Resuscitation 120 (2017) 88–94

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

Increased survival from out-of-hospital cardiac arrest when off duty medically educated personnel perform CPR compared with laymen☆

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ARTICLE INFO

Article history:
Received 9 May 2017
Received in revised form 16 August 2017
Accepted 23 August 2017

Keywords:
Bystander CPR
Out-of-hospital cardiac arrest
Cardiac arrest
Survival

ABSTRACT

Background: Bystander cardiopulmonary resuscitation (CPR) has been proved to save lives; however, whether survival is affected by the training level of the bystander is not fully described.
Aim: To describe if the training level of laymen and medically educated bystanders affect 30-day survival in out-of-hospital cardiac arrests (OHCA).
Methods: This observational study included all witnessed and treated cases of bystander CPR reported to the Swedish Registry of Cardiopulmonary Resuscitation between 2010 and 2014. Bystander CPR was divided into two categories: (a) lay-byCPR (non-medically educated) and (b) med-byCPR (off duty medically educated personnel).
Results: During 2010–2014, 24,643 patients were reported to the OHCA registry, of which 6850 received lay-byCPR and 1444 med-byCPR; 16,349 crew-witnessed and non-witnessed cases and those with missing information were excluded from the analysis. The median interval from collapse to call for emergency medical services was 2 min in both groups ($p = 0.97$) and 2 min from collapse to start of CPR for lay-byCPR versus 1 min for med-byCPR ($p < 0.0001$). There were no significant differences in CPR methods used; 64.3% (lay-byCPR) and 65.7% (med-byCPR) applied compressions and ventilation, respectively ($p = 0.33$). The 30-day survival was 14.7% for lay-byCPR and 17.2% for the med-byCPR group ($p = 0.02$). The odds ratio adjusted for potential confounders regarding survival (med-byCPR versus lay-byCPR) was 1.34 (95% confidence interval, 1.11–1.62; $p = 0.002$).
Conclusions: In cases of OHCA, medically educated bystanders initiated CPR earlier and an increased 30-day survival was found compared with laymen bystanders. These results support the need to improve the education programme for laypeople.

Introduction

Neurologically intact survival from out of hospital cardiac arrest (OHCA) is dependent on various prehospital factors as the time from collapse to start of cardiopulmonary resuscitation (CPR) and use of an automated external defibrillator [1,2]. Early initiation of CPR increases the chance of survival two to four times [2–5].

An increased level of training within the community increases the proportion of patients receiving CPR before arrival of the emergency medical services (EMS) [4]. In Sweden, more than 3 million people out of a population of 10 million have at any time attended a CPR course in the last three decades [4]. Earlier data showed that survival may be affected by what type of bystander administering CPR [6]. Since that report was published, the proportion of bystander CPR (standard CPR and chest compressions only) has increased even further [7,8]. There is still a limited knowledge regarding the category of bystanders [9] and whether the level of training (laymen or medically educated) affects survival.

The aim of this registry-based observational study was to describe 30-day survival from OHCA after bystander CPR and the actions performed by laymen versus off duty medically educated.

☆ A Spanish translated version of the abstract of this article appears as Appendix in the final online version at http://dx.doi.org/10.1016/j.resuscitation.2017.08.234.

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http://dx.doi.org/10.1016/j.resuscitation.2017.08.234
0300-9572/

Methods

This study is based on data from the Swedish Registry of Cardiopulmonary Resuscitation (SRCR). The study was approved by the Regional Ethical Review Board of Linköping, Sweden (2016/468-31).

The swedish registry of cardiopulmonary resuscitation

Data on OHCA where CPR was attempted have been reported by the EMS system since 1990 to a nationwide Swedish health care quality registry, called the Swedish Registry of Cardiopulmonary Resuscitation (SRCR) [10]. Approximately 5500 cases of OHCA are reported to the register annually [2]. For each case of OHCA, reporting is made in two steps: the incidence and follow-up. The incidence report includes information regarding the patient characteristics, location of OHCA, bystanders' training level (laymen or medically educated), probable cause of OHCA, first recorded electrocardiograph (ECG) rhythm and resuscitation procedures such as bystanders' interventions, response times and treatments. In the register, bystanders trainings level is registered as: lay bystander CPR (lay-byCPR, performed by non-medically educated bystanders), off duty medically educated bystander CPR (med-byCPR, performed by bystanders with some form of health care education, e.g. doctors and nurses who are not responding as part of an EMS system) or unknown training level. The EMS staffs ask and identifies; information on times (e.g. collapse to call, collapse to start of CPR), if bystander CPR has been performed, who the bystander is and if they have medical education. If there is more than one bystander on site, the highest level of the bystanders' education is recorded. The data on OHCA are reported in SRCR by the EMS crews immediately after the incident. An online system for registration was introduced in 2007. No registration should be reported at clear signs of death or when treatment is not started [2].

