Circulation

ORIGINAL RESEARCH ARTICLE

Survival in Out-of-Hospital Cardiac Arrest After Standard Cardiopulmonary Resuscitation or Chest Compressions Only Before Arrival of Emergency Medical Services

Nationwide Study During Three Guideline Periods

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BACKGROUND: In out-of-hospital cardiac arrest, chest compression–only cardiopulmonary resuscitation (CO-CPR) has emerged as an alternative to standard CPR (S-CPR), using both chest compressions and rescue breaths. Since 2010, CPR guidelines recommend CO-CPR for both untrained bystanders and trained bystanders unwilling to perform rescue breaths. The aim of this study was to describe changes in the rate and type of CPR performed before the arrival of emergency medical services (EMS) during 3 consecutive guideline periods in correlation to 30-day survival.

METHODS: All bystander-witnessed out-of-hospital cardiac arrests reported to the Swedish register for cardiopulmonary resuscitation in 2000 to 2017 were included. Nonwitnessed, EMS-witnessed, and rescue breath–only CPR cases were excluded. Patients were categorized as receivers of no CPR (NO-CPR), S-CPR, or CO-CPR before EMS arrival. Guideline periods 2000 to 2005, 2006 to 2010, and 2011 to 2017 were used for comparisons over time. The primary outcome was 30-day survival.

RESULTS: A total of 30 445 patients were included. The proportions of patients receiving CPR before EMS arrival changed from 40.8% in the first time period to 58.8% in the second period, and to 68.2% in the last period. S-CPR changed from 35.4% to 44.8% to 38.1%, and CO-CPR changed from 5.4% to 14.0% to 30.1%, respectively. Thirty-day survival changed from 3.9% to 6.0% to 7.1% in the NO-CPR group, from 9.4% to 12.5% to 16.2% in the S-CPR group, and from 8.0% to 11.5% to 14.3% in the CO-CPR group. For all time periods combined, the adjusted odds ratio for 30-day survival was 2.6 (95% CI, 2.4–2.9) for S-CPR and 2.0 (95% CI, 1.8–2.3) for CO-CPR, in comparison with NO-CPR. S-CPR was superior to CO-CPR (adjusted odds ratio, 1.2; 95% CI, 1.1–1.4).

CONCLUSIONS: In this nationwide study of out-of-hospital cardiac arrest during 3 periods of different CPR guidelines, there was an almost a 2-fold higher rate of CPR before EMS arrival and a concomitant 6-fold higher rate of CO-CPR over time. Any type of CPR was associated with doubled survival rates in comparison with NO-CPR. These findings support continuous endorsement of CO-CPR as an option in future CPR guidelines because it is associated with higher CPR rates and overall survival in out-of-hospital cardiac arrest.

Key Words: cardiopulmonary resuscitation ■ heart arrest ■ life support systems ■ out-of-hospital cardiac arrest

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Clinical Perspective

What Is New?

- In this nationwide study running over 3 guideline periods with gradual adoption of compression-only cardiopulmonary resuscitation (CPR), there was a 6-fold higher proportion of patients receiving compression-only CPR and a concomitant almost doubled rate of CPR before emergency medical services arrival over time.
- Any type of CPR was associated with doubled survival rates in comparison with cases not receiving CPR before emergency medical services arrival and this association was observed in all time periods studied.
- We found a small but significantly higher chance of survival after CPR with compression and ventilation in comparison with compression-only CPR.

What Are the Clinical Implications?

- These findings support continuous endorsement of compression-only CPR as an option in CPR guidelines because it is associated with CPR rates and overall survival in out-of-hospital cardiac arrest.
- Randomized, controlled trials are needed to answer the question of whether or not CPR with compression and ventilation is superior to compression-only CPR in cases in which the bystanders have had previous CPR training.

Bystander-initiated cardiopulmonary resuscitation (CPR) is a strong predictor of survival in out-of-hospital cardiac arrest (OHCA).[1,2] Since first described in the 1960s, CPR has consisted of repeated chest compression alternated with rescue breaths.[3] The effect of chest compression is well established, but the importance of mouth-to-mouth ventilation, as part of bystander-initiated CPR, is less clear. The concept of chest compression–only CPR (CO-CPR) has emerged as an alternative to standard CPR (S-CPR) with both chest compression and rescue breaths, because CO-CPR is easier to teach and perform and may be associated with increased CPR rates, and thereby with a higher rate of overall survival.[4,5] Swedish national CPR guidelines were modified in 2006, 2011, and 2016 in accordance with International Liaison Committee on Resuscitation and European Resuscitation Council guideline updates in 2005, 2010, and 2015. In 2005, there was a shift in the compression to ventilation ratio from 15:2 to 30:2, and CO-CPR was introduced as an option if the bystander was unable or unwilling to perform rescue breaths.[6] In the 2010 guidelines, CO-CPR was recommended for dispatcher-assisted CPR (DA-CPR; ie, instructions to bystanders not trained in CPR).[7] The guideline recommendations in 2010 were supported by the results of 2 randomized studies performed in Europe and the United States, and they placed high value on avoiding harm such as that arising from not performing CPR, or performing CPR with poor chest compression and ventilation.[8,9] In the 2015 guidelines, these recommendations remained unchanged, with emphasis on the medical dispatcher's role in identifying cardiac arrest and providing DA-CPR.[10] Changes in CPR rates, methods of CPR, and the impact on 30-day survival after these modifications in recommendations are unclear.

