Factors modifying the effect of bystander cardiopulmonary resuscitation on survival in out-of-hospital cardiac arrest patients in Sweden

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Aim To describe possible factors modifying the effect of bystander cardiopulmonary resuscitation on survival among patients suffering an out-of-hospital cardiac arrest.

Patients A national survey in Sweden among patients suffering out-of-hospital cardiac arrest and in whom resuscitative efforts were attempted. Sixty per cent of ambulance organizations were included.

Design Prospective evaluation. Survival was defined as survival 1 month after cardiac arrest.

Results In all, 14 065 reports were included in the evaluation. Of these, resuscitation efforts were attempted in 10 966 cases, of which 1089 were witnessed by ambulance crews. The report deals with the remaining 9877 patients, of whom bystander cardiopulmonary resuscitation was attempted in 36%. Survival to 1 month was 8·2% among patients who received bystander cardiopulmonary resuscitation vs 2·5% among patients who did not receive it (odds ratio 3·5, 95% confidence interval 2·9–4·3). The effect of bystander cardiopulmonary resuscitation on survival was related to: (1) the interval between collapse and the start of bystander cardiopulmonary resuscitation (effect more marked in patients who experienced a short delay); (2) the quality of bystander cardiopulmonary resuscitation (effect more marked if both chest compressions and ventilation were performed than if either of them was performed alone); (3) the category of bystander (effect more marked if bystander cardiopulmonary resuscitation was performed by a non-layperson); (4) interval between collapse and arrival of the ambulance (effect more marked if this interval was prolonged); (5) age (effect more marked in bystander cardiopulmonary resuscitation among the elderly); and (6) the location of the arrest (effect more marked if the arrest took place outside the home).

Conclusion The effect of bystander cardiopulmonary resuscitation on survival after an out-of-hospital cardiac arrest can be modified by various factors. Factors that were associated with the effect of bystander cardiopulmonary resuscitation were the interval between the collapse and the start of bystander cardiopulmonary resuscitation, the quality of bystander cardiopulmonary resuscitation, whether or not the bystander was a layperson, the interval between collapse and the arrival of the ambulance, age and the place of arrest.

Key Words: Cardiopulmonary resuscitation, bystander, cardiac arrest.

Introduction

Early cardiopulmonary resuscitation started by bystanders increases survival for persons suffering a cardiac arrest outside hospital in regions with effective emergency medicine service systems.

*See Appendix I


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0195-668X/01/060511+09 $35.00/0 © 2001 The European Society of Cardiology
compressions that result in a palpable pulse, and ventilation that gives chest expansion appear to increase survival\(^5\)\(^6\). Delay in starting bystander cardiopulmonary resuscitation has been reported to reduce its effect\(^7\) and bystander cardiopulmonary resuscitation at home appears to be less effective than in public places\(^8\).

The aim of this study, a national prospective observational study of out-of-hospital cardiac arrest in Sweden, was to identify factors that modify the effect of bystander cardiopulmonary resuscitation and to describe the implications of these findings.

**Methods**

**Ambulance registry**

This study is based on material collected within the Swedish ambulance cardiac arrest registry. The registry was started in 1990 with a few ambulance systems. It has been successively joined by more and the registry is now based on reports from some 60% of the ambulance systems in Sweden. These systems cover five million inhabitants of the total population in Sweden, some eight million people.

Most of the ambulance organizations in the registry serve smaller communities with fewer than 100 000 inhabitants and only recently have the larger cities, i.e. Stockholm, Göteborg and Malmö, joined the registry. Some 25% of all case reports emanate from these cities.

The whole of Sweden is served by ambulance dispatch centres with similar protocols for interviewing the people who call for ambulances. All the interviews always begin with a few simple questions to identify suspected cardiac arrest victims. In such cases, an ambulance is immediately dispatched before the interview is continued.

**Ambulance organizations**

Sweden is sparsely populated, but approximately 80% of the population live in cities or large urban areas. Most but not all of them have their own ambulance station. Some 100 ambulance organizations operate in Sweden. They all have a physician as the medical director. Six of ten ambulances are based at hospitals and the other four are co-ordinated with, and based at, fire stations. In some ambulance systems, the only treatment for cardiac arrest victims would be cardiopulmonary resuscitation and defibrillation, while in others a full advanced cardiac life support (ACLS) protocol could be applied, including early intubation and early drug treatment.

