EDITOR'S CHOICE

# Increase in survival and bystander CPR in out-of-hospital shockable arrhythmia: bystander CPR and female gender are predictors of improved outcome. Experiences from Sweden in an 18-year perspective

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## ABSTRACT

**Objectives** In a national perspective, to describe survival among patients found in ventricular fibrillation or pulseless ventricular tachycardia witnessed by a bystander and with a presumed cardiac aetiology and answer two principal questions: (1) what are the changes over time? and (2) which are the factors of importance?

**Design** Observational register study.

**Setting** Sweden.

**Patients** All patients included in the Swedish Out of Hospital Cardiac Arrest Register between 1 January 1990 and 31 December 2009 who were found in bystander-witnessed ventricular fibrillation with a presumed cardiac aetiology.

**Interventions** Bystander cardiopulmonary resuscitation (CPR) and defibrillation.

**Main outcome measures** Survival to 1 month.

**Results** In all, 7187 patients fulfilled the set criteria. Age, place of out-of-hospital cardiac arrest (OHCA) and gender did not change. Bystander CPR increased from 46% to 73%; 95% CI for OR 1.060 to 1.081 per year. The median delay from collapse to defibrillation increased from 12 min to 14 min (p for trend 0.0004). Early survival increased from 28% to 45% (95% CI 1.044 to 1.065) and survival to 1 month increased from 12% to 23% (95% CI 1.058 to 1.086). Strong predictors of early and late survival were a short interval from collapse to defibrillation, bystander CPR, female gender and OHCA outside the home.

**Conclusion** In a long-term perspective in Sweden, survival to 1 month after ventricular fibrillation almost doubled. This was associated with a marked increase in bystander CPR. Strong predictors of outcome were a short delay to defibrillation, bystander CPR, female gender and place of collapse.

## INTRODUCTION

The majority of survivors after out-of-hospital cardiac arrest (OHCA) are patients found in ventricular fibrillation.

Among patients found in ventricular fibrillation, several factors of importance for survival to hospital discharge were described more than 15 years ago in a limited sample from Gothenburg in Sweden and also from other places.[1 2]

The main challenge for the OHCA rescue team is to bring patients found in ventricular fibrillation to hospital with spontaneous circulation on admission to the emergency department. Insufficient is known about the most important factors resulting in failure in reaching this goal and whether the percentage of failures has changed over time. Furthermore, guidelines for treatment have changed.[3 4] New treatment modalities, such as percutaneous coronary intervention (PCI) and mild therapeutic hypothermia, have been introduced.[5 6]

Based on this background, the aim of this survey was to describe, among patients found in bystander-witnessed ventricular fibrillation with a presumed cardiac aetiology (a) changes over time in survival to hospital admission and to 1 month and (b) factors of importance for survival to hospital admission and for survival to 1 month.

## PATIENTS AND METHODS

### Patients

Patients who had a cardiac arrest for which an ambulance was called and in whom cardiopulmonary resuscitation (CPR) was started were included in the Swedish Cardiac Arrest Register.

### Registry and methods

The Swedish Cardiac Arrest Register is a joint venture between the Federation of Leaders in Swedish Ambulance and Emergency Services and the Swedish Council on Cardiopulmonary Resuscitation. The Register started in 1990 and it covers approximately 80% of all patients in Sweden who have experienced an OHCA and undergone CPR. There are about 4000 OHCAs every year, of which more than 3000 are reported to the Register. This study included all the patients in the Register between 1 January 1990 and 31 December 2009, found outside of hospital in bystander-witnessed ventricular fibrillation judged to be of cardiac aetiology.

### Study design

For each case of OHCA, the ambulance crew completed a form with information about age, location of cardiac arrest, probable background to the arrest and a standardised description of the resuscitation procedure, including intervention times, bystander CPR, defibrillation, drug

treatment and status at the first contact. The aetiology behind the cardiac arrest was entirely based on the judgement made by the rescue team, without confirmation by autopsy findings or further clinical data.

In ambulances with manual defibrillators, the first recorded rhythm was defined as ventricular fibrillation, ventricular tachycardia, pulseless electric activity or asystole. For automated external defibrillators, the rhythm was defined as shockable (ventricular fibrillation or ventricular tachycardia) or non-shockable (pulseless electric activity or asystole). In this survey, we have included all patients with a shockable rhythm (including both ventricular fibrillation and pulseless ventricular tachycardia).