The dispatchers use a standard protocol with a specific questionnaire for the identification of cardiac arrest. Telephone-assisted CPR is offered the callers who answer that they do not know how to do CPR. The SRCR has been thoroughly described elsewhere [11], as well as the EMS organization [4].

In Sweden, with a population of 10 million inhabitants in an area of 449,964 km^2, all EMS systems in 21 regions participate and report to SRCR. Continuous retrospective searches of EMS case records are performed to ensure that all treated cases of OHCA are reported to SRCR. Thus, today the register covers all treated cases of OHCA [2,10,11].

Study population

All individuals who experienced OHCA witnessed and treated by a bystander and reported to SRCR from January 1, 2010, to December 31, 2014, were included. The following cases were excluded from the final analyses: OHCA witnessed by EMS responders, not witnessed, not known if witnessed, witnessed but not known whether by EMS or bystander, CPR started after arrival of EMS, not known if CPR started before or after arrival of EMS, not known whether CPR was performed by laymen or medical educated and 30-day survival status not known (Fig. 1).

Outcome measures

The primary endpoint was 30-day survival. The secondary endpoints were response times and the interventions performed during the resuscitation (time from collapse to call for EMS and to start of CPR, time from dispatch of EMS until arrival of EMS, time from collapse until defibrillation, proportion of bystanders who performed compressions and ventilations) and cerebral performance category (CPC) score among survivors at discharge from hospital.

Statistical methods

To compare the two training level groups in the univariate analysis, the Fisher exact test was used for dichotomous variables and the Mann-Whitney *U* test for continuous/ordinal variables.

In the multivariable analysis, multiple logistic regression was used to adjust for potential confounders. These included: age (years), sex (male/female), cause of cardiac arrest (CA) (cardiac/other), location of CA (home/other), time from dispatch of EMS to arrival of EMS (minutes), year of CA and initial ECG rhythm (shockable/other). In addition, when analysing the subgroup of patients found in a shockable rhythm we also adjusted for time from collapse to defibrillation (minutes). For both these cohort separate analyses were performed with and without time from collapse to start of CPR (minutes) included in the model. This was performed using complete data analysis (i.e. including only those patients with available data regarding these adjustment variables) as well as using multiple imputations. The latter was regarded as the primary analysis in the study. Missing data were assumed to be missing at random and 50 imputed datasets were generated with the Markov Chain Monte Carlo method and using the expectation-maximization algorithm. The imputation was performed separately for the all patients group and for the subgroup of patients known to have been found in a shockable rhythm. Rubin's rules were used for pooling the results from the imputed datasets.

All tests are two-sided and *p*-values <0.05 were considered statistically significant. All analysis was performed using SAS for Windows v9.3.

Results

From January 1, 2010, to December 31, 2014, a total of 24,643 patients who experienced OHCA for which CPR was attempted were reported to the registry. Among these, 8619 were known to have been witnessed and to have received CPR before the arrival of EMS. In 133 cases, data on whether CPR was performed by laymen or health care providers were unknown, and in 192 cases the 30-day survival status was missing. The remaining 8294 cases (34% of all reports) were included in the final analysis, i.e. patients who experienced bystander witnessed OHCA and received CPR before arrival of EMS and it was known whether CPR was performed by laymen (lay-byCPR, n = 6850) or by off duty medically educated personnel (med-byCPR, n = 1444); and the survival status at 30-day follow-up was available (Fig. 1). The following results refer to these 8294 patients.

Patient characteristics

Seventy percent of all cases of OHCA, in both the lay-byCPR and the med-byCPR groups, were of cardiac origin. Patients who received lay-byCPR differed significantly from those receiving med-byCPR; they were younger, median age 69 versus 77 years ($p < 0.0001$); there were more males, 72% versus 61% ($p < 0.0001$), more frequently had OHCA at home, 67% versus 50% ($p < 0.0001$) and were more frequently found in a shockable rhythm, 36% versus 29% ($p < 0.0001$, Table 1).

