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Arrhythmia/electrophysiology

Improved outcome in Sweden after out-of-hospital cardiac arrest and possible association with improvements in every link in the chain of survival

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Aims

To describe out-of-hospital cardiac arrest (OHCA) in Sweden from a long-term perspective in terms of changes in outcome and circumstances at resuscitation.

Methods and results

All cases of OHCA ($n = 59\,926$) reported to the Swedish Cardiac Arrest Register from 1992 to 2011 were included. The number of cases reported ($n/100\,000$ person-years) increased from 27 (1992) to 52 (2011). Crew-witnessed cases, cardiopulmonary resuscitation prior to the arrival of the emergency medical service (EMS), and EMS response time increased ($P < 0.0001$). There was a decrease in the delay from collapse to calling for the EMS in all patients and from collapse to defibrillation among patients found in ventricular fibrillation ($P < 0.0001$). The proportion of patients found in ventricular fibrillation decreased from 35 to 25% ($P < 0.0001$). Thirty-day survival increased from 4.8 (1992) to 10.7% (2011) ($P < 0.0001$), particularly among patients found in a shockable rhythm and patients with return of spontaneous circulation (ROSC) at hospital admission. Among patients hospitalized with ROSC in 2008–2011, 41% underwent therapeutic hypothermia and 28% underwent percutaneous coronary intervention. Among 30-day survivors in 2008–2011, 94% had a cerebral performance category score of 1 or 2 at discharge from hospital and the results were even better if patients were found in a shockable rhythm.

Conclusion

From a long-term perspective, 30-day survival after OHCA in Sweden more than doubled. The increase in survival was most marked among patients found in a shockable rhythm and those hospitalized with ROSC. There were improvements in all four links in the chain of survival, which might explain the improved outcome.

Keywords

Cardiopulmonary resuscitation • Registries • Survival

Introduction

The reported incidence of treated out-of-hospital cardiac arrest (OHCA) has varied over time between countries and also among countries.^{1–6} In Europe, the reported incidence of treated OHCA has varied between 17 and 53 per 100 000 person-years.² Recent experience from Sweden suggests some under-reporting on the incidence of OHCA.¹ Furthermore, survival after OHCA has generally

been reported to be low, but there has been variability between reports.^{3,4,8} Nevertheless, in previous studies, there has been an increase in survival over time, regardless of the initial rhythm and witnessed status among patients with OHCA in whom resuscitation was attempted.^{9–13}

At present, there are a number of large registries, such as the Resuscitation Outcomes Consortium (ROC), the Cardiac Arrest Registry to Enhance Survival (CARES), the Victorian Ambulance

Cardiac Arrest Register (VACAR), the European Cardiac Arrest Register (EuReCa), and the Swedish Cardiac Arrest Register (SCAR). However, it is possible to argue about whether they are comparable in terms of validity.¹⁴ These registries gather the data prospectively.^{1,2,14–16} The number of cases in which information is missing when it comes to important clinical variables, as well as the inclusion and exclusion criteria for participation, will determine the comparability of the registries. To document and present OHCA data in a comparable way, the Utstein template is recommended.⁷ An additional factor is that there are also different medical records in the emergency medical service (EMS) systems which will influence the structure of recording and the opportunity to report OHCA data.^{1,17}

The aim of this study is to describe OHCA in Sweden from a long-term perspective in terms of changes in outcome, circumstances at resuscitation, and validity based on the information gathered from the SCAR.

Methods

Study population

Sweden is divided into 21 counties, all of which took part in the current study. In 1992, the population in Sweden was 8 692 013 compared with 9 476 105 inhabitants in December 2011. In December 2011, the most populated vs. the least populated counties were Stockholm (2 087 902) and Gotland (57 327).¹⁸

The population density varied between three inhabitants per km² in Norrbotten and 310 inhabitants per km² in Stockholm. Some areas of Sweden are fairly rural, particularly in northern Sweden.

