Resuscitation 81 (2010) 826–830

Contents lists available at ScienceDirect

Resuscitation

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

Clinical paper

Increased survival after EMS witnessed cardiac arrest. Observations from the Resuscitation Outcomes Consortium (ROC) Epistry—Cardiac arrest☆

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ARTICLE INFO

Article history:
Received 15 August 2009
Received in revised form 4 January 2010
Accepted 3 February 2010

Keywords:
Prehospital
CPR
Bystander
Return of spontaneous circulation
ROSC

ABSTRACT

Background: Out of hospital cardiac arrest (OHCA) is common and lethal. It has been suggested that OHCA witnessed by EMS providers is a predictor of survival because advanced help is immediately available. We examined EMS witnessed OHCA from the Resuscitation Outcomes Consortium (ROC) to determine the effect of EMS witnessed vs. bystander witnessed and unwitnessed OHCA.
Methods: Data were analyzed from a prospective, population-based cohort study in 10 U.S. and Canadian ROC sites. Individuals with non-traumatic OHCA treated 04/01/06–03/31/07 by EMS providers with defibrillation or chest compressions were included. Cases were grouped into EMS-witnessed, bystander witnessed, and unwitnessed and further stratified for bystander CPR. Multiple logistic regressions evaluated the odds ratio (OR) for survival to discharge relative to the EMS-witnessed group after adjusting for age, sex, public/private location of collapse, ROC site, and initial ECG rhythm. Of 9991 OHCA, 1022 (10.2%) of EMS-witnessed, 3369 (33.7%) bystander witnessed, and 5600 (56.1%) unwitnessed.
Results: The most common initial rhythm in the EMS-witnessed group was PEA which was higher than in the bystander- and unwitnessed groups ($p < 0.001$). The adjusted OR (95% CI) of survival compared to the EMS-witnessed group was 0.41, (0.36, 0.46) in bystander witnessed with bystander CPR, 0.37 (0.33, 0.43) in bystander witnessed without bystander CPR, 0.17 (0.14, 0.20) in unwitnessed with bystander CPR and 0.21 (0.18, 0.24) in unwitnessed cases without bystander CPR.
Conclusions: Immediate application of prehospital care for OHCA may improve survival. Efforts should be made to educate patients to access 9-1-1 for prodromal symptoms.
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1. Introduction

Out-of-hospital cardiac arrest (OHCA) is common and lethal.[1] Various prehospital factors are associated with short- and long-term survival after collapse.[2] Short response time, bystander-witnessed collapse, and early access to defibrillation have been associated with improved survival while use of epinephrine during resuscitation is associated with death.[2–7]

Cardiac arrest in the presence of prehospital providers is fundamentally different from true sudden death since the prodromal symptoms reached a sufficient threshold and lasted long enough for recognition, access of the EMS system, and ambulance response. It has been reported that cardiac arrest witnessed by emergency medical services (EMS) providers is a predictor of survival.[8] This may be

☆ A Spanish translated version of the summary of this article appears as Appendix in the final online version at doi:10.1016/j.resuscitation.2010.02.005.

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doi:10.1016/j.resuscitation.2010.02.005

due to the elimination of the delay in EMS response following loss of pulses and the immediate application of life saving measures.

Previous studies of EMS-witnessed OHCA have been limited by single site data collection that requires long study intervals. These extended data collection periods potentially allow secular trends in prehospital care to influence the conclusions. To address this gap in the literature, this prospective, multicenter, cohort study assessed return of spontaneous circulation (ROSC) and survival to hospital discharge among patients with EMS-witnessed cardiac arrest compared to bystander-witnessed, and unwitnessed OHCA stratified by bystander CPR.

