Cardiopulmonary resuscitation, Defibrillation, Survival, Epidemiology

Abbreviations: CPR, cardiopulmonary resuscitation; IHCA, in-hospital cardiac arrest; IQR, interquartile ranges; OHCA, out-of-hospital cardiac arrest; SD, standard deviation; SMD, standardised mean difference.

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Introduction

A substantial proportion of deaths related to cardiac disease occur in hospitals. The mortality rate in patients affected by cardiac arrest in healthcare units is high, and survival is strongly dependent on the location of the event within the hospital.\textsuperscript{1,2} The survival rate of patients on wards with monitoring facilities can be up to twice as high as it is on wards without monitoring facilities.\textsuperscript{3} More advanced surveillance facilitates the prompt recognition of cardiac arrest, resulting in a larger proportion of witnessed cardiac arrests and a shorter time from collapse to treatment.\textsuperscript{4}

In a previous study conducted in a single tertiary hospital, we concluded that the treatment of in-hospital cardiac arrest (IHCA) was characterised by a more rapid start of treatment, over 20 years.\textsuperscript{3} There was a significant increase in 30-day survival, from 44\% to 56\%, on wards with monitoring facilities. On wards without these facilities, there was a substantial decrease in shockable rhythms over time, from 46\% to 26\%. There is a knowledge gap with regard to changes in characteristics and outcome after IHCA on monitoring and non-monitoring wards in recent decades from a nationwide perspective.

The aim of this study was therefore to explore further whether similar changes had taken place in a countywide perspective in Sweden. The primary objective was to describe changes in 30-day survival and changes in the proportion of patients found in shockable rhythms after IHCA in Sweden between 2008 and 2018.

In order to explore possible mechanisms behind eventual changes in survival, we also describe patient characteristics and various aspects of resuscitation during two time periods. The latter data represent secondary objectives and should only be regarded as hypothesis-generating.

Methods

The Swedish Registry for Cardiopulmonary Resuscitation started in 2005 and is a national quality register with the highest degree of certification, including IHCA and out-of-hospital cardiac arrests (OHCA). The registry employs standardised Utstein-style definitions for all variables and outcomes.\textsuperscript{5} At participating hospitals, designated personnel are responsible for the registration of the information associated with cardiac arrest, in a secure online system. The data are collected in two steps, at the initial cardiac arrest event and more than 30 days later. In the first step, baseline information, e.g. location and time of the event, initial rhythm, delays to various actions, treatment given and survival after resuscitation, is prospectively recorded by a nurse or physician attending the event. In the second step, follow-up data, e.g. co-morbidities, probable aetiology of the cardiac arrest and 30-day survival data, are retrospectively recorded by a nurse or physician associated with the register.

Study design and population

We analysed all IHCA registered in the Swedish Registry for Cardiopulmonary Resuscitation, from 1 January 2008 to 31 December 2018. In all, 71 of 73 (97\%) hospitals with cardiac arrest teams in Sweden participated. The number of participating hospitals increased from 45 in 2008 to 71 in 2018. The hospitals ranged in size from general primary-level hospitals with fewer than 50 beds to tertiary-level hospitals with more than 800 beds. The inclusion criterion was a cardiac arrest in which CPR or defibrillation was attempted. Patients younger than 18 years of age were excluded.

The study population was subdivided into four groups according to monitoring facilities on the ward (non-monitoring vs monitoring wards) and initial rhythm (shockable vs non-shockable rhythm) at the time of the cardiac arrest. Each group was further stratified in two time periods, 2008–2013 and 2014–2018 in order to get two groups with equal size in terms of the number of participants. Epidemiological data, including age, gender, co-morbidities (myocardial infarction, heart failure, stroke, diabetes, respiratory insufficiency, cancer and renal dysfunction), time, location and circumstances of the arrest, treatment given and delays, survival immediately after the resuscitation attempt, survival at 30 days, one year and during long term follow-up, were analysed and compared between groups.

Definition of variables

“Cardiac arrest” was defined as the need for CPR or defibrillation. The term “in-hospital” refers to all cardiac arrest occurring within the hospital perimeter. “CPR”, including basic life support and advanced life support, is performed according to the European Resuscitation Council guidelines.\textsuperscript{6} When a cardiac arrest is identified, medical staff call an emergency telephone number and a cardiac arrest team, led by trained healthcare professionals, is immediately activated.