Emergency medical service system

In Sweden, each county is responsible for its EMS system with its own treatment guidelines. Most of the counties are controlled by county councils, while a few counties are controlled by private companies. Medical treatment guidelines, which were designed to be a tool for Swedish EMS health care, were drawn up by a Swedish association working group. These guidelines are recommendations, but following them is not compulsory.¹⁹ Guidelines on the treatment of OHCA were also formulated by the Swedish Resuscitation Council.²⁰ These guidelines adhere closely to the guidelines formulated by the European Resuscitation Council. The dispatch centre provides CPR instructions to the caller when required while waiting for the ambulance. At present, it is estimated that there are almost 300 EMS stations throughout Sweden, giving each municipality one EMS station. During the time period of this study, the educational level of the EMS crew varied. At the beginning of the 1990s, the crews were mostly made up of paramedics and, later in the 2000s, there was a successive increase in registered nurses becoming part of the EMS crew. In some counties, there are also physicians in the EMS system. The medical records used by the EMS differ in the 21 counties and five different medical records are currently available on the market. One of the records is used in more than half the counties. Two of the 21 counties use manual paper records, while the others use digital records.

The Swedish Cardiac Arrest Register (SCAR)

The SCAR was initiated in 1990 and was subsequently appointed as a national quality register.²¹ An annual report shows the outcome and circumstances at resuscitation in both in-hospital and OHCA.²² In 1990–2007, the data, such as personal identification, diagnosis, treatment,

and outcome, were reported manually by the EMS crew on a paper form. Since 2008, the data have been reported online through a web-based reporting system. Since 2010, all EMS systems in Sweden have reported to the SCAR. However, between 1992 and 2010, the completeness of individual reporting varied. It was estimated that the completeness varied between 70 and 100%. At the present time, the coverage is almost 100%. The reporting of a treated OHCA should take place prospectively. The reporting procedure is performed on two parts of a form. The first part of the form is filled out by the EMS crew, using the EMS medical record. The second part requires in-hospital medical records in order to address the required questions and is completed by a local CPR co-ordinator (mostly an experienced nurse). The retrospective analysis is undertaken by a specially trained person who performs a search procedure and then documents the data in the SCAR. These individuals, mostly experienced nurses, were recruited from the EMS systems all over Sweden.

Data collection and analyses

During the time period 1 January 1992 to 31 December 2011, prospective data relating to treated OHCA were reported by the EMS crew in terms of circumstances at resuscitation and initial outcome. For the time period 1 January 2008 to 31 December 2011, retrospective data relating to treated OHCA were searched and retrospectively reported to the SCAR with the aim of obtaining a complete report. Variables which were documented were age, gender, witnessed status, bystander CPR, and delays. These variables were reported, in addition to various treatments in hospital and estimated cerebral function among survivors. Thirty-day survival was always evaluated retrospectively. Information on survival was gathered from the Swedish National Population Registry. Information on death among Swedish citizens reaches this register within 14 days.

The time periods for retrospective data collection varied between the counties. From 1 January 2008 to 31 December 2011, data were collected retrospectively in Västra Götaland. Similar data sampling was undertaken from 1 January to 31 December 2010 in Skåne and Dalarna. From 1 January to 31 December 2011, the retrospective data collection included all 21 Swedish counties.

Reported incidence

All OHCA in which the EMS was called upon and CPR and/or defibrillation were started either prior to or on the arrival of the EMS should be reported to the SCAR.

As a result, patients with OHCA where the EMS was called upon but CPR was not attempted, either before or after the arrival of the EMS, are not included in the register. Death was subsequently confirmed by a physician.

Patients in whom CPR was started prior to the arrival of the EMS who were judged by the EMS crew to be dead (rigor mortis) were excluded.

Cerebral function according to Cerebral Performance Category (CPC) score

In 2008–2011, a validated cerebral function score was used in the web-based system to estimate neurological outcome at discharge from hospital among 30-day survivors. To define cerebral function, the CPC score instrument is used to describe neurological function. A CPC score based on a five-point scale (1–5) where (1) represents good recovery, (2) moderate disabilities, (3) severe disability, (4) vegetative state, and (5) brain dead is used.²³ Information on CPC scores was retrospectively gathered from hospital records at discharge by the CPR co-ordinator (responsible for education in and the organization of CPR within the hospital; mostly a dedicated nurse). Data on CPC scores were reported nationwide.

