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Clinical paper

Effect of bystander CPR initiation prior to the emergency call on ROSC and 30 day survival—An evaluation of 548 emergency calls[☆]Søren Viereck^{a,*}, Thea Palsgaard Møller^a, Annette Kjær Ersbøll^b, Fredrik Folke^a, Freddy Lippert^a^a Emergency Medical Services Copenhagen, University of Copenhagen, Telegrafvej 5, Building 2, 3rd Floor, DK-2750 Copenhagen, Denmark^b National Institute of Public Health, University of Southern Denmark, Øster Farimagsgade 5A, DK-1353 Copenhagen, Denmark

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ABSTRACT

Background: This study aimed at evaluating if time for initiation of bystander cardiopulmonary resuscitation (CPR) – prior to the emergency call (CPR_{prior}) versus during the emergency call following dispatcher-assisted CPR (CPR_{during}) – was associated with return of spontaneous circulation (ROSC) and 30-day survival. The secondary aim was to identify predictors of CPR_{prior}.

Methods: This observational study evaluated out-of-hospital cardiac arrests (OHCA) occurring in the Capital Region of Denmark from 01.01.2013 to 31.12.2013. OHCA were linked to emergency medical dispatch centre records and corresponding emergency calls were evaluated. Multivariable logistic regression analyses were applied to evaluate the association between time for initiation of bystander CPR, ROSC, and 30-day survival. Univariable logistic regression analyses were applied to identify predictors of CPR_{prior}.

Results: The study included 548 emergency calls for OHCA patients receiving bystander CPR, 34.9% (n = 191) in the CPR_{prior} group and 65.1% (n = 357) in the CPR_{during} group. Multivariable analyses showed no difference in ROSC (OR = 0.88, 95% CI: 0.56–1.38) or 30-day survival (OR = 1.14, 95% CI: 0.68–1.92) between CPR_{prior} and CPR_{during}. Predictors positively associated with CPR_{prior} included witnessed OHCA and health-care professional bystanders. Predictors negatively associated with CPR_{prior} included residential location, solitary bystanders, and bystanders related to the patient.

Conclusions: The majority of bystander CPR (65%) was initiated during the emergency call, following dispatcher-assisted CPR instructions. Whether bystander CPR was initiated prior to emergency call versus during the emergency call following dispatcher-assisted CPR was not associated with ROSC or 30-day survival. Dispatcher-assisted CPR was especially beneficial for the initiation of bystander CPR in residential areas.

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Introduction

Approximately 700,000–800,000 people suffer from out-of-hospital cardiac arrest (OHCA) in the United States and Europe annually and survival rarely exceed 10%.^{1–5} Early bystander cardiopulmonary resuscitation (CPR), performed before the arrival of ambulance services (EMS), is one of the most significant predictors of survival after OHCA.^{5–7} In Denmark, several initiatives have been implemented to increase bystander CPR since 2001, including mandatory basic life support (BLS) courses in elementary schools

and when an individual obtains a driver's license. From 2001 to 2010, bystander CPR more than doubled and survival increased threefold,⁶ but since 2012, bystander CPR have reached a high stable level of approximately 65%.⁸ The first link in the chain of survival, namely, early recognition of cardiac arrest by bystanders and/or medical dispatchers, may play an essential role in further increasing bystander CPR.^{9,10}

Two strategies for improving OHCA recognition and performance of high-quality bystander CPR are encouraged in the 2015 European Resuscitation Council guidelines: (1) BLS education for laypeople to obtain the skills necessary to recognise OHCA and provide high-quality bystander CPR; and (2) ongoing training of medical dispatchers to ensure recognition of OHCA during emergency calls and provision of dispatcher-assisted CPR instructions to the bystander.¹¹

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When trying to prioritise strategies to improve bystander CPR in the community, it is important for decision-makers to know the effect of these strategies, yet no studies have compared long-term survival between patients who received bystander CPR prior to the emergency call (CPR_{prior}) and patients who received bystander CPR during the emergency call following dispatcher-assisted CPR instructions (CPR_{during}). Due to a presumed shorter delay from collapse to CPR, we hypothesised that initiation of bystander CPR prior to the emergency call was associated with an increase in survival.