Healthcare facilities were defined as “academic” or “non-academic” hospitals depending on whether there was affiliation to a medical school or a degree-granting university. Ten of the participating hospitals were academic hospitals. Healthcare units were divided into wards with “monitoring” and “non-monitoring” facilities, depending on the availability of continuous surveillance. Monitoring wards include intensive care units, coronary care units, coronary angiography laboratories, operating theatres and emergency departments. The remaining wards, including intermediate wards, are defined as non-monitoring wards. The first documented rhythm of the cardiac arrest is divided into “shockable” and “non-shockable” rhythm, based on the indication for defibrillation or not.\textsuperscript{7} Previous medical history was obtained from the patients’ medical records, based on formerly specified definitions. A prior history of myocardial infarction refers to a myocardial infarction preceding the arrest by 72 h or more. Heart failure includes all forms of heart failure, except for pulmonary oedema within one hour before the arrest. Previous stroke comprises both haemorrhagic and ischaemic stroke before the current hospitalisation period. Diabetes includes both type 1 and type 2 diabetes. Respiratory insufficiency includes all types of respiratory insufficiency with or without the need for a ventilator. Cancer refers to any previous or present malignancy, regardless of severity. Renal dysfunction was defined as an estimated glomerular filtration rate (eGFR) of <60 mL/min using the revised Lund-Malmö formula.\textsuperscript{8}

Validation of the reported data

Validation has been performed at 34 hospitals, comprising a total of 1338 patients, where register data were compared with hospital case record data. From the premises of this validation, information about the place of IHCA and survival was consistent with source data in 99\% of cases. Similarly, information about witnessed status was consistent with source data in 96\% of cases, as well as information on the type of the first rhythm, which was consistent with source data in 94\% of cases.
Statistical methods

Baseline characteristics are reported using means and medians, along with standard deviations (SD) and interquartile ranges (IQR), respectively. Standardised mean differences (SMD) were used to compare groups, and logistic regression was used to calculate the adjusted probability of 30-day survival. Adjustment was made for age, sex, and calendar year. The Kaplan-Meier estimator was used for delineating survival curves in relation to calendar year, and the log-rank test was used to test for differences in survival in relation to calendar year. Due to a relatively low frequency of missing data, complete case analyses were performed throughout the study. Data on age, sex, calendar year and type of ward was complete. Data on initial rhythm was missing in 7.6%, which we deemed as acceptable. Also, previous quality controls have not rejected the assumption that data are missing at random. All analyses were performed in R version 4.0.2 (R Foundation for Statistical Computing).

Ethical approval

Approval was obtained from the ethical review board at the University of Gothenburg, Sweden, 2017-11-06, reference number 692-17.

Results

During the study period, 23,186 unique patients suffered a total of 23,950 IHCA. A total of 54.9% of IHCA occurred on wards without monitoring facilities. A shockable rhythm at the initial electrocardiogram recording was found in 26.3% of the total cases. Men collapsed more often in a shockable rhythm compared with women, with a proportion of 69.5%. Overall 30-day survival for the entire study population was 30.0%, with higher survival for men (31.3%) compared with women (27.9%). The overall mean age was 72.6, SD 13.2 years, with patients on non-monitoring wards being older; 74.0, SD 13.0 years, compared with; 70.9, SD 13.3 years, on the monitoring wards. Patients found in a shockable rhythm were younger; 70.6, SD 12.6 years, than those found in a non-shockable rhythm; 73.3, SD 13.3 years.

Various aspects of IHCA are described, trend changes by year are demonstrated for adjusted survival at 30 days, overall and depending on the monitoring level of the ward and the initially registered rhythm, including the proportion of patients found in a shockable rhythm. Furthermore, changes in patient characteristics and various aspects of resuscitation between two time periods are compared depending on the monitoring level of the ward and the initially registered rhythm.