**Cardiopulmonary resuscitation — training systems**

In 1983 the Swedish Society of Cardiology initiated a national cardiopulmonary resuscitation training programme based on the American Heart Association’s guidelines. The programme was revised in 1987 and again in 1993, this time according to guidelines from the European Resuscitation Council\(^9\).

The training system could be described as a ‘cascade’ in which instructor trainers train instructors who in turn train rescuers. The responsibility for the further dissemination of cardiopulmonary resuscitation training in society lies with the instructor-trainers. This cascade is decentralized as much as possible and is largely self-perpetuating. It thus has a large potential for mass training.

The 3 h totally standardized CPR training programme is for cardiopulmonary resuscitation, designed for medical personnel and laypersons. In an initial 20-min video, all the medical information is conveyed and the rest of the time is spent on stepwise repetitive training with hands-on practice on a manikin. The session ends with formal testing to allow the instructor to evaluate the teaching.

Monitoring of the training system reveals that approximately 250 instructor trainers, 3000 instructors and 100 000 rescuers are certified every year. Since 1983 and up to 1995, 2000 instruction trainers, 25 000 instructors and 1 million rescuers have been trained. In addition to this training system, the Swedish Red Cross have trained some 100 000 rescuers in basic cardiopulmonary resuscitation.

**Study design**

For each case of out-of-hospital cardiac arrest, the ambulance crew completed a form with demographic information such as age, place of arrest, probable background of the arrest, bystander occupation and a standardized description of the resuscitation procedure including intervention times and interventions such as cardiopulmonary resuscitation, defibrillation, intubation, drug treatment and status at first contact. (Bystander was defined as someone not performing cardiopulmonary resuscitation as part of his or her job.)

In ambulances with manual defibrillators, the initial rhythm was defined as ventricular fibrillation, pulseless electrical activity or asystole. For automated external defibrillators, the rhythm was defined as ventricular fibrillation/ventricular tachycardia (i.e. shockable rhythm) and other.

The time of arrest was estimated by interviewing the bystander. The ambulance crew then recorded the time of arrival at the patient’s side, the time of the start of cardiopulmonary resuscitation, the time of the first defibrillation, the time of palpable pulsations, the time of start of transport to hospital and arrival at hospital. The numbers of DC shocks were recorded. Immediate outcome was reported as dead on arrival, dead in the emergency room or admitted alive.

The form was filled in during and immediately after the acute event. The medical director reviewed each form and a copy was sent to a central registry. After
1 month, another copy with additional information about outcome after 1 month, dead or alive, was sent.

Statistical methods

For comparison of dichotomous variables between groups, Fisher’s exact test was used. The interaction between bystander cardiopulmonary resuscitation and each of the other variables was tested in a multiple logistic regression analysis where the two main effects and the interaction term were included in each model. All significance tests were two-tailed and conducted at the 5% significant level.

Results

Introduction

By May 1995, 14 065 reports of cardiac arrest had been collected. Resuscitation was attempted in 10 966 cases. In the remaining 3099 cases, death was obvious. The 1089 cases witnessed by ambulance crews were excluded, as the ambulance crews were not bystanders by definition. All the percentages analysed in the study were based on the 9877 remaining patients in whom resuscitation was attempted.

In 45% of the cases, the patients were suffering from ventricular tachycardia/ventricular fibrillation at the first ECG. In 67%, the cardiac arrest was witnessed by bystanders and bystander cardiopulmonary resuscitation was attempted in 36% of all patients. The median delay from collapse to recording of the first ECG was 14 min. In 5350 witnessed cardiac arrests, resuscitation was attempted in 40% and in 21% of 3106 non-witnessed arrests.

In a univariate analysis, survival at 1 month was significantly higher for patients who received bystander cardiopulmonary resuscitation compared with those who did not (8.2% vs 2.5% with an odds ratio of 3.5, 95% confidence interval (CI) 2.9–4.3). In a multivariate logistic regression analysis in which the initially recorded rhythm was not included in the model, the odds ratio for 1-month survival for patients with bystander cardiopulmonary resuscitation vs no bystander cardiopulmonary resuscitation was 2.5 with a 95% CI of 1.9–3.1. In an identical analysis in which the initially recorded rhythm was included in the model, the odds ratio for patients with bystander cardiopulmonary resuscitation decreased to 2.2 with 95% CI 1.7–2.8.