The aim of this study is 2-fold: first, to describe overall rates of CPR before the arrival of emergency medical services (EMS) and changes in type of CPR in 3 consecutive guideline periods; and second, to assess the association between type of CPR and 30-day survival.

METHODS

Study Design

This is an observational nationwide register-based cohort study. The study received ethics approval from the regional ethics board in Stockholm (Dnr 2016/1532-31). Informed consent was not required. The data that support the findings of this study are available from the corresponding author on reasonable request.

Swedish Register for Cardiopulmonary Resuscitation

The Swedish Register for Cardiopulmonary Resuscitation (SRCR) is a national quality register for reporting OHCA in Sweden.[11] All EMS organizations in all 21 regions in Sweden participate in reporting data to the SRCR. It contains variables in accordance with a standardized (Utstein) template for reporting factors at resuscitation.[12] Incidence reports are completed by the EMS crew after attending an OHCA and include patient characteristics, location of the arrest, probable cause of the arrest, and if the arrest was witnessed. If CPR was initiated before EMS arrival, the method of CPR is classified according to whether chest compression and rescue breaths were provided. The highest medical educational level of the persons performing CPR before EMS arrival is noted. The report also includes first recorded rhythm, EMS time delays, and EMS interventions.

Reports are entered in the register only if EMS or bystanders attempted resuscitation. A physician at each regional level reviews the reports, and data on 30-day survival are obtained through the Swedish population register. Dispatchers follow a standardized protocol for the identification of cardiac arrest. If the caller does not know how to perform CPR, he or she is offered DA-CPR. The incidence of DA-CPR has been recorded in the SRCR since 2007. The register has previously been described elsewhere.[13] From February 2005 through January 2009, there was a randomized, controlled trial concerning instructions to provide CO-CPR or S-CPR at the dispatch center and covering a total of 1276 patients. Participants in this trial were not noted in the SRCR.[8]

Data Collection and Study Population

All consecutive OHCAs recorded in the SRCR between 2000 and 2017 were collected. All ages and etiologies were included. Excluded cases were: OHCAs witnessed by the EMS, nonwitnessed OHCAs, rescue breath–only CPR, cases with no data on type of CPR, and cases with missing data on 30-day survival. Patients enrolled in an ongoing randomized trial conducted to compare CO-CPR with S-CPR were also excluded (Figure 1, flowchart).

Exposure

Included patients were categorized according to 3 types of exposure. If CPR was not initiated before EMS arrival, the case was categorized as NO-CPR. If chest compressions were provided, but rescue breaths were not attempted, the case was categorized as CO-CPR. Finally, if both chest compression and rescue breaths were provided, the case was categorized as S-CPR.

Outcome

The primary outcome was 30-day survival.

Statistical Analyses

To adjust for potential confounders, predefined baseline variables available during the complete time period were obtained. These included: patient's age (years), sex (male/female), etiology (cardiac/noncardiac), location of the cardiac arrest (residential/public area), EMS response time (time from incoming call to dispatch center to EMS arrival in minutes), initial rhythm (ie, ventricular tachycardia/ventricular fibrillation [VT/VF] or

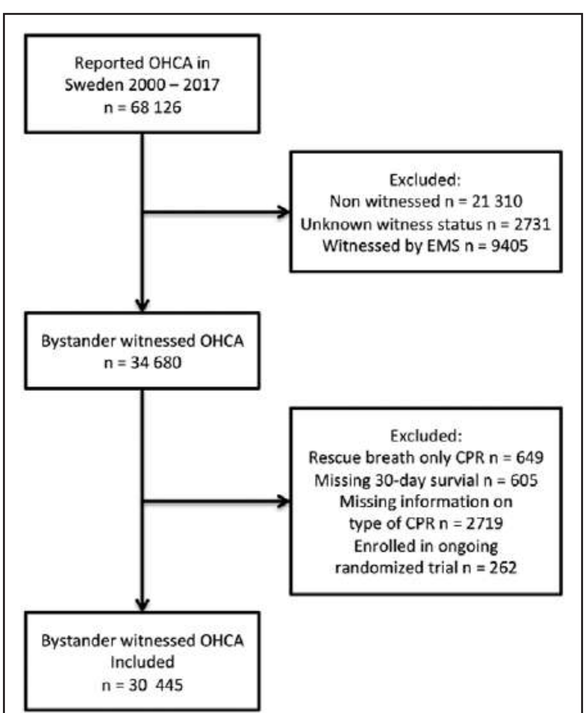

Figure 1. Flowchart, patient inclusion.
CPR indicates cardiopulmonary resuscitation; EMS, emergency medical services; and OHCA, out-of-hospital cardiac arrest.

asystole/pulseless electric activity), calendar year of OHCA, and medical education of the persons performing CPR (medical education [physician, nurse/nursing assistant]/no medical education). Finally, DA-CPR (yes/no) in 2007 to 2017 was noted.