To establish the time of cardiac arrest in witnessed cases, the ambulance crew interviewed the bystanders about the delay from arrest to call. The ambulance crew also classified the aetiology of the arrest based on clinical assessments and bystander information. Their diagnosis was accepted for this study and no further control was made among initial survivors during hospitalisation.

In the analysis of bystander CPR, the profession of the bystander (lay person or healthcare provider not at work) was also described.

Immediate outcome was reported by the ambulance crew as dead on arrival, dead in the emergency room or admitted alive to hospital.

A follow-up was conducted to collect information about whether the patient was dead or alive after 1 month.

### Study end point

We used 'brought to hospital with spontaneous circulation on hospital admission' and 'alive at 1 month' as study end points. Spontaneous circulation was defined as a palpable pulse without ongoing CPR.

### Definition of the cerebral performance categories scores

*CPC 1:* Good cerebral function. Conscious and alert. Can work and live a normal life. There might be minor psychological or neurological defects such as mild dysphasia.

*CPC 2:* Moderate cerebral dysfunction. Conscious. Cerebral function is good enough to allow part-time work in a sheltered environment, using public transport and managing activities of daily living. However, there might be more severe cerebral sequelae involving hemiplegia and dysarthria.

*CPC 3:* Severe cerebral dysfunction. Conscious. Dependent on others for activities of daily living owing to severe cerebral dysfunction (at an institution or at home with exceptional support from family members or others).

*CPC 4:* Coma. No verbal or psychological communication with others.

*CPC 5:* Brain dead.

These analyses of CPC scores were included in the Register from 2008.

### Statistical methods

#### Descriptive statistics

Percentages, mean±SD, or median were reported.

#### Statistical analyses

In the evaluation of proportions, Fisher's exact test was used. In the evaluation of continuous variables, the Mann–Whitney U test was used. Trend tests for associations with the time variable year of OHCA were performed using the Mann–Whitney U test for dichotomous variables and Spearman's rank correlation for continuous variables. Owing to the large number of p values that were created, a p value of $<0.01$ (two-tailed test) was regarded as significant.

#### Multivariate statistical analyses

A forward stepwise logistic regression was used to identify independent predictors of dichotomous dependent variables. Furthermore, analyses of delay times were logarithmically transformed.

## RESULTS

During the time of the survey, there were 52 275 cases of OHCA in which CPR was attempted. Figure 1 is a flow chart for these cases according to the Utstein template.