Factors interacting with bystander cardiopulmonary resuscitation

We found three factors, which interacted with the effect of bystander cardiopulmonary resuscitation on survival.

Age

In 9438 patients, the median age was 71 years. The odds ratio for survival to 1 month (bystander cardiopulmonary resuscitation vs no bystander cardiopulmonary resuscitation) for patients under or equal to 71 years and over 71 years was 2.5 (95% CI 1.9–3.3) and 5.1 (95% CI 3.8–7.1) respectively (Table 1). The P value for interaction was <0.001.

Time to arrival of emergency medicine service

In 6999 patients, the time from collapse to the arrival of the emergency medicine service was known. The median time to arrival was 13 min. The odds ratio for survival to 1 month for patients with arrival times below or equal to and above 13 min was 3.9 (95% CI 3.0–5.0) and 15.8 (95% CI 6.3–52.9) respectively (Table 1). The P value for interaction was <0.01.

Place of cardiac arrest

In 9760 patients, the cardiac arrest took place at home in 61% of cases and in other places in 39% of cases. Of cardiac arrests at home, 24% received bystander cardiopulmonary resuscitation, whereas the figure for arrest outside the home was 47%. The odds ratio for survival to 1 month was 2.0 (95% CI 1.4–2.9) for patients receiving bystander cardiopulmonary resuscitation at home and 3.2 (95% CI 2.4–4.2) for patients receiving bystander cardiopulmonary resuscitation outside the home (Table 1). Although the confidence intervals overlap, place interacted with bystander cardiopulmonary resuscitation in a further interaction analysis. The P value for interaction was =0.049.

Factors with relation to bystander cardiopulmonary resuscitation

Where interaction could not be tested, survival to 1 month was instead tested only between patients who received bystander cardiopulmonary resuscitation with regard to the three remaining factors (Table 2). We found three factors related to the effect of bystander cardiopulmonary resuscitation.

Time to start of bystander cardiopulmonary resuscitation

For 1099 of 3572 patients in whom bystander cardiopulmonary resuscitation was performed, information was known about the time from collapse to the start of cardiopulmonary resuscitation. The median time from collapse to the start of bystander cardiopulmonary resuscitation was 2 min. Survival to 1 month, calculated against all the patients who did not receive bystander cardiopulmonary resuscitation, produced an odds ratio of 8.3 (95% CI 6.3–10.8) for patients receiving bystander cardiopulmonary resuscitation with a delay smaller than or equal to 2 min to the start of bystander cardiopulmonary resuscitation, in contrast to an odds ratio of 2.9 (95% CI 2.0–4.2) for those patients in whom bystander cardiopulmonary resuscitation was started more than 2 min after collapse (Table 2). There was a significant difference in survival to 1 month between patients who
received bystander cardiopulmonary resuscitation ≤2 min after collapse (17·4%) and patients who received bystander cardiopulmonary resuscitation >2 min after collapse (6·9%; P<0·0001; Table 2).

The cumulative curve for times from collapse to the start of bystander cardiopulmonary resuscitation is illustrated in Fig. 1 for all patients in whom bystander cardiopulmonary resuscitation took place, as well as for subgroups such as laypersons, medical personnel, ambulance crews and police officers. The median delay for all patients was approximately 2 min and approximately 1 min for medical personnel.
For 2895 of the 3572 patients in whom bystander cardiopulmonary resuscitation was performed, information on the category of the bystander was known (Table 3). Of the bystanders, 28% were medical personnel, 54% laypersons and 5% police officers or ambulance staff. Thirteen per cent were persons from other categories or not specified (Table 3).

The percentage admitted alive and alive after 1 month was higher for patients resuscitated by medical personnel than by laypersons, and compared to patients with no bystander cardiopulmonary resuscitation there was a five fold and 2.4-fold increase, respectively, in survival to 1 month. A small number of patients were resuscitated by police officers and ambulance personnel with very good survival results. If no bystander cardiopulmonary resuscitation was performed the survival was significantly less (Tables 4 and 5).