2. Materials and methods

2.1. Study design and participants

The Resuscitation Outcome Consortium (ROC) consists of 11 geographically distinct regional centers across North America created to study promising out-of-hospital therapies for cardiac arrest and major trauma.[9] The regional ROC centers are Alabama, Dallas, Iowa, Milwaukee, Pittsburgh, Portland, San Diego and Seattle/King County in the United States and British Columbia, Ottawa, and Toronto in Canada. There are 264 EMS agencies within the consortium. Since December 2005, the ROC Cardiac Epistry (an epidemiological database), has prospectively obtained data on persons suffering OHCA and subsequently treated by a ROC-participating EMS agency. Predefined data related to out-of-hospital treatments and outcomes are collected with explicit operational definitions, including cardiac rhythms, response times, descriptions of all professional responders at each event, details of the timing of CPR and defibrillation, response to interventions, return of spontaneous circulation (ROSC), and survival to hospital discharge.

Included in the analysis were subjects aged 18 years and older with non-traumatic cardiac arrest and treated by a ROC EMS provider with defibrillation or external chest compressions between 04/01/2006 and 03/31/2007. Ten sites provided 12 months of data. One did not contribute to the Cardiac Epistry data during this interval due to delays in establishing the data collection infrastructure at that site. Cases were grouped into EMS-witnessed, bystander witnessed, and unwitnessed. Bystander witnessed and unwitnessed cases were further stratified for bystander CPR creating five non-overlapping groups (EMS-witnessed (EMSW), bystander witnessed cases with bystander CPR (BW-CPR), bystander witnessed cases without bystander CPR (BW) unwitnessed cases with bystander CPR (UW-CPR), and unwitnessed cases without bystander CPR (UW). Definitions of witnessed events were consistent with the National EMS Information System (NEMSIS) dataset (www.nemsis.org). EMSW was defined as cardiac arrest or collapse witnessed by a prehospital responder that was part of the organized EMS response. This does not include law enforcement officers. BW was defined as cardiac arrest or collapse witnessed by a layperson, a healthcare provider, or prehospital/fire responder who were off duty and not part of the organized EMS response.

2.2. Ethical approval

The responsible Institutional Research Board (IRB) or Research Ethics Board (REB) for each research site and the data coordinating center provided ethical approval for data collection and analysis.

2.3. Outcome measurements

The primary outcomes were return of spontaneous circulation and survival to hospital discharge after adjusting for age, sex, public/private location of collapse, ROC site, and initial ECG rhythm.

2.4. Statistical analysis

Multiple logistic regression provided estimates for the odds ratios of bystander witnessed and unwitnessed cases with and without bystander CPR versus EMSW in treated patients, always adjusted for potential site effects. Sequentially more sophisticated models were fit including age, sex, private/public location of arrest and initial ECG rhythm. Missing values for a covariate caused the subject to be dropped from the model. A rhythm category of 'cannot determine' was included for first documented ECG rhythm, but cases with no documented first ECG rhythm assessment were dropped. In this size and type of registry, some errors in time reporting are unavoidable. Therefore, medians and ranges were used to describe key time intervals.

3. Results

Nine thousand nine hundred ninety one cases (9991) cases of treated OHCA were available for analysis of which 1022 (10.2%) were EMS-witnessed, 3369 (33.7%) bystander witnessed, and 5600 (56.1%) unwitnessed. Table 1 describes the demographics and episode characteristics. Age was evenly distributed across groups with a mean age in the sixth decade. The EMS-witnessed group had

Table 1
Demographics and episode characteristics.