CPR actions

The median delay time from collapse to call for EMS was 2 min in both groups. However, the median time from call to dispatch of

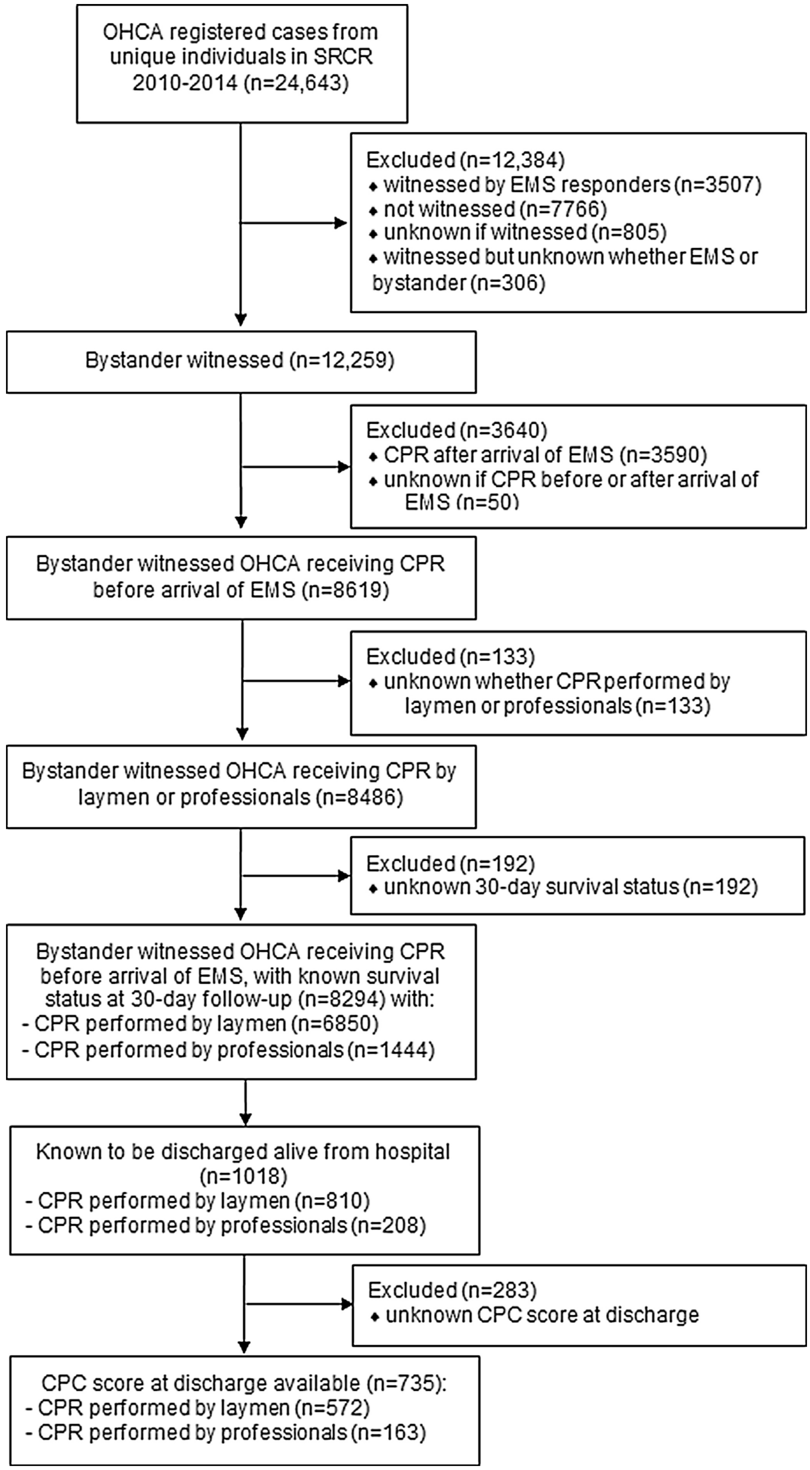

Fig. 1. Flowchart of the study.

Table 1
Baseline characteristics of the patients.