There was a significant difference in survival to 1 month between patients who received bystander cardiopulmonary resuscitation by laypersons (6.0%) and those who received bystander cardiopulmonary resuscitation by non-laypersons (11.1%; P<0.0001; Table 2).

Incomplete bystander cardiopulmonary resuscitation and interaction with bystander cardiopulmonary resuscitation

Of all 9877 patients, 898 were given incomplete bystander cardiopulmonary resuscitation — 620 received only ventilation and 278 only compressions. Survival to 1 month was 4.3% and 6.8%, respectively, compared with 9.7% survival for patients with complete bystander cardiopulmonary resuscitation. There was a significant difference in survival to 1 month between patients who received complete bystander cardiopulmonary resuscitation (9.7%) and incomplete bystander cardiopulmonary resuscitation (5.1%; P<0.0001; Table 2).

### Table 3  Number and proportion of patients given or not given bystander cardiopulmonary resuscitation in relation to bystander characteristics

<table>
<thead>
<tr>
<th>CPR by</th>
<th>%</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laypersons</td>
<td>17</td>
<td>1577</td>
</tr>
<tr>
<td>Medical personnel</td>
<td>8</td>
<td>813</td>
</tr>
<tr>
<td>Police officer, ambulance staff</td>
<td>1</td>
<td>146</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>362</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2895</td>
</tr>
<tr>
<td>No CPR</td>
<td>68</td>
<td>6323</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>9221</td>
</tr>
</tbody>
</table>

### Table 4  Number and proportion of patients surviving in relation to bystander characteristics

<table>
<thead>
<tr>
<th>CPR by</th>
<th>All</th>
<th>Admitted alive</th>
<th>Alive at 1 month</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>n %</td>
<td>n %</td>
</tr>
<tr>
<td>Laypersons</td>
<td>1577</td>
<td>245 15.5</td>
<td>95 6.0</td>
</tr>
<tr>
<td>Medical personnel</td>
<td>811</td>
<td>211 26.0</td>
<td>99 12.3</td>
</tr>
<tr>
<td>Police officers</td>
<td>63</td>
<td>19 30.2</td>
<td>12 8.8</td>
</tr>
<tr>
<td>Ambulance staff</td>
<td>79</td>
<td>25 31.7</td>
<td>15 19.0</td>
</tr>
<tr>
<td>Other</td>
<td>366</td>
<td>48 13.1</td>
<td>19 5.2</td>
</tr>
<tr>
<td>Total</td>
<td>2896</td>
<td>548 18.9</td>
<td>240 8.3</td>
</tr>
<tr>
<td>No CPR</td>
<td>6340</td>
<td>750 11.8</td>
<td>157 2.5</td>
</tr>
<tr>
<td>Total</td>
<td>9336</td>
<td>1298 13.9</td>
<td>397 4.3</td>
</tr>
</tbody>
</table>
The median delay time to defibrillation was 14 min and an interaction analysis between patients with a time to defibrillation of ≤14 min and >14 min did not show any interaction between the time between collapse and first defibrillation and survival (Table 1).

Table 5 Number and proportion of patients with ventricular fibrillation as the presenting rhythm, surviving in relation to bystander characteristics

<table>
<thead>
<tr>
<th></th>
<th>Admitted alive</th>
<th>Alive at 1 month</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>CPR by</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laypersons</td>
<td>834</td>
<td>189</td>
</tr>
<tr>
<td>Medical personnel</td>
<td>489</td>
<td>157</td>
</tr>
<tr>
<td>Police officers</td>
<td>36</td>
<td>17</td>
</tr>
<tr>
<td>Ambulance staff</td>
<td>50</td>
<td>18</td>
</tr>
<tr>
<td>Other</td>
<td>179</td>
<td>36</td>
</tr>
<tr>
<td>Total</td>
<td>1578</td>
<td>417</td>
</tr>
<tr>
<td>No CPR</td>
<td>2586</td>
<td>478</td>
</tr>
<tr>
<td>Total</td>
<td>4164</td>
<td>885</td>
</tr>
</tbody>
</table>

Factors for which no interaction with bystander cardiopulmonary resuscitation was demonstrated

Gender
Of 9391 patients, 69% were men and 31% women. Men were given bystander cardiopulmonary resuscitation in 33% of the cases and women in 29%. Gender did not interact with the effect of bystander cardiopulmonary resuscitation on survival to 1 month (Table 1).