Statistical methods

The data were reported as percentages, the mean, or median. For tests of trends over time, the Mann–Whitney *U*-test was used for dichotomous variables and Spearman's rank correlation was used for continuous/ordered variables. In 2011, for comparisons between prospectively and retrospectively reported cases, Fisher's exact test was used for proportions and the Mann–Whitney *U*-test was used for continuous/ordered variables. The latter test was also used for comparisons of Cerebral Performance Category (CPC) scores between patients found in a shockable rhythm and patients found in a non-shockable rhythm. Change in proportion of renal dysfunction was compared using McNemar's test.

Ethical considerations

Participation in the SCAR is voluntary. No financial compensation is given to the participating counties when data relating to treated OHCA are reported. Ethical permission was authorized by the regional ethics committee in Gothenburg (S394-00).

Results

Circumstances at resuscitation

An increase in the number of reports was observed (Table 1). Age did not change significantly, but there was a minor change in distribution

Table 1 Factors at resuscitation and survival (%; if not otherwise stated)

	1992	1998	2004	2011	P-value for trend
Number of reported OHCA ^a	%	%	%	%	
All (n)	2609	3119	2484	4904	
Per 100 000 person-years (n)	27	34	27	52	
Characteristics					
Age (median; years)	71	72	72	70	0.22
Gender (woman)	30	30	32	32	0.02
Witnessed status					
Crew	10	13	16	15	<0.0001
Bystander	55	56	55	53	0.03
Non witnessed	35	31	29	32	0.04
First rhythm					
First recorded rhythm—VF ^b	35	33	29	25	<0.0001
Survival					
Survival to hospital admission	15	14	20	22	<0.0001
30-day survival (hospitalized) ^c	33	34	35	48	<0.0001

The data represent 21 counties in Sweden.

^aOut-of-hospital cardiac arrest.

^bVentricular fibrillation.

^cOnly included patients hospitalized with ROSC.

of gender (Table 1). There were minor changes in witnessed status, with an increase in crew-witnessed cases (Table 1). The proportion of patients with ventricular fibrillation decreased (Table 1).

The intervals between collapse to call, dispatch to EMS at patient's side, and collapse to first defibrillation are given in Figure 1.

The proportion of patients who received CPR prior to EMS arrival increased substantially (Figure 2).

Survival

From 1992 to 2011, the 30-day survival (Figure 3 and Table 1) and survival to hospital admission (Table 1) increased significantly. The increase was most marked among patients with a shockable rhythm (Figure 3).

Treatment and function after hospital admission

After hospital admission (2008–2011; *n* = 2364), 41% of patients were treated with therapeutic hypothermia and 28% with percutaneous coronary intervention.

In analyses of 30-day survivors, the cerebral function at discharge from hospital is described for 2008–2011 (Table 2). The majority had a CPC score of 1 or 2. The distribution of patients according to CPC score was better among patients found in a shockable rhythm than in those that were not (*P* = 0.003).

When comparing the 64% of patients with information on CPC score with those with missing information, there was no significant difference in any of the variables of age, gender, witnessed status, place of OHCA, initial rhythm, CPR prior to the arrival of the EMS, EMS response time, or delay from collapse to defibrillation.

In one-hundred-and-ninety-two 30-day survivors in central and western Sweden, we analysed the estimated glomerular filtration rate (GFR) according to Modification in Diet in Renal Disease (MDRD). The proportion of patients with reduced renal function (defined as a GFR of less than 60 mL/min) was significantly reduced from 28% on the first day after hospital admission to 10.7% on the last day of hospital admission (*P* < 0.0001).

Validation of data reported prospectively/retrospectively in 2011

In all, 1279 cases (26%) were reported retrospectively. The 30-day survival in this group was 12.0% when compared with 10.2% in prospectively reported cases (*P* = 0.08). In only two aspects of clinically relevant circumstances at resuscitation and outcome were there significant differences between prospectively and retrospectively reported patients; (i) a cardiac aetiology was less frequent in the retrospectively reported group (50 vs. 67%; *P* < 0.0001) and (ii) the median delay between collapse and calling for the EMS was shorter in the retrospectively reported group (1 vs. 3 min; *P* < 0.0001).

Regional differences in 30-days survival

In 2011, the 30-day survival per 100 000 person-years varied between counties, from 8.9 in Halland to 1.2 in Västernorrland (Figure 4).

