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Telephone cardiopulmonary resuscitation is independently associated with improved survival and improved functional outcome after out-of-hospital cardiac arrest☆

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ABSTRACT

Aim of study: This study aims to quantify the relative impact of Dispatcher-Initiated Telephone cardiopulmonary resuscitation (TCPR) on survival and survival with favorable functional outcome after out-of-hospital cardiac arrest (OHCA) in a population of patients served by multiple emergency dispatch centers and more than 130 emergency medical services (EMS) agencies.
Methods: We conducted a retrospective, observational study of EMS-treated adult (≥18 years) patients with OHCA of presumed cardiac origin in Arizona, between January 1, 2011, and December 31, 2014. We compared survival and functional outcome among three distinct groups of OHCA patients: those who received no CPR before EMS arrival (no CPR group); those who received BCPR before EMS arrival and prior to or without telephone CPR instructions (BCPR group); and those who received TCPR (TCPR group).
Results: In this study, 2310 of 4391 patients met the study criteria (median age, 62 years; IQR 50, 74; 1540 male). 32.8% received no CPR, 23.8% received Bystander-Initiated CPR and 43.4% received TCPR. Overall survival was 11.5%. Using no CPR as the reference group, the multivariate adjusted odds ratio for survival at hospital discharge was 1.51 (95% confidence interval [CI], 1.04, 2.18) for BCPR and 1.64 (95% CI, 1.16, 2.30) for TCPR. The multivariate adjusted odds ratio of favorable functional outcome at discharge was 1.58 (95% CI 1.05, 2.39) for BCPR and 1.56 (95% CI, 1.06, 2.31) for TCPR.
Conclusion: TCPR is independently associated with improved survival and improved functional outcome after OHCA.

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Introduction

Out-of-hospital cardiac arrest (OHCA) is a major public health issue [1]. Successful resuscitation hinges on early activation of the emergency response system, early Bystander-Initiated cardiopulmonary resuscitation (BCPR), early defibrillation, high-quality emergency medical services (EMS) CPR and standardized post-arrest care [2]. BCPR rates can reach 70–80% in communities with well-implemented community CPR and Dispatcher-Initiated Telephone CPR (TCPR) programs [3], and increased BCPR rates are associated with a three-and-a-half fold increase in 1-year survival [4]. In most communities, however, BCPR is provided in only one-third to one-half of cases [5–8] and low survival rates persist.

TCPR can potentially double BCPR rates [7,9,10] and is emphasized as an important intervention by the American Heart Association [7]. Results from analyses assessing the potential impact of TCPR on patient outcomes, however, are not uniform. One, in fact, found a trend toward decreased survival [11].

The purpose of this study is to compare survival and functional outcome among three groups of OHCA patients: (1) those who received no CPR prior to EMS arrival (no CPR group), (2) those who received BCPR (BCPR group), and (3) those who received TCPR (TCPR group).

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Methods

Study Design, Setting and Population

This is a retrospective observational study of EMS-treated adult (≥18 years) patients with OHCA of presumed cardiac origin in Arizona, between January 1, 2011, and December 31, 2014. Arizona has 15 counties and 6.7 million residents across urban, suburban, rural and wilderness areas [12].) Arrests were presumed to be of cardiac origin unless the arrest was known to be caused by trauma, drowning, drug overdose, or asphyxia [5]. Cases were excluded if: (1) the patient had a do-not-resuscitate (DNR) order; (2) the arrest was witnessed by EMS providers; (3) the arrest occurred at a medical facility (e.g. doctor's office or nursing home); (4) the telecommunicator was not in immediate contact with the caller at the start of the audio recording but rather spoke first with a telecommunicator transferring the call from another agency; or (5) the audio recording was incomplete or fragmented.

The data collected were exempt from the Health Insurance Portability and Accountability Act (HIPAA) because OHCA has been designated a major public health issue in Arizona and because the Save Hearts in Arizona Registry and Education (SHARE) Program's goal is continuous quality improvement. The Arizona Department of Health Services' Human Subjects Review Board and the University of Arizona Institutional Review Board have granted permission to publish de-identified patient, emergency dispatch center, EMS agency and hospital data. SHARE is registered at ClinicalTrials.gov:# NCT 01999036.