The primary aim of this study was to evaluate if the time for initiation of bystander CPR – prior to the emergency call versus during the emergency call following dispatcher-assisted CPR instructions – was associated with return of spontaneous circulation (ROSC) and 30-day survival. The secondary aim was to identify predictors for CPR_{prior}.

Methods

Study design and setting

This observational study was conducted in the Capital Region of Denmark, which is inhabited by 1.75 million people and covers 2,568 km².¹² In case of an emergency, citizens can contact EMS through a single emergency phone number: 112. Emergency calls are received at a switchboard that locates the caller and identifies the need for fire, police, or medical assistance. Medical calls are forwarded to the Emergency Medical Dispatch Centre (EMDC), which receives approximately 105,000 calls annually.¹³ The EMDC in the Capital Region of Denmark is manned with medical dispatchers who are educated paramedics or registered nurses with experience in emergency care, as well as six weeks of additional training in emergency medicine and communication. Medical dispatchers are assisted by a criteria-based dispatch tool, the Danish Index for Emergency Care.¹⁴ In case of a suspected OHCA, an ambulance and a physician manned Mobile Critical Care Unit are dispatched at response priority A (lights and sirens). Dispatcher-assisted CPR instructions are mandatory. Medical dispatchers can direct bystanders to the nearest available automated external defibrillator (AED) through an interactive map integrated in the dispatch system.¹⁵ In Denmark, BLS and AED training is mandatory in elementary schools and when an individual obtains a driver's license. Approximately 300,000 lay people are educated in BLS and AED use annually.¹⁶ No organised first responder programme is implemented in the Capital Region of Denmark.

Data collection

EMS-treated OHCA patients were identified in the Danish Cardiac Arrest Registry and the Mobile Critical Care Unit database. Duplicate cases from the Mobile Critical Care Unit database were removed. Data were merged with EMDC records via the unique EMS mission identification number or a combination of the unique Danish personal identification number and the date of OHCA.¹⁷ Emergency call recordings were identified by the date/time and address of OHCA. Two investigators (SV and TPM) analysed the emergency call recordings and extracted data using a predefined case report form.¹⁸ To establish uniform registration, 100 randomly selected emergency call recordings of OHCA were evaluated by both investigators prior to data collection, and Cohen's kappa statistics were applied to ensure low interrater variability. Furthermore, an interim analysis comparing data registration praxis from the two investigators was performed. Survival data were obtained from the Danish Civil Registration System.¹⁷ Inclusion criteria were all OHCA patients in the Capital Region of Denmark, treated by EMS during a 1-year period (01.01.2013–31.12.2013). Exclusion criteria

were EMS-witnessed OHCA, unobtainable emergency call recording, patients obviously alive during the emergency call, and patients missing data on bystander CPR or time for initiation of bystander CPR, or cases where no bystander CPR was performed.

Definition of variables

Age was divided into four age groups (<60, 60–69, 70–79, or ≥80 years), based on age distribution in data. OHCA variables including location of OHCA (residential/public), witnessed status (witnessed/unwitnessed), the provision of bystander CPR (yes/no), defibrillation by an AED (yes/no), and ROSC (yes/no) were registered according to the 2004 Utstein guidelines.¹⁹ EMS response time was defined as the time from ambulance dispatch to vehicle arrival.

The bystander's relation to the patient was categorised as “healthcare professional,” “relative,” or “other.” Time for initiation of bystander CPR was categorised as CPR_{prior} or CPR_{during}. The number of bystanders was categorised as “solitary” or “multiple.” Date of death was extracted from the Danish Civil Registration System and 30-day survival was derived.

Statistical analysis

Descriptive analysis was performed by the use of frequency distributions (number, %), as well as, mean values and standard deviations. Fisher's exact test was applied to test the association between time for initiation of bystander CPR and categorical variables (patient and setting characteristics, as well as patient outcome). Student's *t*-test was applied to test the association between time for initiation of bystander CPR and continuous variables (patient age and EMS response time). Due to a skewed distribution of EMS response-time, the variable was log-transformed prior to analysis, and the geometric mean was used for descriptive analysis.