Patients with witnessed and non-witnessed cardiac arrest
Of 8382 patients with cardiac arrest, 63% were witnessed and 37% were not. The witnessed arrests were given bystander cardiopulmonary resuscitation in 39% and the non-witnessed ones in 21%. Witnessed status did not interact with the effect of bystander cardiopulmonary resuscitation on survival to 1 month (Table 1).

Patients with ventricular tachycardia/ventricular fibrillation on first ECG
In 9877 patients with cardiac arrest, the first recorded rhythm was ventricular tachycardia/ventricular fibrillation in 42%. Of these patients, 38% were given bystander cardiopulmonary resuscitation, while 27% were identified as having ‘non-shockable rhythm’. Ventricular tachycardia/ventricular fibrillation or ‘non-shockable rhythm’ on the first recorded ECG did not interact with the effect of bystander cardiopulmonary resuscitation on survival to 1 month (Table 1).

Probable cardiac origin of the cardiac arrest
In 8974 patients with cardiac arrest, there was probable cardiac disease in 74%. Among these patients, 35% were given bystander cardiopulmonary resuscitation. Having cardiac disease or not did not interact with the effect of bystander cardiopulmonary resuscitation on survival to 1 month (Table 1).

Time to defibrillation
In 3269 patients who had been defibrillated, 40% had been given bystander cardiopulmonary resuscitation.

Discussion
Today, it is generally accepted that bystander cardiopulmonary resuscitation increases survival in out-of-hospital cardiac arrests, even if no randomized study has ever been performed. How much bystander cardiopulmonary resuscitation increases survival is, however, still a controversial question.

In prospective observational studies in which patient groups who were or were not given bystander cardiopulmonary resuscitation have been compared, the survival has been increased by up to ten times by bystander cardiopulmonary resuscitation [10]. Confounding factors and/or small numbers of patients hampered most of these studies, however.

Even in wel1-performed studies compensating for all the known confounding factors the effect of bystander cardiopulmonary resuscitation on survival varies remarkably. In our study, the odds ratio for an increase in survival with bystander cardiopulmonary resuscitation was 2.5, while in others the odds ratio varied from 1.5–3.7. Most of these studies have small numbers of patients, giving wide confidence intervals. As any value inside the confidence intervals is as likely to be correct, the results of these studies indicate that the odds ratio for an increase in survival after bystander cardiopulmonary resuscitation could be anything from 1–0.3–5 [11–14].

It is probably of the utmost importance for everyone worldwide who is involved in implementing cardiopulmonary resuscitation to know what effect their work has on survival in out-of-hospital cardiac arrests. If bystander cardiopulmonary resuscitation only increases survival by a factor of 1/03, all their work must be considered of little value. If, on the other hand, survival increases fivefold, bystander cardiopulmonary resuscitation must be regarded as an extremely effective intervention. It is therefore very important to try more exactly to analyse the ‘true’ effect of bystander cardiopulmonary resuscitation on survival. To understand the wide variations described in the effect of bystander cardiopulmonary resuscitation, it is necessary to identify the factors that modify this effect.

Using interaction analysis we have identified three factors. It must be remembered, however, that interaction analysis is a conservative method, in which only factors which interact markedly can be identified and that the results must be interpreted cautiously. There could be other factors, which also interact, even if they were not identified. In our analysis, we have also identified factors which might only be ‘substitute’ factors for other hidden factors.
Age

One surprising outcome in the interaction analysis was that age interacted with the effect of bystander cardiopulmonary resuscitation. From a biological point of view, it is difficult to believe that elderly patients react more positively than younger patients to bystander cardiopulmonary resuscitation. We believe that age was a surrogate factor for some other hidden factor that could only be speculated upon. It is possible that bystanders were more selective about starting bystander cardiopulmonary resuscitation in the older age group and thus selected those with the best chances of survival.