EMS response time and age were treated as continuous variables, calendar year was treated as a categorical variable, and all other variables were treated as dichotomous.

Time periods according to guideline alterations were defined by using calendar years (2000–2005, 2006–2010, and 2011–2017) and used as stratification variables.

To account for missing data (18.4%), multiple imputations were used to impute baseline variables. Missing data on outcome (30-day survival) and exposure (type of CPR) were not imputed. Missing data were assumed to be missing at random, and 30 data sets were imputed using multiple imputations by chained equations.[14] The multiple imputation procedure was used for each of the time periods and all time periods combined. Continuous variables were imputed by predictive mean matching, dichotomous variables by logistic regression, and categorical variables by multinomial logistic regression.

First, CO-CPR and S-CPR were compared with NO-CPR by using multiple logistic regression analyses, adjusting for etiology, sex, age, location, EMS response time, and the year of OHCA. Regression analysis was performed for each of the time periods and all time periods combined. Logistic regression analysis was used for each of the imputed data sets and the results were pooled using Rubin rules.

To test the total effect of CPR, initial rhythm (VT/VF or asystole/pulseless electric activity) was excluded from the primary model because it is potentially influenced by CPR and can be viewed as a mediator of CPR effect.[15] However, because VT/VF is a strong predictor of survival and might be unevenly distributed between the groups for other reasons, secondary analyses including initial rhythm in the model were also performed. The incidence of DA-CPR was not included in the model, because data have been available in the SRCR only since 2007.

Second, the same regression analyses were repeated without using multiple imputations. This approach was also used for subgroup analyses. Subgroups were constructed for sex, age, location of OHCA, cardiac and noncardiac causes of arrest, and EMS response time (0–4 minutes, 5–9 minutes, 10–14 minutes, 15–19 minutes, and ≥20 minutes). In the subgroup analysis, we used the same logistic regression analysis, adjusting for age, sex, etiology, location, EMS response time, and year of OHCA, excluding the specific variable analyzed in each subgroup. Bonferroni correction was used to counterbalance multiple testing.

Finally, S-CPR was compared with CO-CPR. Multiple imputations were used to impute missing baseline variables and multiple logistic regressions to adjust for the same variables as described above, plus the educational level of providers of CPR before EMS arrival.

Categorical variables are presented as proportions and continuous variables as medians (with quartile 1 through quartile 3). Differences in proportions were tested by using the Pearson χ^2 test and differences in medians by using the Kruskal-Wallis test. Differences were considered statistically significant if P was <0.05. To test for changes over time, we performed Cochran Armitage tests for trend. All statistical analyses were performed using R, version 3.4.3 (R Foundation for Statistical Computing, 2017).

Table 1. Distributions of Baseline Variables, by CPR Group, Years 2000 to 2017

Baseline Variables	NO-CPR	S-CPR	CO-CPR
Patients, n (%)	12 186 (40.0)	11 920 (39.2)	6339 (20.8)
Age in years, median (IQR)	75 (65–82)	70 (59–79)	72 (62–81)
Female sex, n (%)	3864 (32.2)	3409 (28.9)	1927 (30.5)
Location, residential, n (%)	8431 (69.4)	7627 (64.3)	4298 (68.0)
Cardiac cause, n (%)	7900 (68.5)	7971 (70.0)	4236 (68.7)
First rhythm VT/VF, n (%)	2700 (23.8)	4110 (36.8)	2038 (33.1)
EMS response time, minutes, median (IQR)	7 (4–10)	10 (6–15)	8 (5–12)
Lay bystander, n (%)	NA	8180 (74.9)	5142 (84.7)
Bystander with medical education, n (%)	NA	2736 (25.1)	929 (15.3)
30-day survival, n (%)	706 (5.8)	1647 (13.8)	853 (13.5)

CO-CPR indicates chest compression–only cardiopulmonary resuscitation; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; IQR, interquartile range; NA, not available; NO-CPR, no cardiopulmonary resuscitation; S-CPR, standard cardiopulmonary resuscitation; VF, ventricular fibrillation; and VT, ventricular tachycardia.

RESULTS

During the study period, 68 126 EMS-treated cases of OHCA were recorded in the SRCR. After exclusion of cases that were nonwitnessed, EMS-witnessed, cases that received rescue breath–only CPR, and cases of missing data on type of CPR or 30-day survival, a total of 30 445 OHCAs remained and were included in the analysis (Figure 1, flowchart).