Multivariable logistic regression analyses were applied to evaluate the association between time for initiation of bystander CPR, and ROSC and 30-day survival. Potential confounders were identified using a causal diagram and the online software www.dagitty.com, and added to the model. Sex and age group-, and fully-adjusted analyses (adjusted for sex, age group, witnessed status, and number of bystanders) were performed with ROSC and 30-day survival as the outcome. The fully-adjusted models were tested for effect modification by including two-way interactions between the time for initiation of bystander CPR and patient age group, witnessed status, and number of bystanders. To identify predictors of CPR_{prior}, univariable logistic regression analyses were applied. Results were reported as odds ratios (ORs) with 95% confidence intervals (CIs) and *p*-values when appropriate. A *p*-value <0.05 was considered significant for all analyses.

Approvals

This study was approved by the Danish Data Protection Agency (j. nr. 2012-58-0004), and the Danish Health Authority (j. nr. 3-3013-1289/1/). Registry-based studies do not need ethical approval in Denmark (j. nr. 16027134).

Results

We identified 1386 non-EMS-witnessed OHCA patients during the one-year study period, corresponding to an incidence of 79.2 OHCA patients per 100,000 inhabitants per year. In 355 cases, the emergency call was not obtainable, so the cases were excluded. We reviewed the remaining 1,031 emergency calls and excluded an additional 483 patients due to predefined exclusion criteria. In total, 548 OHCA patients were included in this analysis (Fig. 1).