When comparing the three counties with the highest 30-day survival (Halland, Sörmland, and Jönköping) with the three with

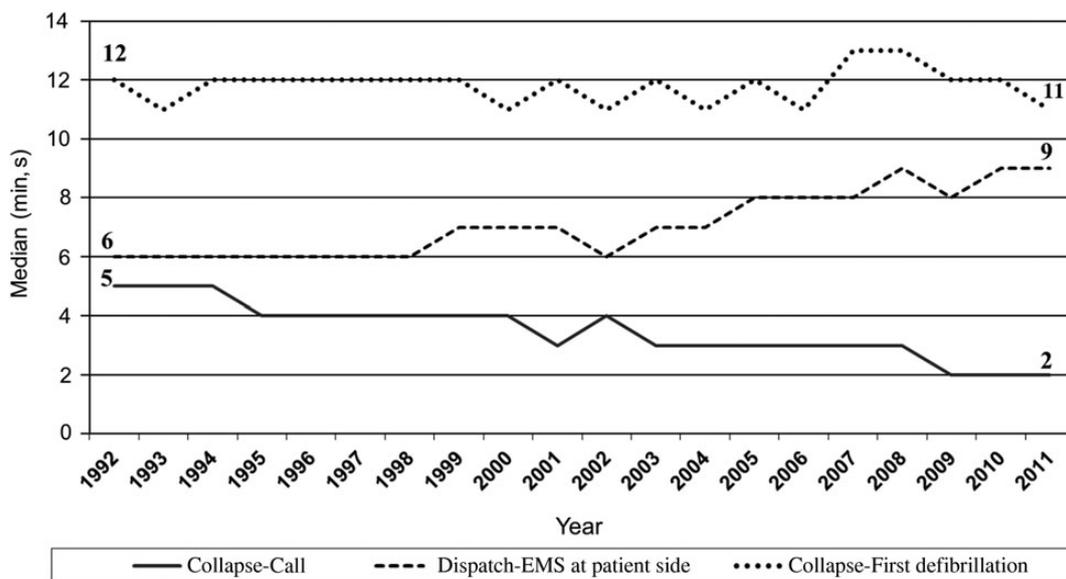


Figure 1 Changes in delay from 1992 to 2011. The intervals between collapse to call (missing information in 20%), dispatch to EMS at patient's side (missing information in 14%), and collapse to first defibrillation (missing information in 16%).

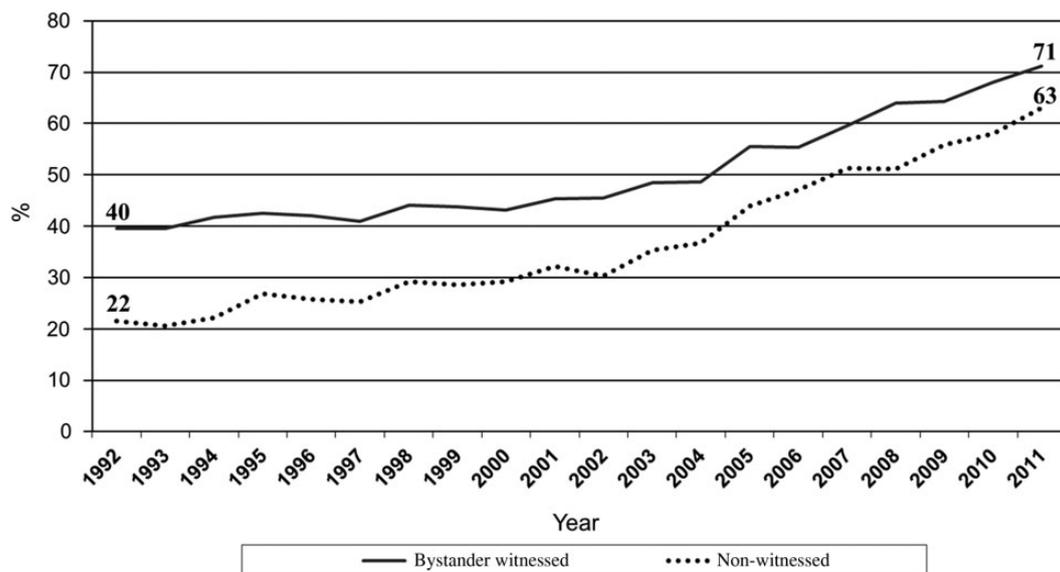


Figure 2 Proportion of first-responder CPR prior to arrival of EMS from 1992 to 2011. Bystander-witnessed cases ($P < 0.0001$). Missing information in 2%. Non-witnessed cases ($P < 0.0001$). Missing information in 3%.