Survival

The overall adjusted 30-day survival increased from 24.7% in 2008 to 32.5% in 2018. Among patients suffering an IHCA on monitoring wards, the adjusted 30-day survival increased from 33.5% in 2008 to 43.5% in 2018, and among patients suffering an IHCA on non-monitoring wards, the adjusted 30-day survival increased from 17.6% in 2008 to 23.1% in 2018 (Fig. 1). The adjusted 30-day survival increased markedly both among patients with a shockable and a non-shockable rhythm, from 53.7% in 2008 to 64.9% in 2018 for shockable rhythm, and from 14.2% in 2008 to 22.0% in 2018 for non-shockable rhythm (Fig. 2). Also, the adjusted 30-day survival in both academic and in non-academic hospitals increased (Fig. 3). The increased adjusted 30-day survival appeared to be more marked in younger
patients than in the elderly, and among patients >85 years of age, the adjusted 30-day survival did not change at all (Fig. 4).

Finally, not included in the original aim and thus presented as supplementary data, in a follow-up up to 10 years, it was demonstrated that among patients suffering an IHCA, the long term survival prognosis is poor regardless of calendar year of cardiac arrest and even worse for patients suffering the arrest on non-monitoring wards (Supplementary Fig. 1).

**Proportion of patients found in shockable rhythms**

The proportion of patients found in shockable rhythms decreased overall from 31.6% in 2008 to 23.6% in 2018. Among patients suffering an IHCA on monitoring wards, the proportion of patients found in shockable rhythms decreased from 42.5% to 35.8%, and among patient suffering an IHCA on non-monitoring wards, the proportion decreased from 20.1% to 12.9% (Fig. 5).

**Patient characteristics and various aspects of resuscitation**

When looking at changes in relation to monitoring level of the ward, two changes of presumed clinical relevance (standardised mean difference (SMD) more or equal to 0.1) appeared; (1) there was an increase in the previous history of respiratory insufficiency on non-monitoring wards over time. (2) There was also a decrease in the use of buffering agents on both types of wards (Supplementary Table 1).

When looking at changes in relation to the first recorded rhythm, we found that the proportion of patients found in shockable rhythms and defibrillated before the arrival of the cardiac arrest team, increased over time from 71.0% to 80.9%. Furthermore, the proportion of patients with a previous history of heart failure decreased among patients found in a shockable rhythm. In contrast, patients with a previous history of respiratory insufficiency increased among patients found in a non-shockable rhythm. Finally, the use of buffering agents decreased over time, independent of the initial rhythm (Supplementary Table 2).

**Discussion**

In this study of all in-hospital cardiac arrests in the Swedish Registry of Cardiopulmonary Resuscitation between 2008 and 2018, the most crucial finding was the increased 30-day survival in all facilities, regardless of monitoring level of the ward and the initial rhythm, despite shockable rhythms decreasing over time. An increased proportion of patients defibrillated before the arrival of the cardiac arrest team, when found in a shockable rhythm, may have contributed to the improved survival rates. Presumably, other causes are involved as well.

The entire study group was characterised by a relatively high age (mean age >70 years of age) at the occurrence of cardiac arrest, even though “do not attempt resuscitation” orders have been reported to be relatively high among the elderly. In agreement with previous studies, we found an inverse relationship between survival and age. Several studies have indicated a clear association between increasing age and poor outcome and vice versa. However, recent research suggests that biological rather than chronological age might be a better predictor of mortality.

Our study is not the first to report on an increase in survival after IHCA in a countrywide perspective. From the Get With The Guidelines-Resuscitation (GWTS-R) registry, it was recently reported that the survival after IHCA had increased over time in a 17-year perspective. Similarly to our findings, their results suggested a more marked increase in survival in younger patients.

It is only possible to hypothesise about the mechanisms accountable for an increase in the 30-day survival trend. A possible explanation could be a change in the patients co-morbidity. However, the only relevant changes in co-morbidity was a decrease in heart failure among the patients found in a shockable rhythm, as well as an increase in the history of respiratory insufficiency among patients found in a non-shockable rhythm or suffering an IHCA on a non-monitoring ward. Although, in previous studies, a history of respiratory insufficiency has been strongly associated with reduced survival after IHCA. Conversely, the change in co-morbidity observed in our study would, at least in one aspect, tend to decrease rather than increase the survival rate after IHCA. The decrease in heart failure over time would, on the other hand, tend to improve outcome.