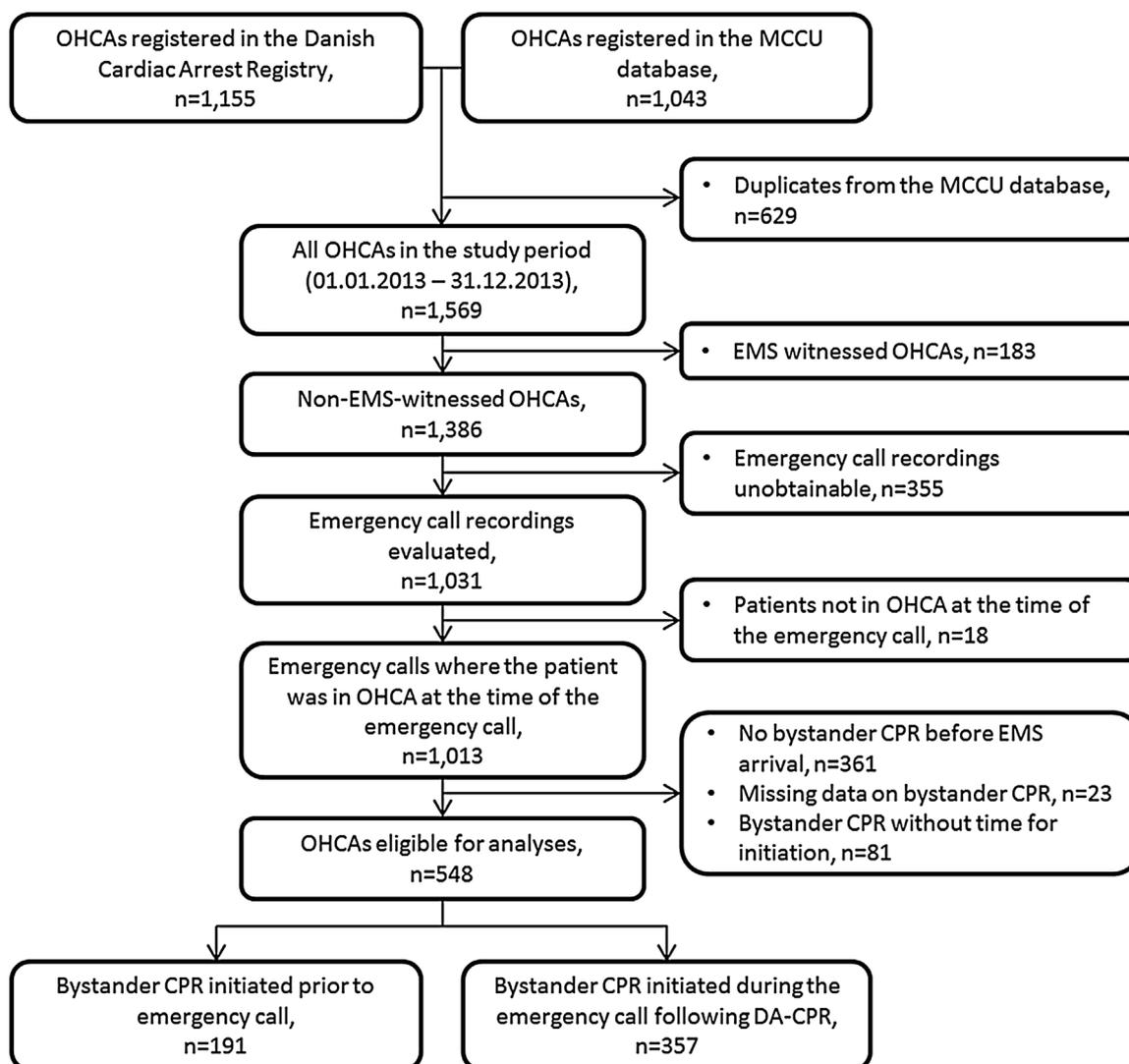


Fig. 1. Data collection.

Flowchart describing the data collection process. CPR, cardiopulmonary resuscitation; DA-CPR, dispatcher-assisted cardiopulmonary resuscitation; EMS, emergency medical services; MCCU, mobile critical care unit; OHCA: out-of-hospital cardiac arrest.

Among included OHCA patients, 34.9% ($n=191$) were in the CPR_{prior} group and 65.1% ($n=357$) were in the CPR_{during} group. No significant differences were observed between the CPR_{prior} and the CPR_{during} group with regard to age (68.0 years vs. 69.5 years, $p=0.57$), patient sex (68.3% female vs. 62.5% male, $p=0.21$), EMS response time (06:03 min vs. 05:51 min, $p=0.64$), or ROSC (41.2% vs. 33.8%, $p=0.11$).

The CPR_{prior} group, compared to the CPR_{during} group, had a significantly higher proportion of witnessed OHCA (63.7% vs. 49.0%, $p=0.001$), OHCA in public places (62.3% vs. 27.8%, $p<0.001$), multiple bystanders (89.1% vs. 64.7%, $p<0.001$), and healthcare professional bystanders (42.1% vs. 24.2%, $p<0.001$). The proportion of cases where the bystander was related to the patient was significantly lower in the CPR_{prior} group (19.7% vs. 45.2%, $p<0.001$). In the CPR_{prior} group, significantly more patients were defibrillated by an AED (14.0% vs. 2.4%, $p<0.001$) and 30-day survival was significantly higher (27.2% vs. 16.7%, $p=0.006$) (Table 1).

The sex- and age group-adjusted logistic regression analyses showed significantly higher odds of 30-day survival in the CPR_{prior} group compared to the CPR_{during} group (OR=1.81, 95% CI: 1.31–2.50), but after further adjusting for witnessed status and number of bystanders, there was no significant difference

(OR=1.14, 95% CI: 0.68–1.92). We found no association between the CPR_{prior} group and ROSC in either model (sex- and age group-adjusted OR=1.23, 95% CI: 0.93–1.61; fully-adjusted OR=0.88, 95% CI: 0.56–1.38) (Fig. 2). The tests for effect modification in the fully-adjusted model with 30-day survival as the outcome were not significant (p -values ≥ 0.19).

The following predictors were positively associated with CPR_{prior} : witnessed OHCA (OR=1.82, 95% CI: 1.27–2.62) and healthcare professional bystanders (OR=2.28, 95% CI: 1.55–3.36). The following predictors were negatively associated with CPR_{prior} : residential location (OR=0.23, 95% CI: 0.16–0.34), solitary bystanders (OR=0.22, 95% CI: 0.13–0.37), and bystanders related to the patient (OR=0.30, 95% CI: 0.19–0.46) (Fig. 3).

Discussion

The main finding of this study was that 65% of bystander CPR provided to OHCA patients was initiated during the emergency call following dispatcher-assisted CPR. Initial analyses showed a significant association between bystander CPR initiated prior to the emergency call and 30-day survival. Nevertheless, after adjusting for witnessed status and number of bystanders, the