Variable	All patients (n = 8294)	Lay-byCPR (n = 6850)	Med-byCPR (n = 1444)	p value[b]
Median age (10th, 90th percentile), years (150/12)[a]	70 (48,87)	69 (47,86)	77 (53,90)	<0.0001
Female sex, % (0/0)	29.9	27.9	39.3	<0.0001
Cardiac cause of cardiac arrest, % (394/68)	70.3	70.4	69.8	0.70
Collapse at home, % (0/0)	64.4	67.4	50.2	<0.0001
Ventricular fibrillation or ventricular tachycardia as initial ECG rhythm, % (298/68)	35.0	36.3	28.9	<0.0001

ECG, electrocardiographic.

[a] Denotes the number of patients with missing information in the two groups, respectively.

[b] For difference between Lay-byCPR and Med-byCPR.

Table 2
Response times and interventions for OHCA.

Variable	All patients (n = 8294)	Lay-byCPR (n = 6850)	Med-byCPR (n = 1444)	p value[c]
Median intervals (10th, 90th percentile), minutes				
Collapse to call for EMS(1733/344)[a]	2 (0,9)	2 (0,9)	2 (0,9)	0.97
Call for EMS to dispatch of EMS (504/101)	1 (0,3)	1 (0,3)	0 (0,2)	<0.0001
Dispatch for EMS to arrival of EMS (1537/82)	10 (4,22)	11 (5,23)	9 (4,20)	<0.0001
Collapse to start of CPR (729/126)	2 (0,12)	2 (0,13)	1 (0,8)	<0.0001
Collapse to defibrillation[b] (341/42)	13 (6,25)	14 (7,25)	11 (4,23)	<0.0001
Bystander actions performed, %				
Chest compressions only (741/82)	33.5	33.8	32.6	0.43
Ventilation only (741/82)	0.7	0.8	0.4	0.22
Chest compressions and ventilation (741/82)	64.6	64.3	65.7	0.33

EMS, emergency medical services.
[a] Denotes number of patients with missing information in the two groups, respectively.
[b] For patients found with ventricular fibrillation or ventricular tachycardia (n = 2376/397).
[c] For difference between Lay-byCPR and Med-byCPR.

EMS was longer in the lay-byCPR group (1 min) than in the med-byCPR group (0 min, $p < 0.0001$) as time from collapse to start of CPR (2 min vs 1 min, $p < 0.0001$). The median delay from dispatch for EMS to arrival of EMS was also longer in the lay-byCPR group (11 versus 9 min; $p < 0.0001$), as was the median delay from collapse to defibrillation (14 versus 11 min; $p < 0.0001$). However, there was no significant difference in the proportion of patients who received chest compressions only or standard CPR (Table 2).

Survival

The 30-day survival rate was 14.7% for patients who received lay-byCPR and 17.2% for patients who received med-byCPR ($p = 0.02$). Using multiple imputations to handle missing data and adjusting for age, sex, cause of CA, location of CA, dispatch to arrival of EMS, year and initial ECG rhythm, the odds ratio regarding 30-day survival for patients who received med-byCPR in relation to lay-byCPR was 1.34 (95% confidence interval (CI), 1.11–1.62, $p = 0.002$) and 1.24 (95% CI, 1.03–1.50, $p = 0.03$) when also adjusting for time from collapse to start of CPR. In the subgroup of patients found in a shockable rhythm and also adjusting for time from collapse to defibrillation the corresponding odds ratios were 1.20 (95% CI, 0.93–1.54, $p = 0.17$) and 1.15 (95% CI, 0.89-1.49, $p = 0.29$), respectively. Similar results were found when only the patients with complete data on the same covariates were included in the analysis (Table 3).

When analysing subgroups according to baseline characteristics, 30-day survival was significantly higher in the med-byCPR group when patients were younger, were men, had CA of cardiac aetiology and were found in VF/VT. On the other hand, when CA occurred at home survival was significantly higher among those in the lay-byCPR group (Table 4).

Cerebral function among survivors

A total of 1018 patients were known to have survived until discharge and of these information on the CPC score at discharge was available for 735 patients (lay-byCPR, n = 572; med-byCPR, n = 163; Fig. 1). For these patients there was a lower CPC score among those receiving med-byCPR ($p = 0.03$ for trend; Fig. 2).