	All treated cardiac arrest	EMS witnessed	Bystander witnessed		Unwitnessed		*p*-Value
			Bystander CPR	No bystander CPR	Bystander CPR	No bystander CPR	
Total	9991	1022	1898	2206	1471	3394	
Age (years)	66.3 (16.9)	67.6 (16.4)	65.8 (16)	68 (15.8)	64.2 (18.3)	66.1 (17.3)	<0.001
Age (range)	(18–106)	(19–100)	(18–105)	(18–106)	(18–103)	(18–103)	
Female	3642 (37%)	426 (42%)	620 (33%)	730 (33%)	590 (40%)	1276 (38%)	<0.001
Sex unknown or missing[a]	13 (0.1%)	0 (0.0%)	6 (0.3%)	1 (0.0%)	1 (0.1%)	5 (0.1%)	
Public location[b]	1608 (16%)	134 (13%)	545 (29%)	374 (17%)	190 (13%)	365 (11%)	<0.001
Location unknown or missing[a,b]	7 (0.1%)	1 (0.1%)	2 (0.1%)	2 (0.1%)	1 (0.1%)	1 (0.0%)	
9-1-1 to arrival[c] median (range in min)	5.4 (0.2877)	5.7 (0.2874)	5.5 (0.12874)	5.4 (0.2876)	5.5 (0.2877)	5.2 (0.2876)	<0.001
9-1-1 to arrival time missing[a,c]	339 (3.4%)	43 (4.2%)	64 (3.4%)	68 (3.1%)	45 (3.1%)	119 (3.5%)	
Epinephrine used	7396 (80%)	649 (69%)	1438 (82%)	1668 (81%)	1139 (83%)	2502 (80%)	<0.001
Epinephrine use unknown or missing[a]	729 (7.3%)	86 (8.4%)	137 (7.2%)	155 (7.0%)	102 (6.9%)	249 (7.3%)	

Age presented as mean (SD), 9-1-1 to arrival time presented as median (range), other variables presented as *N* (%). *p*-Values are ANOVA for means, Chi-square for percentages and Mood test for medians.

[a] Missing is percent of total—all others are percent of reported.

[b] Does not include residence, residential institution, or healthcare facility.

[c] Reported dispatch time to arrival of first vehicle on-scene.

Table 2
Presenting EMS rhythm and EMS CPR.

	All treated cardiac arrest	EMS witnessed	Bystander witnessed		Unwitnessed		*p*-Value
			Bystander CPR	No bystander CPR	Bystander CPR	No bystander CPR	
Total	9991	1022	1898	2206	1471	3394	
VT/VF[a]	2446 (25%)	245 (25%)	805 (45%)	710 (33%)	229 (16%)	457 (14%)	<0.001*
PEA	2050 (21%)	424 (43%)	343 (19%)	560 (26%)	177 (12%)	546 (16%)	
Asystole	3999 (41%)	173 (18%)	474 (26%)	653 (30%)	852 (60%)	1847 (56%)	
AED no shock	949 (10%)	75 (8%)	132 (7%)	206 (10%)	140 (10%)	396 (12%)	
Cannot determine	228 (2%)	61 (6%)	47 (3%)	32 (1%)	24 (2%)	64 (2%)	
Missing rhythm[b]	319 (3%)	44 (4%)	97 (5%)	45 (2%)	49 (3%)	84 (2%)	
EMS CPR[c]	9864 (99%)	973 (96%)	1863 (98%)	2190 (99%)	1466 (100%)	3372 (99%)	<0.001
Missing EMS CPR[b,c]	8 (0.1%)	7 (0.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.0%)	

Data presented as *N* (%). *p*-Values computed with Chi-square test.
[a] VT/VF includes AED shock recommended.
[b] Missing is percent of total—all others are percent of reported.
[c] Reported manual or mechanical chest compressions.
* *p*-Value for difference of first available rhythm (all categories except missing).

Table 3
Return of spontaneous circulation and survival outcomes.

	All treated cardiac arrest	EMS witnessed	Bystander witnessed		Unwitnessed		*p*-Value
			Bystander CPR	No bystander CPR	Bystander CPR	No bystander CPR	
Total	9991	1022	1898	2206	1471	3394	
ROSC[a] noted	2998 (58%)	437 (59%)	789 (66%)	798 (62%)	325 (57%)	649 (47%)	<0.001
Survival to hospital discharge	837 (8%)	184 (18%)	283 (15%)	207 (10%)	52 (4%)	111 (3%)	<0.001
Missing survival[b]	91 (1%)	15 (1%)	23 (1%)	29 (1%)	7 (0%)	17 (1%)	

Data presented as *N* (%). *p*-Values computed by Chi-square test.
[a] Return of spontaneous circulation.
[b] Missing is percent of total—all others are percent of reported.

larger female representation (42%) than the other groups (33–40%). Bystander witnessed arrests more often occurred in a public location. EMS response time, as measured by the 9-1-1 call arriving at dispatch to vehicle arrival time on-scene, were comparable, with median times around 5.5 minutes. Significantly fewer EMS-witnessed arrests used epinephrine (69% versus 80–83%).