the lowest 30-day survival (Västernorrland, Västerbotten, and Gotland), no significant differences were observed with respect to age, gender, witnessed status, place, initial rhythm, CPR prior to EMS arrival, and delay from collapse to defibrillation. In contrast, the EMS response time was longer in the counties with low survival (mean 15 vs. 11 min; median 10 vs. 9 min; $P = 0.007$). The

proportion of patients found in a shockable rhythm tended to be lower in the counties with low 30-day survival (23 vs. 28%; $P = 0.054$).

The number of ambulances per 100 000 inhabitants was 4.9 in counties with high 30-day survival and 7.0 in counties with low 30-day survival. However, the number of ambulances per 1000

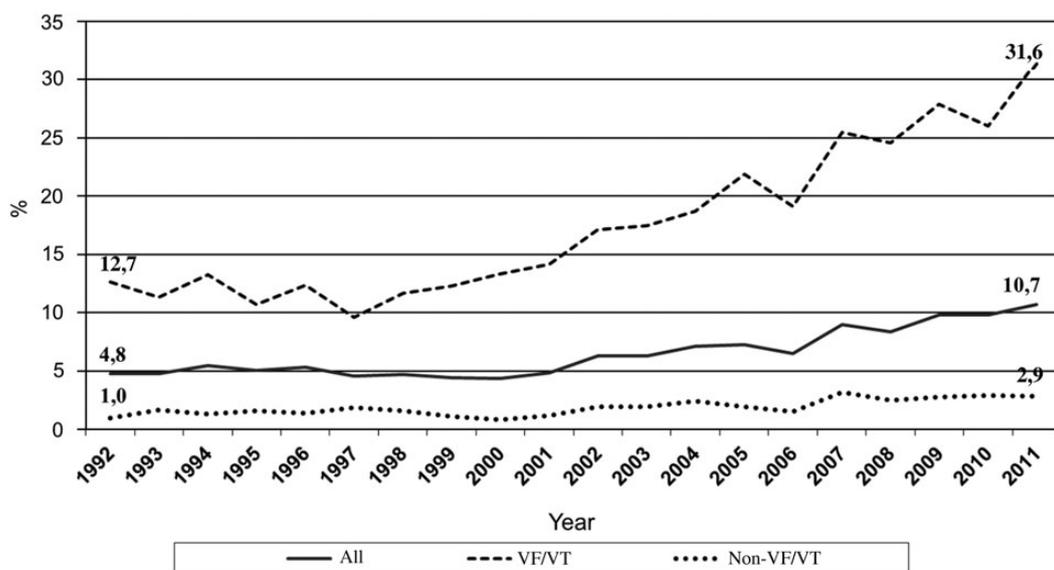


Figure 3 Changes in 30-day survival from 1992 to 2011. All patients ($P < 0.0001$). Missing information in 1%. Patients found in ventricular fibrillation ($P < 0.0001$). Missing information in 1%. Patients found in a non-shockable rhythm ($P < 0.0001$). Missing information in 0.8%.

Table 2 Cerebral function at discharge from hospital (% , if not otherwise stated)

CPC score ^a (among survivors)	2008 (n = 90)	2009 (n = 170)	2010 (n = 286)	2011 (n = 289)	All (n = 835)	VF ^b (n = 577)	Non-VF (n = 171)
1	82	81	79	85	82	83	76
2	13	11	14	12	13	13	14
3	5	6	6	2	4	3	9
4	0	1	1	1	0.5	1	0.5
5	0	1	0	0	0.5	0	0.5

^aCerebral Performance Category score.

^bInformation on rhythm in missing in 87 cases.

square km was 2.1 in counties with high 30-day survival and 0.8 in counties with low 30-day survival.

Discussion

The main finding over time in this study was the increase in the number of reported OHCA in combination with an increase in 30-day survival, particularly among patients found in a shockable rhythm.