Discussion

The main finding of this study was that 30-day survival was positively associated with CPR when performed by medically educated bystanders compared with laymen. These results are similar to those previously reported from this register, 6.2% and 10.8% for lay-byCPR and med-byCPR, respectively [6], however with a markedly higher 30-day survival rate in both groups during the present study period, 14.7% and 17.2%, respectively. Thus, 30-day survival appears to have doubled in the last decade in this patient cohort. This was found despite the fact that the proportion of patients found with a shockable rhythm has decreased over time (lay-byCPR, 38% in 2005 versus 36% in 2017; med-byCPR, 44% in 2005 versus 29% in 2017). One of the mechanisms behind the decreased proportion of patients presenting with an initial shockable rhythm may have been the increased response time by the EMS [12,13]. Our findings are in line with other reports in regards to lower incidence of patients in shockable rhythm [14–16]. A higher proportion of patients in the lay-byCPR group were found with a shockable rhythm and, despite this, the survival rate for this group was lower than that of the med-byCPR group. The mechanisms behind the difference in survival between the two bystander categories are unclear and we can only speculate on potential factors. Overall, cerebral function for most of the survivors was favourable in both groups. Hansen et al. [1] reported that bystander initiated CPR is associated with an improvement in neurological outcomes.

Treatment goals for OHCA in the community, as stated by the Swedish Resuscitation Council, suggest that a call to EMS and the start of CPR should be initiated within 1 min and defibrillation should be performed within 5 min after collapse. In the present study, the median time from collapse to the call for EMS was 2 min in both groups. As in our study, the study reported in 2005 described earlier initiation of CPR by medically educated bystanders. A contributing factor might that CPR instructions are only given to callers who do not know how to do CPR. A contributing factor explaining the reduced time from collapse to defibrillation seen in the medical cohort may be the difference in response time by the EMS (9 min versus 11 min). This finding may be explained by the fact that intervention by a lay bystander was more common at home, which might be associated with longer geographic distances. Prehospital predictors of increased survival rates include a shorter EMS response time, a shorter time to CPR and a shorter time to defibrillation [3,17,18]. Thereby, the improved outcome observed in the med-byCPR group may partly be a result of earlier CPR and defibrillation. The multivariable analysis, when adjusting for time from collapse to start of CPR, suggests that the time interval is important, but does not fully explain the difference in survival between the groups.

Strömsöe et al. [19] speculate that if the time interval from OHCA to call for EMS, from OHCA to start of CPR and to first defibrillation could be improved, an additional 300–400 patients could be successfully resuscitated in Sweden each year. Based on the results of the present study, the time interval from collapse to call for EMS needs to be reduced for both bystander groups. Lay bystanders also need to reduce the time interval from collapse to start of CPR. Thus,

Table 3
Multivariable analyses of 30-day survival: 2010–2014.

	Lay-byCPR, number	Med-byCPR, number	Lay-byCPR, % survival	Med-byCPR, % survival	OR (95% CI)[a]	p
All Patients						
Complete case analysis 1[b]						
Unadjusted[b]	4772	1248	13.2	15.0	1.16 (0.97,1.38)	0.10
Adjusted[c]	4772	1248			1.28 (1.03,1.60)	0.02
Complete case analysis 2[b]						
Unadjusted[b]	4403	1181	13.2	15.1	1.17 (0.97,1.40)	0.10
Adjusted[d]	4403	1181			1.22 (0.97,1.52)	0.09
Multiple imputation of missing data						
Unadjusted	6850	1444	14.7	17.2	1.20 (1.03,1.40)	0.02
Adjusted[c]	6850	1444			1.34 (1.11,1.62)	0.002
Adjusted[d]	6850	1444			1.24 (1.03,1.50)	0.03
VT/VF Patients						
Complete case analysis 3[b]						
Unadjusted[b]	1573	327	29.1	40.4	1.65 (1.29,2.11)	<0.0001
Adjusted[e]	1573	327			1.21 (0.90,1.62)	0.20
Complete case analysis 4[b]						
Unadjusted[b]	1533	324	29.1	40.4	1.65 (1.29,2.12)	<0.0001
Adjusted[f]	1533	324			1.18 (0.88,1.58)	0.28
Multiple imputation of missing data						
Unadjusted	2376	397	30.3	40.3	1.55 (1.25,1.93)	<0.0001
Adjusted[e]	2376	397			1.20 (0.93,1.54)	0.17
Adjusted[f]	2376	397			1.15 (0.89,1.48)	0.29