Patient Characteristics

Of the included patients, 40.0% received NO-CPR, 39.2% received S-CPR, and 20.8% received CO-CPR (Table 1). The NO-CPR group had the highest median age, the highest proportion of women, and the highest proportion of arrests occurring at home. This group also had the lowest proportion with cardiac etiology and VT/VF as the initial rhythm. The median EMS response time was significantly different between groups; in the NO-CPR group, it was 7 minutes, in the S-CPR group it was 10 minutes, and in the CO-CPR group it was 8 minutes. The proportion of medically educated bystanders was higher in the S-CPR group than in the CO-CPR group (25.1% versus 15.3%). The distribution of missing variables is presented in Table I in the online-only Data Supplement, and baseline variables for each time period are shown in Table II in the online-only Data Supplement.

Changes in CPR Rates

In Figure 2, the rates of NO-CPR, S-CPR, and CO-CPR for each year are shown. Comparing the different time periods, the proportion of patients receiving any type of CPR before EMS arrival changed from 40.8% in the first time period to 58.8% in the second period to 68.2% in the last time period. The proportion of patients receiving S-CPR changed from 35.4% to 44.8% to 38.1%, and the proportion receiving CO-CPR changed from 5.4% to 14.0% to 30.1%, respectively. The proportion of CO-CPR changed for both bystanders with medical and no medical education during the study period (Table III in the online-only Data Supplement). Among patients receiving CPR before EMS arrival, DA-CPR changed from 35.0% in 2007 to 49.0% in 2017 (Table IV in the online-only Data Supplement).

Thirty-Day Survival

Thirty-day survival was higher in the later time periods for all groups, as shown in Figure 3. Both S-CPR and CO-CPR were associated with higher survival in all time periods.

Overall, 30-day survival was 5.8% among patients receiving NO-CPR, 13.8% among patients receiving S-CPR, and 13.5% among patients receiving CO-CPR (Table 2). After multiple imputations, adjusting for differences in baseline characteristics, both the S-CPR and CO-CPR groups showed higher odds ratios (ORs) for survival than the NO-CPR group (2.6; 95% CI, 2.4–2.9 and 2.0; 95% CI, 1.8–2.3, respectively). When initial rhythm was included in the model, S-CPR and CO-CPR remained associated with higher survival, but the adjusted ORs where lower (2.0; 95% CI; 1.8–2.2 and 1.6; 95%; CI 1.4–1.8, respectively). For all analyses adjusted for initial rhythm, see Table V in the online-only Data Supplement and Figures I and II in the online-only Data Supplement.

When analyzing cases without using multiple imputations, the associations were similar: OR, 2.6 (95% CI, 2.4–2.9) and OR, 2.0 (95% CI, 1.8–2.2) for S-CPR and CO-CPR, respectively (Figure 4). When the analyses were restricted to the last guideline period, excluding patients who received DA-CPR, the adjusted ORs were 2.8 (95% CI, 2.4–3.3) for S-CPR and 2.4 (95% CI, 2.0–2.8) for CO-CPR.

In comparison of S-CPR with CO-CPR there was no difference in overall 30-day survival (13.8% versus 13.5% [OR, 1.03; 95% CI, 0.94–1.13]), but after adjusting for baseline characteristics and factors at resuscitation, S-CPR was associated with a significantly higher chance of 30-day survival (OR, 1.2; 95% CI, 1.1–1.4; Table VI in the online-only Data Supplement).

Subgroup Analyses of 30-Day Survival

In Figure 4, 30-day survival and adjusted ORs in subgroups are presented. After adjustments, there were similar associations with regard to cardiac and noncardiac etiology, age, and location in comparison of the S-CPR and CO-CPR groups with the NO-CPR group.