Number of reports

The number of reported OHCA events has increased dramatically. A number of factors might explain this finding. First, an increasing number of EMS systems have joined the register. Second, a weak yet ongoing improvement in feedback to the EMS systems through register reports and lectures has hopefully increased awareness of the register and the importance of complete reporting.²⁴ Creating

a successful feedback strategy to a staff organization requires more than a written report.²⁵ The third and probably most important factor is the introduction of retrospective reporting of the cases that were originally missing, which has had a massive impact on the recruitment of cases to the register.²⁶

Increase in survival

A number of mechanisms might explain the marked observed increase in 30-day survival. They might be related to the four links in the chain of survival. This is consistent with previous research.²⁷

The first link

The shortened delay from collapse to calling for the EMS, which was clearly demonstrated, might be one explanation for the increase in 30-day survival.²⁸ It is also important that the dispatcher perceives and interprets OHCA when someone calls for help and also starts telephone CPR instruction when required.²⁹ Increased awareness

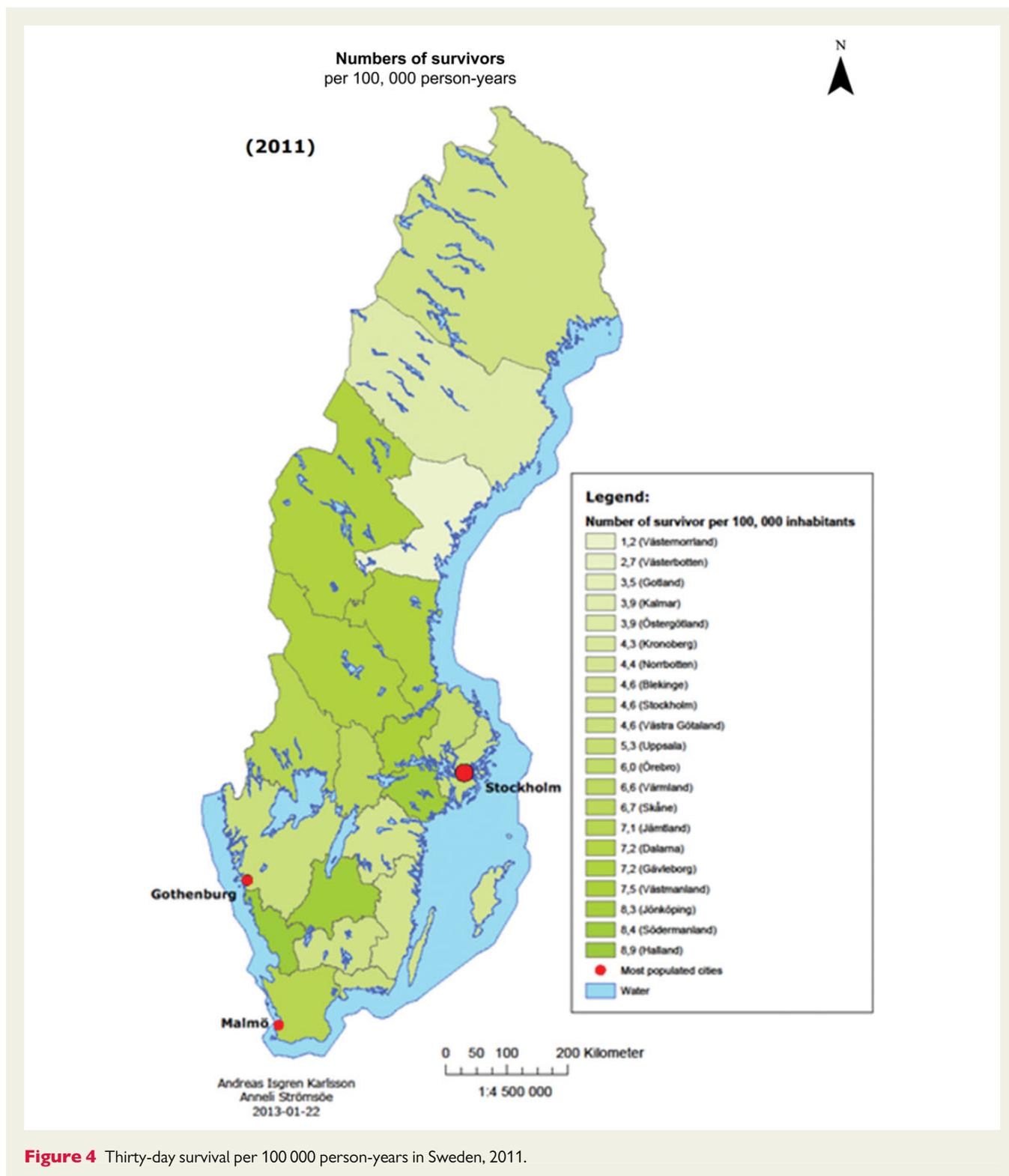


Figure 4 Thirty-day survival per 100 000 person-years in Sweden, 2011.

in society due to constant information and campaigns about the chain of survival might have influenced laypersons, as well as medically educated persons, in the community to call more rapidly.³⁰ The increasing availability of mobile telephones might also have been of importance.

The second link

It has been shown that, the earlier CPR is given, the greater the likelihood of survival after a cardiac arrest, regardless of where the arrest takes place.³¹ In Sweden, the proportion of OHCA in which CPR is

started prior to the arrival of the EMS has increased markedly during the last 20 years. There are three explanations for these findings.

- (1) Nationwide efforts to increase laypersons' and medically educated persons' knowledge of CPR;
- (2) Increased support from fire departments and police all over the country. They are often on the scene prior to the EMS and can start CPR before EMS arrival.³²
- (3) Increasing activity from the dispatcher to support the caller to perform CPR. Callers are mostly interviewed in a relatively structured manner.

The third link

It has been shown that, the shorter the interval between collapse and defibrillation, the greater the likelihood of survival after a cardiac arrest.^{33,34} We found a moderate decrease in the delay to defibrillation. Various factors could modify this critical aspect. The EMS response time has increased. This will counteract the goal of reducing the delay to defibrillation. The major mechanisms behind the increase in EMS response times are: (1) an increasing burden on the EMS (more cases per EMS unit); increasing traffic density situation, particularly in urban areas, and (3) an increasing burden on the EMS due to many other new tasks (direct admission of patients to coronary care unit, stroke unit, and hip X-ray).