VF, ventricular fibrillation; VT, ventricular tachycardia; CA, cardiac arrest; EMS, emergency medicine services.
[a] Odds ratio and corresponding confidence interval for med-byCPR in relation to lay-byCPR regarding 30-day survival.
[b] For patients with no missing data on the adjustment variables as defined in[c,d,e] and [f] below, respectively.
[c] Adjusted for age, sex, cause of CA, location of CA, time from dispatch to arrival of EMS, initial ECG rhythm and year of CA.
[d] Adjusted for age, sex, cause of CA, location of CA, time from dispatch to arrival of EMS, initial ECG rhythm, year of CA and time from collapse to start of CPR.
[e] Adjusted for age, sex, cause of CA, location of CA, time from dispatch to arrival of EMS, time from collapse to defibrillation and year of CA.
[f] Adjusted for age, sex, cause of CA, location of CA, time from dispatch to arrival of EMS, time from collapse to defibrillation, year of CA and time from collapse to start of CPR.

Table 4
Subgroup analyses of 30-day survival.

	Lay-byCPR, n	Med-byCPR, n	Lay-byCPR, % survival	Med-byCPR, % survival	OR (95% CI)[a]	p
Age						
≤70 years	3584	520	20.3	29.6	1.65 (1.34,2.03)	<0.0001
>70 years	3116	912	8.5	10.3	1.24 (0.97,1.59)	0.09
Sex						
Female	1914	567	8.8	10.1	1.16 (0.85,1.59)	0.35
Male	4936	877	17.0	21.8	1.36 (1.14,1.62)	0.0007
Cause of CA						
Cardiac	4544	961	15.4	18.6	1.26 (1.05,1.51)	0.01
Non-cardiac	1912	415	13.3	12.5	0.93 (0.68,1.28)	0.66
Location of cardiac arrest						
At home	4614	725	9.5	5.5	0.56 (0.40,0.78)	0.0006
Other location	2236	719	25.6	28.9	1.18 (0.98,1.43)	0.08
Initial ECG rhythm						
VF/VT	2376	397	30.3	40.3	1.55 (1.25,1.93)	<0.0001
Asystole or pulseless electrical activity	4176	979	4.1	5.5	1.35 (0.99,1.85)	0.06
Year of CA						
2010	1200	261	12.1	16.5	1.44 (0.99,2.08)	0.06
2011	1382	289	15.4	18.0	1.20 (0.86,1.68)	0.28
2012	1413	300	14.5	15.7	1.10 (0.78,1.54)	0.61
2013	1443	311	15.0	17.4	1.19 (0.86,1.65)	0.30
2014	1412	283	16.2	18.4	1.16 (0.83,1.62)	0.37

CA denotes cardiac arrest; ECG, electrocardiographic; EMS, emergency medical services; VF, ventricular fibrillation; VT, ventricular tachycardia.
[a] Odds ratio and corresponding 95% confidence interval for med-byCPR in relation to lay-by CPR regarding 30-day survival.

at CPR training, it is important to further emphasize early call for help, early start of CPR and early defibrillation [20–22]. Additionally, the emergency medical dispatcher has a key-role to support the bystander in identifying the cardiac arrest and how to act during the resuscitation [3]. Some studies report limited bystander performance and that CPR could be significantly improved [23,24]. Despite this, Hasselqvist et al. [4] showed a linear relationship between the increased proportion of people in the community who were trained in CPR and the increased proportion of OHCA patients who received CPR before arrival of EMS. They found a significantly higher 30-day survival rate among patients who received bystander CPR.

According to the European Resuscitation Council guidelines, high-quality CPR is essential for improving outcomes [3].

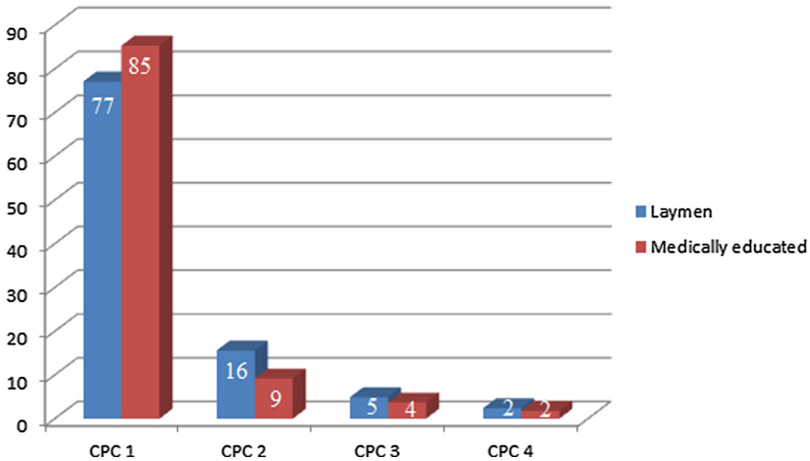

Fig. 2. Cerebral performance categories (CPC) score at discharge. Results are presented as percentages.