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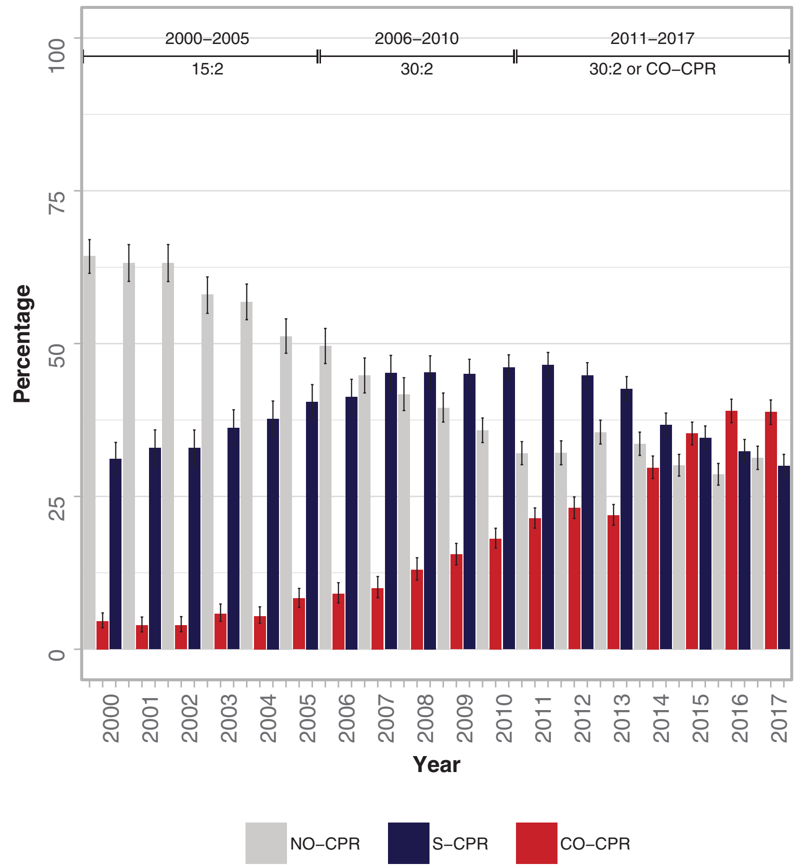


Guideline period	2000–2005	2006–2010	2011–2017
NO–CPR, n (%)	3834/6472 (59.2)	3050/7403 (41.2)	5240/16463 (31.8)
S–CPR, n (%)	2288/6472 (35.4)	3318/7403 (44.8)	6273/16463 (38.1)
CO–CPR, n (%)	350/6472 (5.4)	1035/7403 (14.0)	4950/16463 (30.1)

Figure 2. Percentage of NO-CPR, S-CPR, and CO-CPR, by year and guideline period.
CO-CPR indicates chest compression–only cardiopulmonary resuscitation; NO-CPR, no cardiopulmonary resuscitation; and S-CPR, standard cardiopulmonary resuscitation.

Among women, survival was lower in all groups in comparison with men, and the association with survival after CPR was less pronounced. For EMS response times, the adjusted OR for 30-day survival was higher in both the S-CPR and CO-CPR groups when EMS response times where shorter than 10 minutes. When EMS response times were 10 to 14 minutes there was no statistically significant benefit of CO-CPR, but S-CPR remained associated with higher survival. For EMS response times longer than 14 minutes, neither type of CPR was associated with higher survival in comparison with NO-CPR.

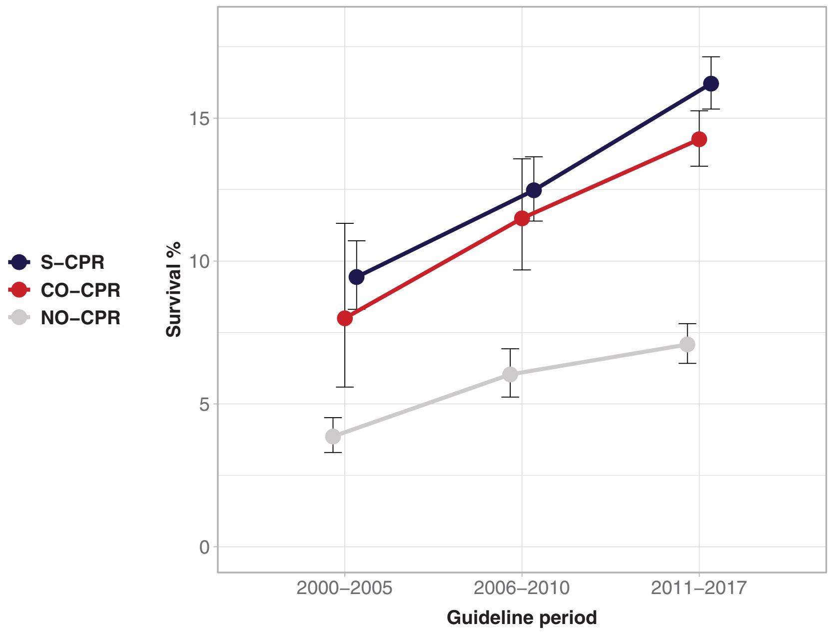
DISCUSSION

In this national register study performed during 3 consecutive time periods of different CPR guidelines, our main finding was a 6-fold higher proportion of patients receiving CO-CPR and an almost doubled rate of CPR before EMS arrival over time. Patients in both the S-CPR group and the CO-CPR group showed doubled survival rates in comparison with those not receiving CPR before EMS arrival.