The delay from collapse to the start of CPR and to defibrillation is both crucial and inversely proportional to the chance of survival in cardiac arrest. We did not find any marked changes over time, neither in the proportion of patients receiving CPR before the arrival of the cardiac arrest team nor in the delay from collapse to start of CPR.
However, the proportion of patients found in a shockable rhythm and defibrillated before the arrival of the cardiac arrest team increased, which may have contributed to the increased survival. We believe the best explanation for this improvement is greater awareness and CPR training of the staff. However, the delay from collapse to defibrillation did not change over time.

One notable and to some extent puzzling observation was the marked decrease in shockable rhythms in the event of cardiac arrest, primarily on non-monitoring wards. A similar finding has been reported in a single tertiary hospital, and it has moreover been repeatedly observed among patients with OHCA. The underlying mechanism remains unexplained, but it is possible to speculate about an association with a decreased cardiac aetiology in cardiac arrest due to a number of factors, including improved cardiovascular pharmacological treatment, the use of early revascularisation in acute myocardial infarction and more frequent implantation of internal cardioverter defibrillators.

The survival of patients found in a shockable rhythm was high, more than half survived to one year (56.8%) in the later time period, and if the event occurred on a ward with monitoring facilities, a full 64.2% survived to one year. Even if the one-year survival rate for patients suffering a non-shockable cardiac arrest was substantially lower (16.6%), the chance of survival increased considerably during the study period. In this context, it should be recognised that the prognosis after a cardiac arrest with a non-shockable rhythm is significantly worse, as previously stated.

Taking other results into consideration, we presume that the improved 30-day survival after IHCA could be explained by the generally better-trained staff, resulting in a higher proportion of patients defibrillated before the arrival of the cardiac arrest team. Enhanced quality of CPR and a more positive attitude to CPR among healthcare professionals may be other contributory factors. Another possibility is an increased selection of the population through “do not attempt resuscitation” orders, excluding an increasing number of elderly individuals and patients with multiple disorders, from resuscitation. Finally, a more assertive approach to finding and treating reversible causes of the cardiac arrest through invasive vascular procedures, besides more refined post-arrest critical care, might also be part of the reason.

The reported 30-day survival in Sweden may be regarded as relatively high. There are not many national reports regarding survival after IHCA in Europe. A report from the United Kingdom found an overall unadjusted survival to hospital discharge of 18.4% and a recent report from the Danish registry of IHCA reported an unadjusted 30-day survival of 27.8%.

In order to broaden the perspective, we finally present long term survival of our study groups. There appear to be relatively even declines in long term survival, regardless of monitoring level of the ward. Such a finding should be related to the relatively high age of the patients at the time of cardiac arrest.

Study strengths and limitations

The study was population-based with well-defined inclusion/exclusion criteria and considerable sample size. Basically, all adult patients suffering an IHCA in whom resuscitation was attempted in the majority of hospitals in Sweden, during a period of 11 years, were prospectively and retrospectively recorded. Treatment interventions and survival from IHCA have only been described from a national perspective in a few countries in Europe. All the variables included in the analyses were strictly defined a priori.

In spite of this, limitation to a single country makes extrapolation to other healthcare systems and hospitals outside Sweden difficult. As with all registry studies, there was missing information. Finally, there are uncertainties regarding the time intervals that were measured.

Conclusions

In an 11-year perspective, resuscitation in in-hospital cardiac arrest in Sweden was characterised by an overall increase in the adjusted 30-day survival, both on monitoring and non-monitoring wards, despite a decrease in shockable rhythms, particularly on non-monitoring wards. An increased proportion, among the patients found in a shockable rhythm, who were defibrillated before the arrival of a cardiac arrest team may have contributed to the finding.

Authors’ contributions

All authors have directly participated in the planning and implementation of the study, and in the analyses and interpretation of data. All authors have read and approved the final version of the submitted manuscript. There are no related manuscripts or abstracts, published or unpublished, by any of the authors of this paper.

Conflicts of interest

None of the authors has any conflict of interest to declare.

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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.2020.09.015.

References