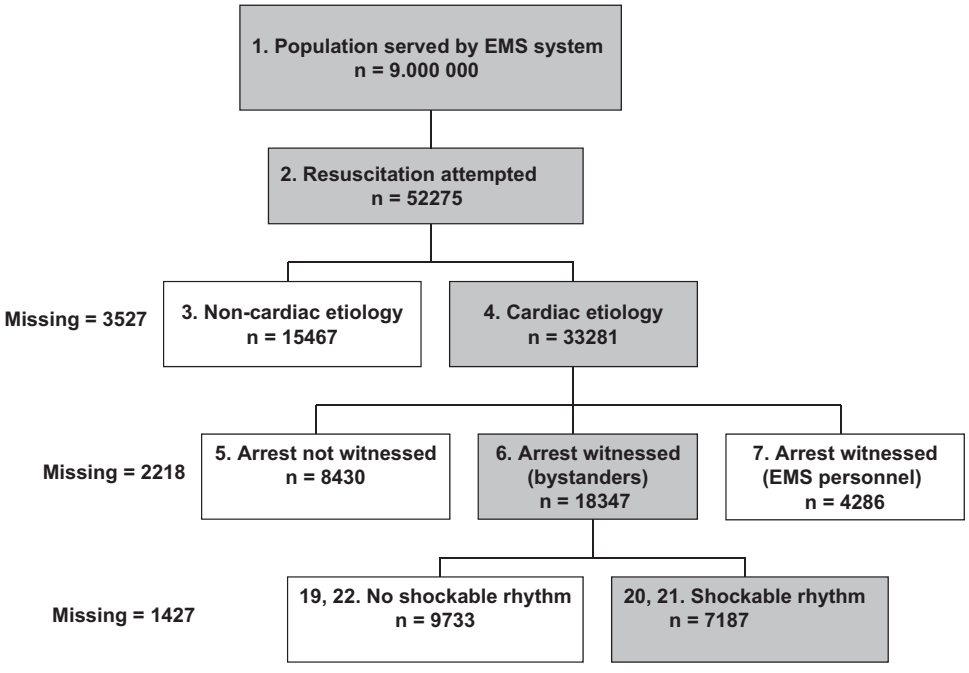


**Figure 1** Flow chart according to Utstein criteria.

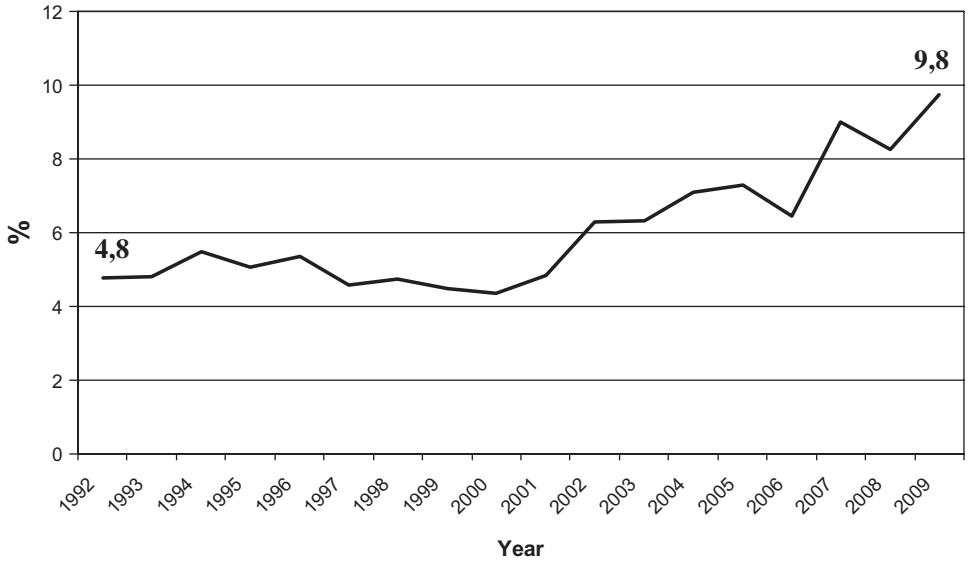


**Figure 2** Change in survival to 1 month from 1992 to 2009 among all patients in the register, regardless of initial arrhythmia.

From 1992 until 2009, the percentage of patients who were alive after 1 month increased from 4.8% to 9.8% (p<0.0001) (figure 2). There was no significant change in survival among patients found in a non-shockable rhythm.

Information on initial rhythm, witnessed status and aetiology was available in 40 107 cases. Among them, 7187 cases (18%) were bystander witnessed, found in ventricular fibrillation and with a presumed cardiac aetiology. The remaining part of the survey will focus on these 7187 cases.

## Overall characteristics

The median age was 71 years and 19% were women. In 55%, OHCA took place at home and, in 55%, bystander CPR was undertaken. Among the cases in which bystander CPR was undertaken, 69% were performed by lay persons and 31% by healthcare providers (outside work). Table 1 shows the baseline characteristics of all patients and in relation to survival. A successive decrease in age and delay to defibrillation and a successive increase in bystander CPR and OHCA outside the home was seen from patients who died to those who survived to hospital admission and to 1 month, respectively.

Table 2 shows the baseline characteristics in relation to gender. Women were older, received bystander CPR less frequently and had an OHCA outside the home less often than men.

The median delay from OHCA until defibrillation was 12 min for men and women.

## Changes over time

Changes are described between 1992 and 2009. There was no change in age, gender distribution or place of OHCA. There was an increase in bystander CPR from 46% to 73% (95% CI for OR; 1.060 to 1.081 per year: p for trend <0.0001; figure 2). Among patients in whom bystander CPR was performed, the percentage of lay bystander CPR increased from 56% in 1992 to 80% in 2009 (p<0.0001). There was an increase in the median delay from collapse to defibrillation from 12 min to 14 min (p for trend 0.0004).

The percentage of patients with a pulse on admission to hospital increased from 28% to 45% (95% CI for OR; 1.044 to 1.065 per year; p for trend <0.0001; figure 2) and the percentage who were alive after 1 month increased from 12% to 23% (95% CI for OR; 1.058 to 1.086 per year; p for trend <0.0001; figure 3).