However, important factors favouring more rapid defibrillation were:

- (1) A shortened delay to calling for the EMS.
- (2) An increase in the proportion of crew-witnessed cases.
- (3) The increasing dispatch of the fire brigade and the police, which were often on the scene before the EMS.
- (4) An increase in public-access defibrillation, which has been used more frequently during the last few years.

For the past few years, there has been an ongoing nationwide Automated External Defibrillator (AED) register which has not yet been linked to the SCAR. In the future, the dispatch centre may use the national AED register to guide the caller to the nearest AED.

The fourth link

We found a marked increase in 30-day survival among patients who survived the initial phase of resuscitation and had return of spontaneous circulation (ROSC) on admission to hospital. Various aspects of the treatment in the pre-hospital setting and in post-resuscitation care might influence this finding. The scientific documentation of the effect of therapeutic hypothermia,³⁵ as well as early PCI,³⁶ can be discussed. However, others have reported a marked increase in survival after these treatment procedures were introduced in post-resuscitation care.³⁷

In this study, we were unable to describe changes in the use of these treatments over time. However, we know that (with very few exceptions) they have been introduced in Sweden during the last decade.

As a result, the increased use of therapeutic hypothermia and early PCI might have contributed to the increase in survival that was found in this survey.

Other factors that might have contributed to the increase in survival were as follows.

- (1) The introduction of retrospectively reported OHCA cases. There has been a successive increase in the proportion of retrospectively reported cases. These cases were recently reported to have a higher 30-day survival rate than prospectively reported cases.²⁶ In 2011, there was no significant difference in 30-day survival between the two groups, although a trend was seen towards higher survival in the retrospectively reported cohort.
- (2) A change in guidelines might also result in improved survival after OHCA, although this has never been proven. The guidelines on CPR are constantly under development and the degree of implementation of the guidelines varies in countries all over the world.^{38–41} Sweden adheres closely to resuscitation guidelines as recommended by the European Resuscitation Council.
- (3) The national register data on OHCA might result in feedback to the EMS crew, which might result in improved attitudes to resuscitation and thereby improved survival. The best example is Stockholm, the capital of Sweden, which had a very low survival rate 10 years ago. However, based on feedback from the SCAR, various intervention projects have started, resulting in improved survival.⁴² It is to be hoped that feedback to various EMS systems will improve even further in the near future.