Interval between collapse and arrival of ambulance

We found that bystander cardiopulmonary resuscitation had a more marked effect on survival if there was a long interval between collapse and the arrival of the ambulance than if this interval was short. Although this has not been demonstrated in previous studies, this is an expected observation. With a short interval between collapse and the start of advanced cardiac life support, the victim has a fairly good chance of survival even if bystander cardiopulmonary resuscitation was not performed.

Location of cardiac arrest

Location of cardiac arrest interacted, so that bystander cardiopulmonary resuscitation given to those suffering a cardiac arrest at home was less effective than for cardiac arrest victims outside the home. This finding has no obvious explanation. The location of cardiac arrest was evidently only a surrogate factor; the place where the cardiac arrest victim was found could not directly influence the effect of bystander cardiopulmonary resuscitation. The explanation for the difference in survival could, however, only be speculated upon. One reason why some patients who suffer a cardiac arrest at home have less chance of survival could be that they have a more severe underlying heart disease or other concomitant disease, which forces them to stay at home.

In previous reports, it has been shown that overall survival for cardiac arrest at home was lower in multiple regression analysis[6,11]. These reports also suggested that underlying heart disease among those suffering cardiac arrest at home, was a likely explanation for their lower survival.

Three further factors were identified which appeared to modify the effect of bystander cardiopulmonary resuscitation on survival, although interaction analyses could not be performed.

The delay from collapse to the start of bystander cardiopulmonary resuscitation

This delay was found to be a powerful modifying factor. The effect was more than doubled if bystander cardiopulmonary resuscitation was started within 2 min after cardiac arrest compared with a later start. The importance of an early start with bystander cardiopulmonary resuscitation has previously been demonstrated in a more selected group of patients, those with a witnessed cardiac arrest and showing ventricular fibrillation on the first recorded ECG[7]. The markedly decreasing effect of bystander cardiopulmonary resuscitation on survival if there is a long delay from arrest to its start illustrates the previously described deleterious effects of prolonged ischaemia on the human body[12]. Our result underscores the importance of good lay cardiopulmonary resuscitation training, with the emphasis on the need to act rapidly.

Bystander category

The category of the bystander also modified the effect of bystander cardiopulmonary resuscitation, where bystander cardiopulmonary resuscitation by laypersons was less effective than bystander cardiopulmonary resuscitation given by others. We have no data to explain this difference, but we could previously demonstrate that medical professionals start bystander cardiopulmonary resuscitation earlier than laypersons, probably because they were better prepared to intervene (Fig. 1). It also seems probable that these other groups were better trained and therefore gave more effective cardiopulmonary resuscitation.

In one published study, 60% of all bystanders were medical personnel[13], while in our study more than 50% were laypersons. Such differences could account for some of the variation in the effect of bystander cardiopulmonary resuscitation on survival in the published studies.

In approximately one-third of the cases, bystander cardiopulmonary resuscitation was incomplete in the sense that the patients only received either chest compressions or ventilation. In the univariate analysis based on a few patients, there was a trend towards better survival for patients receiving only chest compressions than only ventilation, and incomplete bystander cardiopulmonary resuscitation was associated with a lower survival than complete bystander cardiopulmonary resuscitation. In the current discussion of whether to abandon ventilations in the bystander cardiopulmonary resuscitation algorithm, these facts are too weak to support any conclusory statement.

Quality of bystander cardiopulmonary resuscitation

One other factor, perhaps the most important, has previously been identified, namely the quality of bystander cardiopulmonary resuscitation. In three studies, it has been demonstrated that only what has been called 'effective' cardiopulmonary resuscitation increased survival, i.e. the chest rises with inflation and chest compression gives a palpable pulse[10-12].
In one of the studies, 75% of the bystander cardiopulmonary resuscitation that was given was judged to be effective and doubled survival compared with no bystander cardiopulmonary resuscitation. ‘Ineffective’ bystander cardiopulmonary resuscitation had no effect on survival[10]. In the other two studies, 45% and 46% of all bystander cardiopulmonary resuscitation was judged as effective with a marked effect on survival, while ineffective cardiopulmonary resuscitation had no effect at all[5,6,12].