## Factors of importance for outcome

### Univariate analysis

Age below or above the median did not influence early survival, but survival to 1 month was higher in younger patients.

**Table 1** Baseline characteristics in relation to survival*

| Characteristics | All patients n=7187 | Dead before hospital admission n=4794 | Survival to hospital† n=1290 | Survival to 1 month n=976 | p Value§ |
|---|---|---|---|---|---|
| Age (years; mean±SD) (186)‡ | 69±12 | 69±12 | 72±11 | 66±13 | 0.051 |
| Gender (%) (237)‡ n (%) | | | | | |
| Female | 1343 (19) | 772 (17) | 333 (26) | 200 (21) | <0.0001 |
| Bystander CPR (156)‡ n (%) | | | | | |
| Yes | 3842 (55) | 2430 (52) | 649 (51) | 696 (73) | <0.0001 |
| Place (64)‡ n (%) | | | | | |
| Outside home | 3235 (45) | 1966 (41) | 551 (43) | 649 (67) | <0.0001 |
| Delay from cardiac arrest to defibrillation (median; min) (1164)‡ | 12 | 13 | 11 | 9 | <0.0001 |

*Information on survival was missing in 127 patients.
†Survival to hospital meant that patients survived to hospital admission but did not survive to 1 month.
‡Number of patients with missing information.
§p Value refers to the distribution of patients in the three right columns (all patients not included).
CPR, cardiopulmonary resuscitation.

**Table 2** Baseline characteristics in relation to gender*

| Characteristics | Women n=1343 | Men n=5607 | p Value |
|---|---|---|---|
| Age (years; mean±SD) | 71±13 | 69±12 | <0.0001 |
| Bystander CPR n (%) | | | |
| Yes | 671 (51) | 3048 (56) | 0.003 |
| Place n (%) | | | |
| Outside home | 529 (40) | 2591 (47) | <0.0001 |
| Delay from cardiac arrest to defibrillation (median; min) | 12 | 12 | 0.968 |

*Missing information in 237 patients.
CPR, cardiopulmonary resuscitation.

Female gender, cardiac arrest outside the home, bystander CPR and a short delay to defibrillation were all strongly associated with early and late survival (table 3).

### Multivariate analysis

Increasing age was associated with an increase in early survival and with a decrease in late survival.

Female gender, OHCA outside the home, bystander CPR and a shorter delay from collapse to defibrillation were all strongly associated with increased early and late survival (table 4).

### Post-resuscitation care

In a subset analysis in 2008 and 2009 among patients who were brought alive to a hospital ward (n=236), we found that 34% underwent PCI, 3% underwent coronary artery bypass grafting, 54% received therapeutic hypothermia and 47% were treated with β blockers. Among patients who were discharged alive, a subset analysis (n=113) revealed that 34% received an internal cardioverter–defibrillator.

### Cerebral performance

In a subset analysis (2008–9) of patients who were discharged alive from hospital (n=98), the distribution according to CPC score was as follows: (CPC 1 (76%), CPC 2 (18%), CPC 3 (4%) and CPC 4 (3%)).

### Number of defibrillations in relation to gender

Among 5259 men, the mean number (±SD) of defibrillations was 4.8±4.6 and, among 1262 women, the mean number of defibrillations was 4.4±4.3 (p=0.005).

## DISCUSSION

The main finding in this survey was that during an 18-year period in Sweden survival to 1 month almost doubled among patients found in ventricular fibrillation when witnessed by a bystander and judged to be of cardiac aetiology.

Another important observation was that the increase in survival appeared to be associated with a marked increase in bystander CPR.

However, for the 1-month survival, other factors may also have contributed.

This indicates that during the past decade post-resuscitation care has changed and, as shown in our survey, many patients today are offered early revascularisation and mild therapeutic hypothermia. It has been suggested that this treatment improves outcome, at least among patients found in ventricular fibrillation.[5 6]

The increase in bystander CPR over time is a reflection of mass education in CPR in the community in Sweden.[7] Our figures are very high, but they should be related to previous knowledge that bystander CPR is over-represented among patients found in ventricular fibrillation, since bystander CPR increases the percentage of patients found in ventricular fibrillation.[8 9]

The reason why, in this survey, we focused on the subset with a bystander-witnessed OHCA found in ventricular fibrillation and with a presumed cardiac aetiology is that according to the Utstein criteria[10] this is the key target group, in whom the chance of success is best (ambulance crew-witnessed cases excluded).