CO-CPR Is Associated With Higher Rates of Bystander-Initiated CPR

Barriers to the initiation of bystander CPR include fear of being incapable, causing harm, and infection.[16] CO-CPR is easier to perform for the bystander and could theoretically be associated with increased CPR rates.[5] Our findings indicate that the endorsement of CO-CPR in CPR guidelines is associated with higher overall CPR rates, which may be linked with overall survival. This is in line with previous findings reported from the United States and Japan.[4,17]

The reasons for the change in CO-CPR (and overall bystander-initiated CPR) over time are probably multifactorial. New guidelines published in 2010, where instructions to perform CO-CPR in cases of DA-CPR



	Type of CPR	2000–2005	2006–2010	2011–2017
30–day survival	NO–CPR	148/3834 (3.9 %)	184/3050 (6.0 %)	371/5240 (7.1 %)
	S–CPR	216/2288 (9.4 %)	414/3318 (12.5 %)	1017/6273 (16.2 %)
	CO–CPR	28/350 (8.0 %)	119/1035 (11.5 %)	706/4950 (14.3 %)
MI AOR*	NO–CPR	ref	ref	ref
	S–CPR	3.07 (2.44–3.87)	2.44 (2.02–2.95)	2.61 (2.28–2.97)
	CO–CPR	1.90 (1.23–2.94)	1.85 (1.44–2.38)	2.11 (1.84–2.43)

Figure 3. Thirty-day survival for each category of CPR, by guideline period (%).
AOR indicates adjusted odds ratio; CO-CPR, chest compression–only cardiopulmonary resuscitation; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; MI, multiple imputations; NO-CPR, no cardiopulmonary resuscitation; OHCA, out-of-hospital cardiac arrest; and S-CPR, standard cardiopulmonary resuscitation. *Adjusted for age, sex, cause, location, EMS response time, and year of OHCA.

were introduced, represent a potential contributor. Also, even before the new recommendation for CO-CPR in 2010, a randomized trial performed to compare instructions to perform CO-CPR with instructions to perform S-CPR for untrained bystanders was ongoing in Sweden in 2005 to 2009 and probably had an influence on the change of CO-CPR at that time. However, the proportion of patients with bystander CPR who received DA-CPR in 2007 to 2015 was stable at ≈40%, and we do not believe that it explains the whole change in CO-CPR. In a recent study by Nord et al,[18] CO-CPR was used in an equal manner among both lay bystanders and bystanders with medical education in 2010 to 2014, implying that even highly trained bystanders perform CO-CPR even if they are trained to give rescue breaths. Reasons for this could include focus on minimizing interruptions in chest compressions, and the introduction of CO-CPR as an option in CPR training, as well, during the later time period of the study. One could speculate that CPR-trained bystanders to some extent misinterpreted or chose to interpret the new guidelines to the advantage of CO-CPR. Finally, campaigns from abroad such as the American Heart Association's initiative Hands Only CPR and dissemination of the concept of CO-CPR in social media could have influenced public awareness and opinion of CO-CPR.[5]

Is CO-CPR Equally Effective as Standard CPR?

We found no difference in crude 30-day survival rates between patients receiving S-CPR versus CO-CPR, but after adjustment there was a significantly higher chance of survival in favor of S-CPR. This is in line with the results of a large observational study by Kaneko et al.[19] Our finding is important, but we were not able to adjust for potential confounders such as the use of DA-CPR (because data were not available for the whole time period) or previous CPR training among lay

Table 2. Thirty-Day Survival, Year 2000 to 2017

CPR Group	No. of Patients (%)	Unadjusted OR (95% CI)	AOR* (95% CI)	AOR VT/VF† (95% CI)
NO-CPR	706/12 186 (5.8)	Ref	Ref	Ref
S-CPR	1647/11 920 (13.8)	2.61 (2.38–2.86)	2.61 (2.37–2.88)	1.99 (1.79–2.20)
CO-CPR	853/6339 (13.5)	2.53 (2.28–2.81)	2.01 (1.80–2.25)	1.58 (1.40–1.78)

AOR indicates adjusted odds ratio; CO-CPR, chest compression–only cardiopulmonary resuscitation; EMS, emergency medical services; NO-CPR, no cardiopulmonary resuscitation; OR, odds ratio; S-CPR, standard cardiopulmonary resuscitation; VF, ventricular fibrillation; and VT, ventricular tachycardia.

*AOR (after multiple imputation), adjusted for age, sex, cause, location, EMS response time, and year of out-of-hospital cardiac arrest.

†AOR VT/VF=AOR+adjusted also for first rhythm VT/VF.