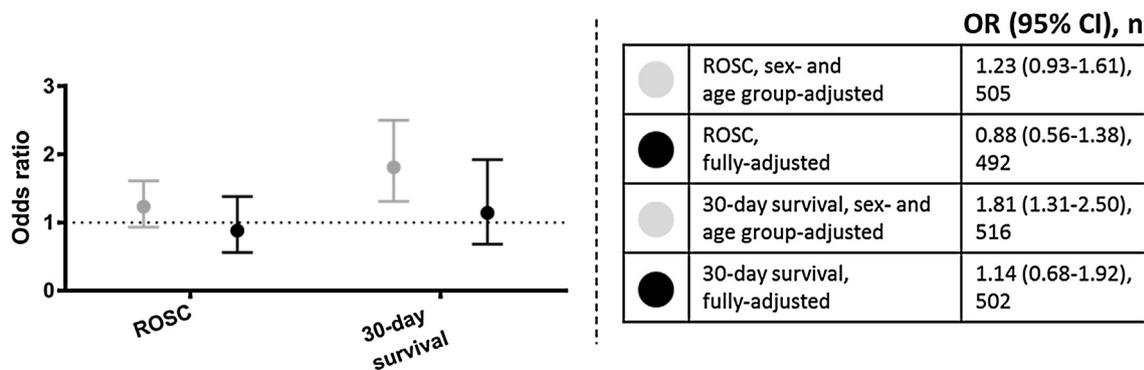
Table 1
Patient and setting characteristics and patient outcomes for the study population.

	OHCA included in the analysis (n = 548)			p-Value
	CPR _{prior} (n = 191)	CPR _{during} (n = 357)	Missing	
Patient characteristics				
Male patient, n (%)	123 (68.3)	210 (62.5)	32	0.21
Patient age, mean ^a (SD)	66.7 (16.8)	67.6 (17.9)	32	0.57
Setting characteristics				
Witnessed OHCA, n (%)	121 (63.7)	174 (49.0)	3	0.001
Public location, n (%)	114 (62.3)	97 (27.8)	16	<0.001
Multiple bystanders, n (%)	164 (89.1)	227 (64.7)	13	<0.001
Health care prof. caller, n (%)	75 (42.1)	83 (24.2)	27	<0.001
Caller related to patient, n (%)	35 (19.7)	155 (45.2)	27	<0.001
Mean ^b EMS response time, mm:ss (95% CI)	05:57 (05:31–06:26)	06:00 (05:45–06:17)	14	0.86
Defibrillated by an AED, n (%)	24 (14.0)	8 (2.4)	40	<0.001
Patient outcome				
ROSC, n (%)	77 (41.2)	118 (33.8)	12	0.11
30-day survival, n (%)	49 (27.2)	56 (16.7)	41	0.006

AED, automated external defibrillator; CI, confidence interval; CPR_{during}, bystander CPR initiated during the emergency call, following dispatcher-assisted CPR; CPR_{prior}, bystander CPR initiated prior to the emergency call; EMS, emergency medical services; mm:ss, minutes:seconds; OHCA, out of hospital cardiac arrest; ROSC, return of spontaneous circulation; SD, standard deviation.

^a Arithmetic mean.

^b Geometric mean.

**Fig. 2.** Effect of bystander CPR.

The effect of bystander CPR initiated prior to the emergency calls versus bystander CPR initiated during the emergency call, following dispatcher-assisted CPR on ROSC and 30-day survival. Fully adjusted: adjusted for sex, age group, witnessed status, and number of bystanders. CI, confidence interval; CPR, cardiopulmonary resuscitation; OR, odds ratio; ROSC, return of spontaneous circulation.

analyses showed no association between bystander CPR initiated prior to the emergency call, and ROSC or 30-day survival. We identified two factors positively associated with initiation of bystander CPR prior to the emergency call (witnessed OHCA and healthcare professional bystanders) and three factors negatively associated with initiation of bystander CPR prior to the emergency call (residential location, solitary bystanders, and bystanders related to the patient).

The fact that 65% of bystander CPR was initiated during the emergency call following dispatcher-assisted CPR, highlights the important role of the medical dispatcher. The dispatcher may increase recognition of OHCA and eliminate existing barriers for initiation of bystander CPR by taking over responsibility and providing clear CPR instructions.^{20,21} Few other studies have reported the proportion of OHCA patients receiving bystander CPR initiated prior to the emergency call. One study reported that 15.3% of OHCA patients received bystander CPR prior to the emergency call.²² Three other studies of more narrow populations – two only evaluating OHCA patients recognised during the emergency call and one only including witnessed OHCA – reported that 14–20% of OHCA patients received bystander CPR prior to the emergency call.^{9,23,24} We report a higher proportion of OHCA patients receiving bystander CPR initiated prior to the emergency call compared to these studies; this may be the consequence of a range of national initiatives that have

been implemented throughout the past decade in Denmark with the goal of educating lay people on BLS.⁶ Results from the other studies mentioned above are from highly selected subgroups and were reported as secondary outcomes, thereby impeding a direct comparison to our results.