### Factors of importance for outcome

As shown in many previous studies, bystander CPR was strongly associated with increased survival.[11–13] This is in agreement with the findings in this survey and further highlights the importance of early bystander CPR in order to increase survival.

It has previously been reported that, among all patients with OHCA, in whom CPR was started regardless of the initial rhythm and witnessed status, women are more likely to be brought alive to hospital.[14–18]

A recent report from the American Heart Association National Registry of Cardiopulmonary Resuscitation stated that women of childbearing age had better survival after in-hospital cardiac arrest than men.[19]

The mechanism behind the greater chance of being brought to hospital with spontaneous circulation on admission among women found in a shockable rhythm can only be speculated upon. We do not know whether the previous history differed between women and men. Despite being reported as being of a cardiac aetiology, the occurrence and extent of acute

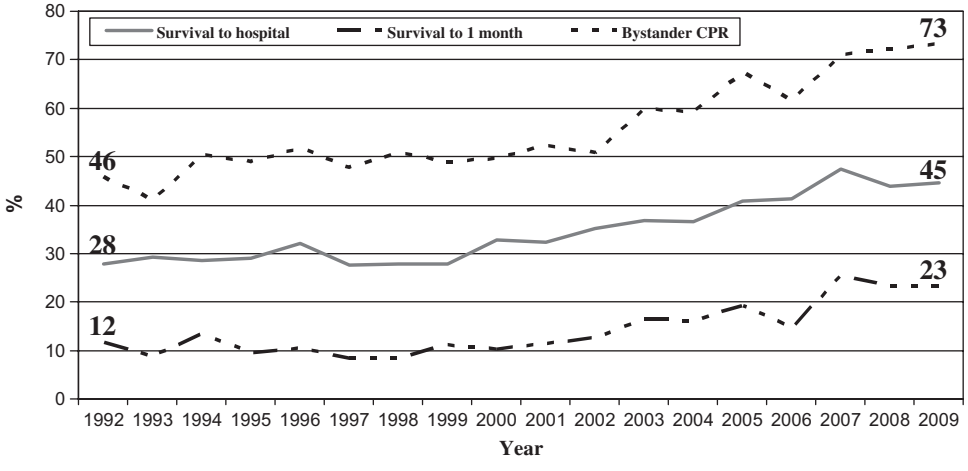


**Figure 3** Change in the proportion of patients who (a) received bystander cardiopulmonary resuscitation (CPR), (b) were admitted to hospital alive and (c) survived to 1 month, among all patients found in ventricular fibrillation or pulseless ventricular tachycardia between 1992 and 2009.

**Table 3** Factors associated with outcome in univariate analyses

| Factors | Brought to hospital on admission with pulse OR (95% CI) | Alive at 1 month OR (95% CI) |
|---|---|---|
| Age (years) (328, 239)* | | |
| >71 (median) | 1.006 (1.002 to 1.010) | 0.98 (0.97 to 0.98) |
| ≤71 | | |
| Gender (381, 311) | | |
| Female | 1.62 (1.44 to 1.84) | 1.14 (0.96 to 1.34) |
| Male | | |
| Place (209, 141) | | |
| At home | 0.61 (0.55 to 0.68) | 0.35 (0.30 to 0.41) |
| Outside home | | |
| Bystander CPR (297, 231) | | |
| Yes | 1.46 (1.32 to 1.62) | 2.53 (2.18 to 2.95) |
| No | | |
| Delay from cardiac arrest to defibrillation (1282, 1227) | | |
| >Median | 0.32 (0.28 to 0.36) | 0.24 (0.20 to 0.29) |
| ≤Median | | |

*Number of patients with missing information.
CPR, cardiopulmonary resuscitation.

myocardial ischaemia was not reported and might differ between women and men.

It has been suggested that the response of the autonomic nervous system in acute myocardial ischaemia differs among women and men,[20 21] with a vagal tone that is more markedly activated in women.[20] It has been suggested that this is a protective reaction, resulting in lower oxygen requirements among women. Among patients undergoing sudden coronary death, women more frequently have erosions, with a higher prevalence of late-stage thrombi than ruptures.[22] A number of animal studies have suggested that oestradiol after cardiac arrest has a neuroprotective[23–27] and a cardioprotective effect.[28]

It is also possible to consider whether gender is of importance for the quality of chest compressions, particularly when performed by bystanders. This can be examined both from the bystander's perspective and from the patient's perspective. If a cardiac arrest occurs at home, the bystander and the patient are usually of different genders. When the bystander is a man, chest compressions might be more effective (deep enough), owing to the greater body weight and strength of a man compared with a woman.