Cerebral function according to the Cerebral Performance Category (CPC) score

During the past few years, 94% of 30-day survivors were estimated to have a good or relatively good cerebral function according to CPC score.

In agreement with previous experience from Gothenburg, we found signs of better cerebral function among 30-day survivors found in a shockable rhythm than among 30-day survivors found in a non-shockable rhythm.⁴³ It is worth noting that the reliability of the CPC score has been the subject of argument in terms of conformity with the quality-of-life assessment, as well as other functional testing.⁴⁴

Other aspects of organ dysfunction

Theoretically, there is a risk that various organs could be damaged as a result of an ischaemic insult caused by prolonged ischaemia among patients who survive an OHCA. This is less well described in the literature. In a minor subset of 30-day survivors, we found no data to support the hypothesis that renal dysfunction is a major problem among 30-day survivors of OHCA in a prolonged perspective, as only about 10% had a reduced estimated GFR at the end of hospitalization. However, our results suggest that there might be a proportion of survivors with a reversible reduction in renal function at an early stage after OHCA. These findings need to be confirmed in a larger cohort of 30-day survivors after OHCA.

Validated data reported prospectively/retrospectively

The proportion of cases that were reported retrospectively in 2011 was almost identical to the proportion that was previously reported from parts of Sweden.

The most striking finding was the similarity between the two groups, which suggests that previously prospectively reported data have been relatively representative of the OHCA population in Sweden where CPR was attempted. There is currently no good explanation of why patients in the retrospectively reported group had a higher prevalence of a cardiac aetiology and a shorter delay from collapse to calling for the EMS.

It can be assumed that there is more uncertainty in a retrospective evaluation of delay.

There was a trend towards higher 30-day survival in retrospectively reported cases. This is in agreement with previous findings.²⁶ One explanation of this finding might be that some patients who were quickly and successfully defibrillated from ventricular fibrillation either prior to or after the arrival of the EMS were not prospectively reported to the SCAR.

Number of survivors per 100 000 person-years

The following might contribute to the variability in the number of saved lives between regions: organizational factors, geography, educational factors, attitudes, and some degree of under-reporting.

With regard to the EMS response time, we found that, in the counties with lower 30-day survival, the EMS response time was longer. Earlier research has also indicated that, the longer the time taken until EMS arrival, the lower the 30-day survival.⁴⁵ Organizational factors, including the number of vehicles, might play a role. This is supported by the observation that the number of ambulances per 1000 square kilometres was much lower in the counties with lower 30-day survival. Other aspects worth discussing are the population density in rural areas and the traffic situation, particularly in cities. Less populated areas and more frequent traffic in cities most probably have a negative impact on the EMS response times, as previously reported by the SCAR.¹

Limitations

During the 20 years in which data were collected, the representativeness of the study sample varied. This might affect the trustworthiness of our results.

Due to different record systems in the different counties, the appropriateness in terms of OHCA detection retrospectively might vary between regions, thereby resulting in selection bias.

We have not extensively validated register data vs. source data. However, in a small sample from two Swedish regions (Gothenburg and Dalarna in 2010), we found high conformity between register data and source data from EMS medical records. The deviation rate was less than 5% in all the comparisons that were made.

Data were missing for all the variables that were collected, regardless of whether they were prospectively or retrospectively collected. No correction for missing data such as multiple imputations was made.

Information on post-resuscitation care among hospitalized patients and on the CPC score among 30-day survivors was only available in a subset of patients.

Finally, there might be some variability in the decision relating to when to initiate CPR and when to withdraw the treatment. This might affect the reported OHCA incidence.

Conclusions

From a long-term perspective, 30-day survival after OHCA in Sweden more than doubled. The increase in 30-day survival was most marked among patients found in a shockable rhythm and those that had ROSC on hospital admission. There were improvements in all four links in the chain of survival, which might explain the improved outcome.

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Conflict of interest: none declared.

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