The literature clearly states that early bystander CPR improves survival.^{5–7} Our study showed a crude difference in 30-day survival between the CPR_{prior} and CPR_{during} groups in favour of CPR_{prior}; however, this difference was not present after adjusting for sex, age group, witnessed status, and number of bystanders. In witnessed versus unwitnessed OHCA, there is a clear advantage in the reduced time from collapse to bystander CPR and defibrillation, which improves survival.^{5–7,25} In addition, one study suggests that the presence of multiple bystanders improves the quality of bystander CPR.²⁶ Also, multiple bystanders could increase the chance of retrieving an AED. Increased quality of CPR and the availability of an AED could improve chances of survival.^{27–30}

The results of this study reject our hypothesis that initiation of bystander CPR prior to the emergency call was associated with survival. The reason for this may be that the delay of bystander CPR initiation from the CPR_{prior} group to the CPR_{during} group is minimal and, therefore, without significant influence on survival. We know that overall delay to treatment is strongly correlated with chance of survival after OHCA.^{7,25} Nonetheless, high-quality evidence

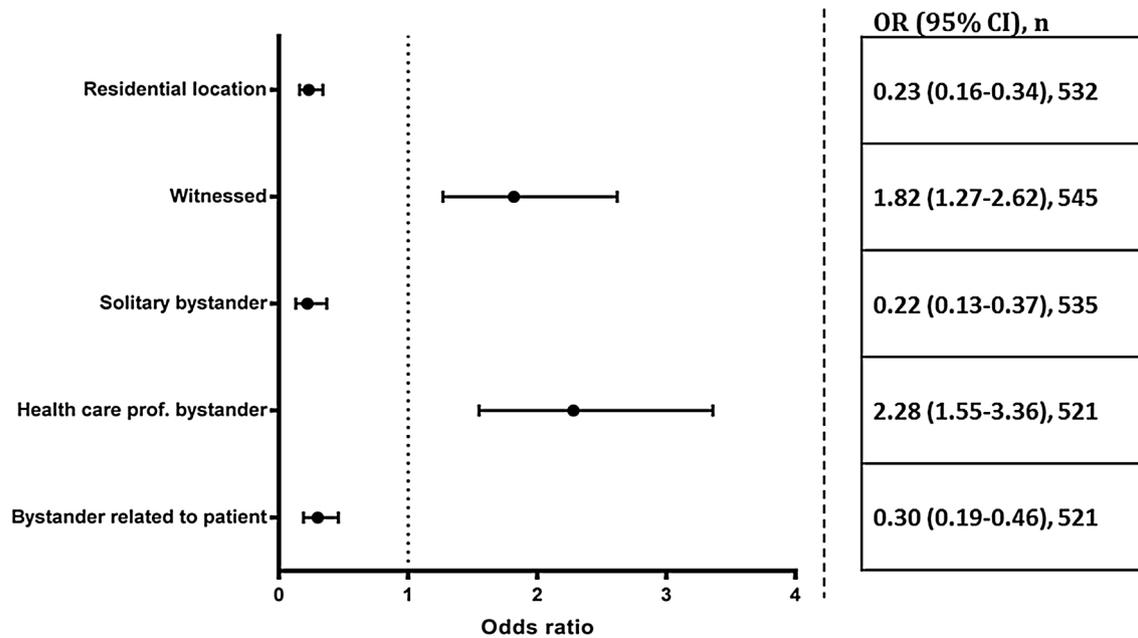


Fig. 3. Predictors of bystander CPR.

OR for predictors of bystander CPR initiated prior to the emergency call versus bystander CPR initiated during the emergency call, following dispatcher-assisted CPR. CI, confidence interval; CPR, cardiopulmonary resuscitation; OR, odds ratio.

regarding the exact effect of single-minute delays in the initiation of bystander CPR is sparse and the most commonly cited study is based on a graphic model from 1993.³¹ Quality of dispatcher-assisted CPR can potentially improve quality of bystander CPR³²; therefore another explanation may be that the dispatcher is more engaged in the CPR_{during} group, and therefore the quality of the dispatcher-assisted CPR provided in this group is better, leading to enhanced quality of bystander CPR for the patient.