The first documented ECG rhythm was not uniformly distributed (Table 2). The highest rate of pulseless ventricular tachycardia/ventricular fibrillation (VT/VF) was seen in bystander witnessed with bystander CPR group (45%) and ranged down to 14% in the unwitnessed without bystander CPR group. Asystole accounted for more than half of the unwitnessed cases with, and without, bystander CPR while pulseless electrical activity (PEA) was predominant in the EMS-witnessed group (43%).

Return of spontaneous circulation (ROSC) defined as ROSC observed by the EMS crew at any point during the resuscitation occurred most often in the EMS-witnessed and bystander witnessed groups (Table 3). Survival to hospital discharge was highest in EMS-witnessed (18%) and bystander witnessed with bystander CPR groups (15%) and lowest in the unwitnessed with bystander CPR group (3%).

When compared to EMSW, the adjusted odds of survival to hospital discharge were lower in all other groups (bystander witnessed with bystander CPR: 0.41, 95% CI 0.36, 0.46), (bystander witnessed without bystander CPR: 0.37, 95% CI 0.33, 0.43), (unwitnessed with bystander CPR: 0.17, 95% CI 0.14, 0.20), and (unwitnessed without bystander CPR: 0.21, 95% CI 0.18, 0.24) groups when adjusting for age, sex, location of arrest, and first reported ECG rhythm (Table 4).

4. Discussion

Victims of cardiac arrest witnessed by prehospital providers are more likely to achieve ROSC and survive to hospital discharge than unwitnessed cases of OHCA and bystander witnessed cases without bystander CPR in spite of a higher proportion of PEA as the first rhythm of arrest.

Two previous studies have associated EMS-witnessed cardiac arrest with improved survival. A before and after report from the Ontario Prehospital Advanced Life Support (OPALS) group indicated there was higher survival in an EMS-witnessed cohort when compared to non-EMS-witnessed cardiac arrest.[8] More recently, a Swedish report also indicated higher survival in EMS-witnessed cases when compared to bystander witnessed and unwitnessed cases.[10] Although informative, the Canadian and Swedish studies were conducted over six- and 14-year intervals, respectively. Long study intervals potentially introduce bias from secular trends in

Table 4
Adjusted odds ratio of survival relative to EMS witnessed group.

	All treated cardiac arrest	Bystander witnessed		Unwitnessed	
		EMS witnessed	Bystander CPR	No bystander CPR	Bystander CPR
Adjusted for					
Site only	1.00	0.75 (0.68, 0.84)	0.48 (0.43, 0.53)	0.14 (0.12, 0.16)	0.16 (0.14, 0.18)
Site, age, sex and private/public location	1.00	0.61 (0.54, 0.68)	0.45 (0.40, 0.50)	0.12 (0.10, 0.14)	0.15 (0.13, 0.17)
Site, age, sex, private/public location and first EMS rhythm	1.00	0.41 (0.36, 0.46)	0.37 (0.33, 0.43)	0.17 (0.14, 0.20)	0.21 (0.18, 0.24)

Data presented as OR (95% CI).

training, treatment protocols, and equipment. The present investigation adds to the current body of knowledge with a large, prospectively collected data set from a single year in a multinational research consortium.