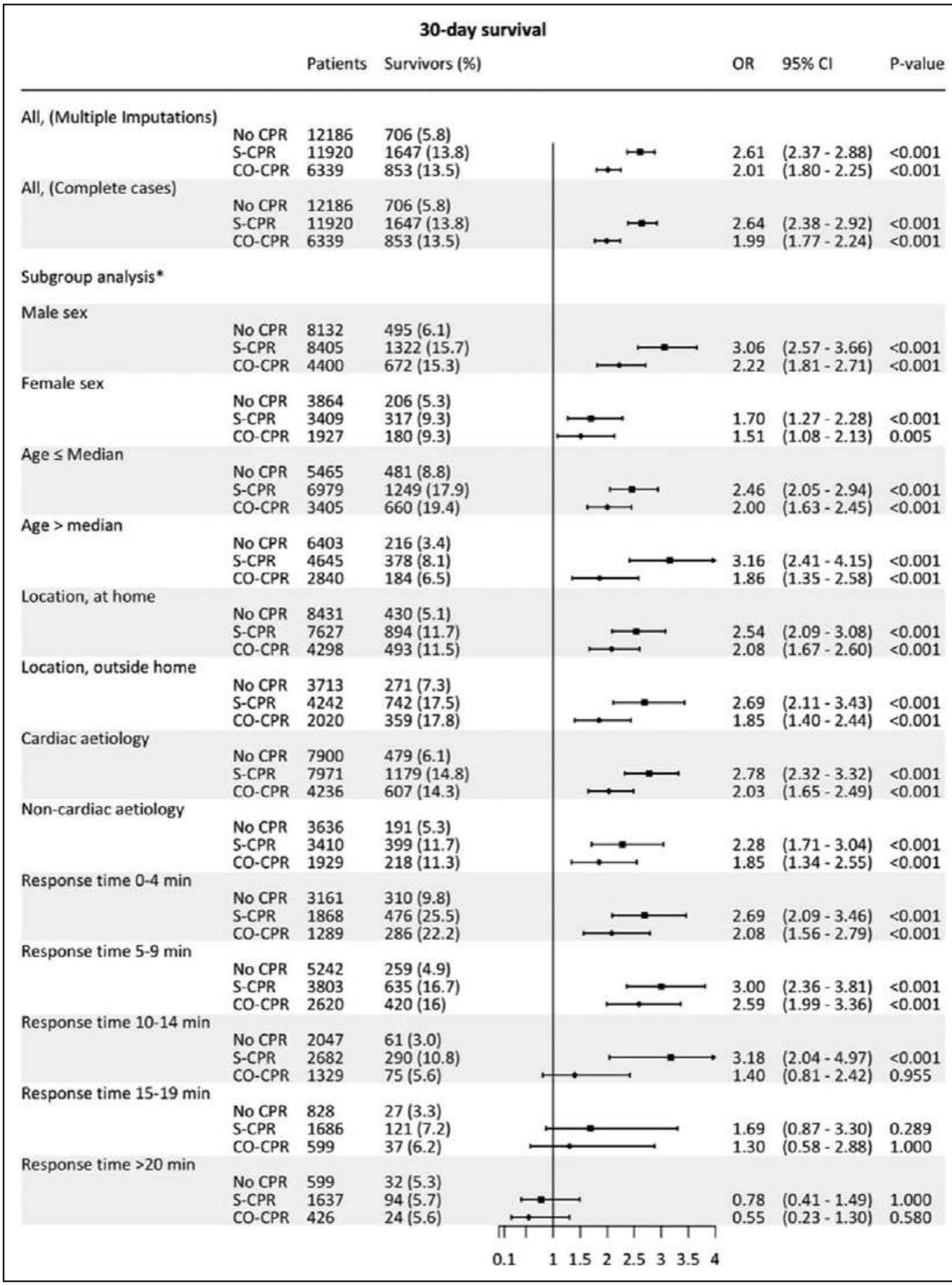


Figure 4. Adjusted OR for 30-day survival and subgroup analysis.

For subgroups confidence intervals and *P* values are Bonferroni corrected. Significant interactions were found for CO-CPR and response time (P=0.0004), CO-CPR and sex (P=0.0015), S-CPR and sex ($P\leq$0.0001), S-CPR and age (P=0.011), and S-CPR and cardiac cause (P=0.026). CO-CPR indicates chest compression–only cardiopulmonary resuscitation; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; OHCA, out-of-hospital cardiac arrest; and S-CPR, standard cardiopulmonary resuscitation. *Adjusted for age, sex, cause, location, EMS response time, and year of OHCA.

bystanders. There are discrepancies in the results from previous observational studies in which S-CPR and CO-CPR were compared. This could be explained in part by differences in patient selection in previous studies. In one observational study by the SOS-Kanto Study Group,[20] there was higher survival after CO-CPR in subgroups such as patients found in VT/VF, patients who had apnea, or patients in whom CPR was started within 4 minutes after collapse. Another recent observational study by Kitamura et al[21] found that CO-CPR is associated with better neurological outcome after bystander-witnessed OHCA of medical origin. In the present study, we included cases of all etiologies in the analysis to evaluate the impact of guideline recommendations at a national level. The exact mechanisms linking early CPR with survival are probably multifactorial. One of the most prominent predictors of survival is VT/VF at first rhythm analysis.[2] In our primary outcome analyses, we did not adjust for initial rhythm. There are 2 main reasons for this. First, observational human data suggest that CPR can modify VF and postpone deterioration of VT/VF to asystole.[15,22] Therefore, the effect of CPR could be mediated in part through sustained VT/VF until first rhythm analysis.[15,23] Second, we hypothesized that the quality of CPR could also influence this effect and, therefore, when assessing different types of CPR, adjusting for initial rhythm could be misleading.[24] Nevertheless, the incidence of VT/VF is unevenly distributed between the groups for other reasons as well (not fully adjusted for, or unmeasured). Therefore, we performed secondary analyses (with VT/VF in the model), which showed that the association of both CO-CPR and S-CPR with survival was less pronounced but still significant. We chose to limit the analysis to witnessed OHCA. The main reason for this is that the time of arrest is unknown and any intervention performed late in the course of the arrest will probably have minimal effect. Therefore, when comparing different types of CPR, the inclusion of nonwitnessed OHCA could dilute differences between the groups.