Our study showed that bystanders with a healthcare professional background were more inclined to initiate bystander CPR prior to the emergency call. This is likely explained by the education and training in BLS that most healthcare professionals have received. Witnessed OHCA was a predictor of bystander CPR initiation prior to the emergency call; however, agonal breathing (which is present in up to 55% of witnessed OHCA) has shown to hinder the recognition of OHCA.^{23,33,34} The negative association between initiation of bystander CPR prior to the emergency call and OHCA in residential location, solitary bystanders, and bystanders related to the patient highlights that dispatcher-assisted CPR instructions are very important for the initiation of bystander CPR in these groups. This emphasises the potential for dispatcher-assisted CPR for solitary bystanders where the chance of CPR training obviously is poorer, bystanders in residential areas for whom bystander CPR are historically lower, and for spouses with a lack of confidence in initiating bystander CPR on their partners.^{35,36}

Future perspectives

Recent data from the Danish Cardiac Arrest Registry show that, following an impressive development during the past decade, bystander CPR in Denmark has reached a stable level of approximately 65%.⁸ Our data do not make it possible to determine which interventions should be given the highest priority – improved education of laypeople or better training of medical dispatchers – in order to further improve bystander CPR rates. By ensuring educated laypeople and well-trained medical dispatchers, it is possible to take advantage of the synergy between those initiatives, to increase bystander CPR.

Dispatcher-assisted CPR has been shown to increase bystander CPR significantly,^{11,37,38} particularly in residential areas with less bystander CPR and a positive influence of dispatcher-assisted CPR, as demonstrated in this study.³⁵ To increase the amount and quality of dispatcher-assisted CPR in the future, there should be increased efforts to audit suspect OHCA emergency calls, focus on early recognition of OHCA, improve performance of dispatcher-assisted CPR, and provide quality assurance of dispatcher-assisted CPR. These efforts have been proven effective in Singapore and Arizona, and are recommended by the American Heart Association.^{22,39,40} In cases where bystander CPR is initiated prior to the emergency call, dispatcher-assisted CPR protocols for medical dispatchers should be adjusted to verify the presence of OHCA and ensure the quality of bystander CPR performance.

Limitations

Our study had several limitations. First, the main limitation is the observational design of this study; as a result, we can only report associations between variables and not causality. Furthermore, the number of OHCA patients that were defibrillated by an AED was very small in our population ($n = 32$); this small population of AED patients makes it impossible to make reliable adjustments for this variable in the analyses evaluating the effect of bystander CPR initiated prior to the emergency call on ROSC and 30-day survival. Second, in 355 cases, it was not possible to link OHCA to the EMDC and extract the emergency call recording. This could partly be explained by missing values on the unique Danish personal identification number or identification numbers used for data linkage, corrupted files from the emergency call database, or calls handled by another dispatch centre outside of the study region. A sensitivity analysis comparing OHCA patients where emergency calls were obtainable versus unobtainable showed only significant differences in location and bystander CPR, but no difference in age, sex, witnessed status, or ROSC, indicating that this exclusion did not bias the main outcomes. To meet this challenge, a unique identification number connecting the OHCA registry, EMDC report and emergency call recording is key. Third, the relatively small number

of patients can potentially have affected the power of the results for the association between the initiation of bystander CPR initiated prior to the emergency call and ROSC or 30-day survival. Finally, in order to evaluate the specific effect of time intervals in the early phase after collapse, we would need the exact time from collapse until start of CPR in the two groups reported in this study, but unfortunately, reliable and accurate collection of such data is very difficult.

Conclusions

In 34.9% of OHCA patients, bystander CPR was initiated prior to the emergency call, whereas in the remaining 65.1% of OHCA patients, bystander CPR was initiated following dispatcher-assisted CPR instructions. When comparing the two groups, we found no association between bystander CPR initiated prior to the emergency call and ROSC or 30-day survival. Dispatcher-assisted CPR was especially beneficial for the initiation of bystander CPR in residential areas, among solitary bystanders, and among bystanders related to the patients.

Conflict of interest statement

Authors report no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.resuscitation.2016.11.020>.

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