Data collection and measurement

The emergency calls were processed at eight regional dispatch centers covering about 80% of Arizona's population. Trained personnel audited recordings of the calls using a structured data form and a standardized process published previously [10]. An Utstein-style OHCA EMS database pooling from more than 130 agencies was linked with in-hospital post-resuscitation process and outcome data from 46 hospitals [13]. SHARE is a statewide public health program and collaboration between the University of Arizona, the Arizona Department of Health Services, emergency dispatch centers, EMS agencies and hospitals. It is designed to improve patient outcomes by assessing OHCA incidence and process of care. The program and its results have been described in detail [5,8,10,14,15].

Each OHCA case was classified into one of three groups for statistical analysis: (1) no CPR before EMS arrival; (2) BCPR before EMS arrival and prior to or without telephone CPR instructions; and (3) TCPR before EMS arrival. BCPR was considered to have been performed if the start of bystander chest compressions without emergency dispatcher (telecommunicator) CPR instructions was confirmed during the emergency call or in the EMS first care report. TCPR was considered provided if telecommunicators started CPR instructions that resulted in the initiation of bystander chest compressions. Telecommunicators are expected to provide CPR instructions if the patient is deemed not conscious and not breathing or not breathing normally. (See http://ow.ly/Ui7E8)

Outcome measures

The primary outcome was survival to hospital discharge. The secondary outcome was survival to hospital discharge with favorable functional outcome. Favorable functional outcome was defined as a Cerebral Performance Category (CPC) score of 1 (good cerebral performance) or 2 (moderate cerebral disability) at hospital discharge [16].

Statistical Analysis

Continuous variables were summarized by median and interquartile range (IQR) and were compared between multiple groups of patients using the Kruskal-Wallis test. Categorical variables were summarized by frequency and proportion and were compared between multiple groups by either Chi-squared or Fisher's exact test, as appropriate. Logistic regression was used to associate any binary outcome measure with potential risk factors and confounders. Likelihood ratio test was used to test for the association of any variable with the outcome, and for categorical variables the Wald test was used for the comparison between the referent category and any other category. The effect of the continuous variable age in the logistic regression was checked nonparametrically using penalized thin plate regression splines through the generalized additive model [17]. All patient characteristics, risk factors and intervention variables in Table 1 along with dispatch center were included in an initial logistic regression model, and the backward elimination procedure was used to remove the covariates one by one with p-value threshold of 0.05 while always keeping the CPR group, EMS arrival categories and the demographics (gender and age) in the model. The software environment R [18] was used for the analysis and the R package mgcv [17,19] was used for the generalized additive model. All tests were two-sided with $\alpha = 0.05$.

Results

A total of 4391 cases with linked 9-1-1, EMS and outcome data in the SHARE Program database were evaluated. Roughly 75% of the audios investigated were from dispatch centers with protocols based on American Heart Association (AHA) guidelines [2,7] and provide compression-only CPR instructions for adult arrests of presumed cardiac origin. Of 4391 patients, 2310 met the study criteria (median age, 62 years; IQR 50, 74; 1540 male). Of the 2081 excluded, 1877 (90.2%) did not meet the study criteria while 204 (9.8%) were missing data. Exclusion criteria are presented in Fig. 1. Overall rate of survival and favorable functional outcome were 11.5% and 8.7%, respectively.

The respective proportion of patients in the no CPR, BCPR and TCPR groups were: 32.8% (n = 758), 23.8% (n = 550) and 43.4% (n = 1002). Table 1 shows event characteristics and clinical outcomes across these three groups. The proportion of male patients was significantly different ($p = 0.007$) across the groups. The proportion of males was highest (70.5%) in the Bystander-Initiated CPR group. Age was also significantly different ($p < 0.001$) with the highest median (66 years) in the no CPR group. The proportion of incidents in public locations was significantly different ($p < 0.001$) with the highest (30.2%) in the BCPR group. The proportion of witnessed arrests was also significantly different ($p < 0.001$), with the BCPR group having the highest rate (42.4%). The proportion of cases with shockable initial rhythm and sustained return of spontaneous circulation (ROSC) was significantly different ($p < 0.001$ and $p = 0.0137$, respectively) as well, with the BCPR group having the highest rates (34.5% and 20.4%, respectively).

The three groups had significantly different rates of survival to hospital discharge ($p = 0.0006$) and favorable functional outcome ($p < 0.001$). The BCPR group had the highest rates (15.1% and 12.4%, respectively), followed by the TCPR group (12.0% and 8.5%). The no CPR group had the lowest rates (8.3% and 6.3%).