In our subgroup analysis, both CO-CPR and S-CPR were associated with a higher chance of survival regardless of underlying etiology. This is important, because distinguishing the cause of a cardiac arrest is challenging for bystanders, especially for those without medical education.

When EMS response times were between 10 and 14 minutes, CO-CPR was not associated with higher survival, suggesting that ventilation is crucial when EMS response times are prolonged.[25] When the EMS response time was >14 minutes, neither type of CPR was associated with higher survival, although the absolute numbers of survivors were few.

In the update of the European guidelines in 2017, it was recommended that all bystanders perform chest compression in all cases of cardiac arrest and that those who are trained, able, and willing to give rescue breaths and chest compression do so for all adult patients in cardiac arrest. However, the guidelines acknowledge an evidence gap regarding trained bystanders when comparing high-quality S-CPR with CO-CPR.[26] In Sweden, there is an on-going national randomized, controlled trial (clinical trials number NCT02401633) concerning this question.

We found higher 30-day survival over time for all groups of patients during the study period, including those not receiving bystander CPR. This indicates that several mechanisms other than higher rates of CPR before EMS arrival have contributed to higher survival over time. Such temporal mechanisms could be faster recognition of OHCA at dispatch centers, availability of public automated external defibrillators, more advanced/aggressive treatments and updated CPR algorithms for EMS, and more aggressive in-hospital treatment such as fast coronary intervention and improvements in post–cardiac arrest care. We could not control for these factors in our analysis, but any type of CPR was associated with survival rates 2 to 3 times higher regardless of which time period was studied.

Strengths and Limitations

The current study has several strengths. First, we included all OHCAs in Sweden during 3 different guideline periods covering 18 years, and all bystander-witnessed cases regardless of presumed underlying etiology were included. Second, we tested the relationships by using 2 different assumptions concerning missing values (multiple imputation analysis) to correct for missing data.[27] Third, we tested the relationships under 2 different assumptions concerning the causal pathway between CPR and survival, and our results were robust. Fourth, our sources of data are based on national registers that have remained consistent over time. There are also several limitations in our study that must be acknowledged. First, the results are based on register data, with a risk of misclassification of rescue breaths and chest compression at the time of EMS arrival and a relatively large amount of missing data regarding baseline variables. Second, we were not able to report the neurological function of survivors because of a large amount of missing data. Third, because only witnessed OHCAs were included in this study, our findings should not be interpreted as being valid for nonwitnessed OHCA. Fourth, we did not have information on DA-CPR over the whole study period, and, therefore, we were not able to adjust for this. Fifth, there is a lack of data on other important aspects of resuscitation when EMS arrived at the scene (eg, how quickly ventilation was provided, and what types of medication were used). Sixth, there was a randomized, controlled trial in which CO-CPR and S-CPR in DA-CPR were compared in Sweden in 2005 to 2009 that partly confounds the higher rates of CO-CPR during those years. Finally, other temporal changes occurring simultaneously, such as public awareness through social media, and foreign campaigns promoting CO-CPR are likely to have cross-contaminated the guideline periods used in our study.

Conclusions

In this nationwide study of witnessed OHCA during 3 periods of different CPR guidelines, there was an almost

2-fold higher rate of CPR before EMS arrival and a concomitant 6-fold higher rate of CO-CPR over time. Any type of CPR was associated with doubled survival rates in comparison with NO-CPR. These findings support continuous endorsement of CO-CPR as an option in future CPR guidelines because it is associated with higher CPR rates and survival in OHCA.

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Principal investigator Hollenberg had full access to all the data and takes responsibility for the accuracy of the data. The present study was designed by Drs Hollenberg, Svensson, Herlitz, Riva, and Ringh. Dr Herlitz as chief executive officer of the Swedish Register for Cardiopulmonary Resuscitation collected the data. All data were analyzed by Drs Jonsson, Riva, and Hollenberg. The first draft was written by Drs Hollenberg, Riva, and Jonsson. All coauthors participated intellectually and practically in the writing of the article.

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Disclosures

None.

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