Talikowska et al. [25] state in a review that the quality of chest compressions is associated with improved patient survival. High-quality CPR emphasizes compressions of adequate depth and rate, full chest recoil after each compression, minimizing pauses in compressions and avoiding excessive ventilation [26,27]. As a support for the rescuer, the emergency medical dispatcher has an important supporting role to provide the caller with telephone assistance on CPR (i.e. instructions on how to perform CPR) [3]. In Sweden, the dispatcher-assisted CPR system was introduced in 1998. Previous participation in practical CPR training increases bystanders' willingness to intervene in emergencies with their practical CPR skills [20,28–31]. Unfortunately, practical CPR skills decline 3–6 months after initial training [20,31]. Repeated short cycles of CPR training (of health care professionals) at frequent intervals within a year leads to better quality CPR compared with less frequent training sessions [32,33]. Therefore, frequent brief retraining sessions may be essential [20].

We speculate that the factors contributing to the overall increased survival rate during the last decade (despite the fact that the proportion of patients with an initial shockable rhythm decreased over time and the EMS response time increased) include large-scale teaching of CPR to laymen, possibly improved quality of CPR, the implementation of telephone-assisted CPR and probably generally better reporting from EMS [4,8]. To improve survival after OHCA, bystanders' interventions are crucial [1,13,20]. New techniques as using smartphones apps and mobile-phone text-messages increase the rate of bystander-initiated CPR and contribute to earlier defibrillation at OHCA [34,35]. In most cases of OHCA witnessed by a bystander, CPR was administered by lay persons (83%), thus it is important to train the public in CPR. The present study supports the need for further large-scale teaching of lay people [20,21]. A important step in increasing the rate of bystander CPR is to educate all school children, by legislate mandatory CPR training in the school curriculum [36]. The Swedish compulsory school curriculum specifies, since 2011, that CPR skills are a core content in grade 7–9 [37]. However, the most optimal method and frequency of training is unclear and further research is needed [20,27,38].

Limitations

This study includes only cases of OHCA witnessed by a bystander. Thus, a large number of unwitnessed cases were excluded from the analysis. Furthermore, as an observational register study, the well-known drawback of unobserved potentially important confounders could have biased the results, compared with a randomized clinical trial. Data are reported to the registry retrospectively and there were varying amounts of data missing for most variables. However, Strömsöe et al. [11] did not find a marked difference between cases reported prospectively and those reported retrospectively within this database. There is a risk that some medically educated bystanders training level can be missed. However, if the medically educated training level has been missed, it would rather lessen than enhance any differences between groups. There is also a risk that medically educated bystanders might not start CPR on patients that are clearly deceased, which may lead to selection bias and improved survival in med-byCPR group. We do not know anything about the accuracy of times estimated by bystanders, the quality of CPR performed or the number of bystanders being present during the resuscitation and there is no data available on whether the bystanders had previously participated in CPR training. In this study, we could not report the rate of those alive when hospitalized. However, Nordberg et al. [39] showed that improvement in pre-hospital actions resulted in increased survival (ROSC as well as in long term) after OCHA, mainly in the pre-hospital phase.

Conclusions

Medically educated bystanders initiated CPR earlier in cases of OCHA and such an intervention was associated with an increased 30-day survival compared with interventions performed by lay bystanders. However, even when CPR was started by lay bystanders, the 30-day survival rate was higher than previously reported data from this register. Thus, our results support an improvement in education programmes of lay people, with more focus on early call to EMS and early start of high-quality CPR.

Conflict of interest statement

None declared.

Contributors

AN contributed to the study design, analysed the results and wrote the initial draft of the manuscript. LN, LS, AC and JH contributed to the study design, analysed the results and revised the manuscript. TK contributed to the study design, performed statistical analysis, analysed the results and revised the manuscript.

Acknowledgments

The study was supported by the Foundation for Cardiopulmonary Resuscitation in Sweden, the Swedish Resuscitation Council, the Swedish Heart-Lung Foundation (award number 20130629) and the County Council of Östergötland. The funders had no role in the study design, data analysis, decision to publish, or preparation of the manuscript.

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