Although in this cohort we could not identify the reason EMS-witnessed cardiac arrest patients accessed 9-1-1, a previous study identified chest pain and dyspnea as the most common symptoms leading to EMS-witnessed OHCA.[8] As at least 40% of cardiac arrest victims treated by EMS providers suffer myocardial ischemia prior to collapse, it is likely that a significant proportion of these patients suffer signs and symptoms leading up to the event.[11] Prevention of cardiac arrest is likely to provide better outcomes than treatment after cardiac arrest. Therefore, it is reasonable to assume that early access of emergency care should reduce mortality from cardiac arrest if the treatments rendered prevent impending cardiac arrest. However, even though it has not been empirically tested, these data combined with previous reports suggests that if a patient suffers cardiac arrest during the attendance of a paramedic, the immediate application of medical care may improve outcome over bystander witnessed and unwitnessed cases. This concept further advances public education initiatives to call 9-1-1 early for cardinal symptoms like chest pain.

The present data suggest that bystander CPR after witnessed arrest is associated with an increased probability of VF/VT being the first recorded rhythm. This effect of bystander CPR may indirectly contribute to survival, but this is less evident when the model adjusts for both rhythm and bystander CPR and the known effects of age, sex, and location of arrest potentially indicating that prehospital treatments (e.g. airway management, drug administration) may have different effects on short- and long-term survival.[2] When considering the multi-factorial nature of resuscitation, the true effect of bystander CPR is difficult to reconcile. Studies reporting this association have typically reported modest odds ratios for bystander CPR predicting survival.[12–14] However, previous studies attempting to model the effectiveness of cardiac arrest interventions have not identified bystander CPR as an independent predictor of survival although in some cases, the interaction of bystander CPR and another predictor (e.g. time to first CPR) does predict survival.[2,15] Some of this variability in results may be due to the population studied. If CPR converts some patients from asystole to VF they still may not be survivable. If the population studied is limited to only those with an initial rhythm of VF, some are in the earliest minutes of cardiac arrest and bystander CPR is less important for successful defibrillation. Our data seem to confirm that CPR in bystander witnessed arrests is associated with increased survival.

The principal limitation to this study is the selection of ROC sites that reflects the NIH peer-review selection process. Most sites that were selected to participate in ROC had an established research track record. The investigators selected the EMS agencies affiliated with these sites based on known, or perceived, ability to implement and rigorously perform an interventional study. This selection bias may imply different organizational structure and patient care protocols that affect the generalizability of analyses performed on ROC data. Furthermore, EMS training and protocols may vary from agency to agency and therefore it is impossible to determine what made a difference.

This is a retrospective analysis and we cannot conclude the immediate EMS intervention improves outcome or if this is an association seen in a selected subpopulation of OHCA. However, data were prospectively collected using narrowly defined data elements standardized across ROC. Our prehospital data are primarily based on abstracting the patient care record created by the prehospital provider and subject to potential variability in the interpretation of some of the data points.[16]

Nevertheless this is the largest study with clearly defined and prospectively collected data from a single year in a multinational research consortium that analyzes the survival of EMS-witnessed OHCA patients. Survival was higher after EMS-witnessed OHCA when compared to bystander witnessed or unwitnessed cases. Odds of survival to discharge in witnessed OHCA with bystander CPR was not equivalent to immediate care by EMS providers when adjusting for age, sex, location of arrest, and initial ECG rhythm in spite of a greater incidence of PEA as the initial rhythm of EMS-witnessed cases.

5. Conclusions

The immediate application of advanced prehospital care by EMS personnel after the onset of OHCA may improve survival. Educating patients about the importance of seeking medical care and accessing 9-1-1 for prodromal symptoms is likely to improve survival for OHCA.

Conflict of interest

The authors have not reported conflicts of interest related to this manuscript.

Acknowledgements

The Resuscitation Outcome Consortium (ROC) was supported by a series of cooperative agreements to 10 regional clinical centers and one data Coordinating Center (5U01 HL077863, HL077881, HL077871, HL077872, HL077866, HL077908, HL077867, #1HL077885, HL077877, HL077873) from the National Heart, Lung and Blood Institute in partnership with the National Institute of Neurological Disorders and Stroke, U.S. Army Medical Research & Material Command, The Canadian Institutes of Health Research (CIHR)—Institute of Circulatory and Respiratory Health, Defence Research and Development Canada, the Heart and Stroke Foundation of Canada, and the American Heart Association.

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