Finally, it is possible to speculate that in a defibrillation the chance of success might be increased in women owing to their smaller thorax volume and smaller heart.

There was no significant difference between women and men in survival to 1 month in the univariate analysis. However, in the multivariate analysis, female gender was a strong independent predictor of increased survival. This is best explained by a difference in baseline characteristics (women were older, received less bystander CPR and less often had an OHCA outside the home). The finding that women required fewer shocks than men might also indicate a more favourable response to treatment among women. However, the clinical relevance of the latter finding needs to be discussed.

**Table 4** Independent predictors of early and late survival

| Predictors | Brought to hospital on admission with pulse OR (95% CI) | Alive at 1 month OR (95% CI) |
|---|---|---|
| Increasing age | 1.009 (1.004 to 1.014) | 0.98 (0.97 to 0.98) |
| Female gender | 1.82 (1.57 to 2.10) | 1.43 (1.17 to 1.75) |
| Cardiac arrest at home | 0.77 (0.68 to 0.87) | 0.50 (0.42 to 0.60) |
| Bystander CPR | 1.70 (1.50 to 1.92) | 2.47 (2.06 to 2.96) |
| Increasing delay to defibrillation | 0.30 (0.26 to 0.36) | 0.24 (0.20 to 0.29) |

CPR, cardiopulmonary resuscitation.

We have recently reported that, among survivors of OHCA, women constituted the minority.[29] We now report that female gender is a predictor of improved outcome when found in a shockable rhythm. This is best explained by the fact that women have an OHCA less frequently than men, in particular OHCA with the feature of ventricular fibrillation.

The observation that increasing age was associated with a significant increase in the chance of bringing the patient to hospital with spontaneous circulation on admission is surprising. Although the clinical relevance might be argued, the opposite was expected. Long-term outcome—that is, survival to 1 month and survival to hospital discharge, has previously been reported to be associated with age (poorer prognosis with increasing age).[30 31] This is in agreement with the findings in this study.

As expected, there was a clear inverse association between the delay to defibrillation and survival, in agreement with many previous studies.[32] This again highlights the importance of reducing the delay to defibrillation even further, with the help of automated external defibrillators in appropriate places all over the country.[33] This is important, despite the tendency towards a decrease in the incidence of ventricular fibrillation which has been demonstrated in our Register, as well as in other registers.[34 35]

We found an increasing delay to defibrillation. A number of mechanisms might explain this observation. The emergency medical service (EMS) response time is critical. Heavier traffic and reluctance on the part of car drivers to make way for EMS vehicles have been discussed. Other contributory factors might be an increase in the burden on various EMS organisations in the country, resulting in a lack of resources. The increase in EMS response time that was observed is worrying, but it is in line with observations in various parts of the world (unpublished observations). This might be one of the explanations for the decrease in ventricular fibrillation that has been reported.

The fact that having ventricular fibrillation at home indicates a smaller chance of initial success when simultaneously considering age, gender and delay might be considered somewhat surprising. However, other factors, such as comorbidity, have most probably influenced the results.[36]

### Estimated cerebral function

In a subset analysis, our data indicate good cerebral function in the majority of survivors found in ventricular fibrillation. However, since this was a subset analysis, caution in the interpretation of these data is recommended.

### Limitation

Although the Utstein template has recommended cardiac aetiology as an important target group, there is uncertainty about the aetiology in many cases of OHCA, particularly since the autopsy rate has decreased over time.

Other factors not included in this analysis might have influenced outcome. One example is ethnicity. However, a recent report suggested that ethnicity had no major impact on outcome after OHCA.[37]

## CONCLUSION

In an 18-year perspective in Sweden, survival to 1 month after ventricular fibrillation almost doubled. This was associated with

a marked increase in bystander CPR. Strong predictors of outcome were a short delay, bystander CPR, female gender and place of collapse.

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**Competing interests** None.

**Ethics approval** This study was conducted with the approval of the ethical committee in Gothenburg, Sweden.

**Provenance and peer review** Not commissioned; externally peer reviewed.

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