It was expected that the percentage of bystanders giving effective bystander cardiopulmonary resuscitation would vary considerably in different studies, depending on the cardiopulmonary resuscitation training system in that region and that this could thus account for some of the differences noted in the effect of bystander cardiopulmonary resuscitation on survival.

Even if we had no registration of the quality of cardiopulmonary resuscitation in our study, we must assume that there is also an unknown percentage of bystanders giving ineffective bystander cardiopulmonary resuscitation in our system and that this therefore influences our calculations of the effect of bystander cardiopulmonary resuscitation on survival.

Was there a ‘true’ value for the effect of bystander cardiopulmonary resuscitation on survival?

Our study and those of others demonstrate a wide range of effects of bystander cardiopulmonary resuscitation on survival. Our analysis of factors modifying the effect of bystander cardiopulmonary resuscitation also explains these differences in effect to some extent. The effect will vary depending on the distribution of the different modifying factors.

In regions where the majority of bystanders are health care personnel and a high proportion of bystander cardiopulmonary resuscitation was given outside the home, the effect of bystander cardiopulmonary resuscitation on survival would be high. On the other hand, if a high percentage of the bystanders were laypersons and most of the bystander cardiopulmonary resuscitation was started at home, the effect on survival would be much smaller.

Could any of the modifying factors be changed to increase the effect of bystander cardiopulmonary resuscitation on survival?

Some of the factors that were shown to interact with bystander cardiopulmonary resuscitation could not be changed, i.e. age and location of cardiac arrest. On the other hand, the proportion of bystanders that give effective cardiopulmonary resuscitation could be changed by better cardiopulmonary resuscitation training systems, with more time for hands-on practice. The cardiopulmonary resuscitation training could also influence the delay from cardiac arrest to the start of bystander cardiopulmonary resuscitation. The importance of rapid action should be emphasized.

How much could the modifying factors change the effect of bystander cardiopulmonary resuscitation on survival?

From known data, simple calculations could be made that help us to understand the powerful role of these modifying factors. In two studies[5,6], it has been demonstrated that only approximately 50% of bystanders give effective cardiopulmonary resuscitation and that ineffective cardiopulmonary resuscitation does not increase survival. If we assume that this was also true in our study, where the odds ratio for the effect of bystander cardiopulmonary resuscitation on survival was 2.5, the ‘true’ effect of bystander cardiopulmonary resuscitation would be equivalent to an odds ratio of 5.0. Varying the percentage of bystanders giving effective cardiopulmonary resuscitation from 25% to 75% would change the calculated odds ratio for the whole patient material from 1.25 to 3.75.

A change in the median delay from collapse to the start of cardiopulmonary resuscitation would have a similar dramatic effect on the effect of bystander cardiopulmonary resuscitation. If bystander cardiopulmonary resuscitation in all patients was started within the first 2 min and all the other factors remain unchanged, including the distribution of delay times within the first 2 min, the odds ratio for survival would be 8.3. This should be compared with an odds ratio of only 2.9 if bystander cardiopulmonary resuscitation was started later than 2 min after the cardiac arrest in all patients, where the other factors remained unchanged. The effect of bystander cardiopulmonary resuscitation would be more than twice as high for the first alternative.

Limitations of the study

The interaction analyses do not account for intervariable interaction, which could, of course, exist.

The results of this study must be interpreted cautiously. Interaction analysis is a conservative method in which only factors that interact markedly can be identified. Other factors could interact as well, even if they were not identified.

On the other hand, some of the interacting factors might only be surrogate factors. One example from our study is ‘location of arrest’, where it is obvious that location in itself cannot play a role in the effect of bystander cardiopulmonary resuscitation but must mirror some other hidden factor or factors.
Conclusion

The effect of bystander cardiopulmonary resuscitation on survival after out-of-hospital cardiac arrest can be modified by various factors. Factors that were associated with the effect of bystander cardiopulmonary resuscitation were the quality of bystander cardiopulmonary resuscitation, the interval between collapse and the start of bystander cardiopulmonary resuscitation, whether the bystander was a layperson or not, the interval between collapse and the arrival of the ambulance, age and the place of arrest.

This study was supported by grants from the Swedish Heart and Lung Foundation, Stockholm and by the Gothenburg Medical Society, Göteborg.

References


Appendix I