Table 2 shows results from a logistic regression analysis for survival to hospital discharge by CPR group. The covariates include patients' CPR group, age, gender, witnessed status, location of OHCA and EMS response time. After adjusting for potential confounders and risk factors, both the BCPR group and the TCPR group had significantly higher survival rates compared to the no CPR group [aOR (BCPR) = 1.51; 95% confidence interval [CI]: 1.04, 2.18, $p = 0.029$; aOR (TCPR) = 1.64; 95%CI: 1.16, 2.30; $p = 0.005$].

Table 3 reports the parallel analysis for favorable functional outcome at discharge. After adjusting for the potential confounders and risk factors, both the BCPR group and the TCPR group had significantly higher rates of favorable functional outcome compared to the no CPR group [aOR (BCPR) = 1.58; 95% CI: 1.05, 2.39, $p = 0.029$;

Table 1
Patient and OHCA Characteristics and Clinical Outcomes.

Group		All [a]	No CPR[a]	Bystander-Initiated CPR[a]	Dispatcher-Initiated Telephone CPR[a]	p-value*
# of Subjects		2310	758	550	1002	
Gender	F	770 (33.3%)	240 (31.7%)	162 (29.5%)	368 (36.7%)	**0.007**
	M	1540 (66.7%)	518 (68.3%)	388 (70.5%)	634 (63.3%)	
Age		62 (50, 74)	66 (53, 77)	63 (51, 74)	60 (48, 71)	<0.001
Location of OHCA	Residential	1962 (84.9%)	654 (86.3%)	384 (69.8%)	924 (92.2%)	<0.001
	Public	348 (15.1%)	104 (13.7%)	166 (30.2%)	78 (7.8%)	
Witnessed	No	1537 (66.5%)	508 (67%)	317 (57.6%)	712 (71.1%)	<0.001
	Yes	773 (33.5%)	250 (33%)	233 (42.4%)	290 (28.9%)	
EMS Dispatch to Arrival Time (min)		5 (4, 6)	5 (4, 6)	5 (4, 6)	5 (4, 6)	0.720
Shockable Initial Rhythm	No	1719 (74.4%)	596 (78.6%)	358 (65.1%)	765 (76.3%)	<0.001
	Yes	579 (25.1%)	158 (20.8%)	190 (34.5%)	231 (23.1%)	
	Unknown	12 (0.5%)	4 (0.5%)	2 (0.4%)	6 (0.6%)	
Intubated	No	843 (36.5%)	288 (38%)	203 (36.9%)	352 (35.1%)	0.447
	Yes	1345 (58.2%)	428 (56.5%)	322 (58.5%)	595 (59.4%)	
	Unknown	122 (5.3%)	42 (5.5%)	25 (4.5%)	55 (5.5%)	
Sustained ROSC	No	1859 (80.5%)	626 (82.6%)	423 (76.9%)	810 (80.8%)	0.014
	Yes	377 (16.3%)	111 (14.6%)	112 (20.4%)	154 (15.4%)	
	Unknown	74 (3.2%)	21 (2.8%)	15 (2.7%)	38 (3.8%)	
Transported to CRC	No	1011 (43.8%)	349 (46%)	219 (39.8%)	443 (44.2%)	0.073
	Yes	1298 (56.2%)	408 (53.8%)	331 (60.2%)	559 (55.8%)	
	Unknown	1 (0%)	1 (0.1%)	0 (0%)	0 (0%)	
Survival at Discharge	No	1976 (85.5%)	672 (88.7%)	451 (82%)	853 (85.1%)	0.001
	Yes	266 (11.5%)	63 (8.3%)	83 (15.1%)	120 (12.0%)	
	Unknown	68 (2.9%)	23 (3%)	16 (2.9%)	29 (2.9%)	
CPC at Discharge	Good (1,2)	201 (8.7%)	48 (6.3%)	68 (12.4%)	85 (8.5%)	0.001
	Poor (3, 4, 5)	2020 (87.4%)	683 (90.1%)	459 (83.5%)	878 (87.6%)	
	Unknown	89 (3.9%)	27 (3.6%)	23 (4.2%)	39 (3.9%)	

OHCA indicates out-of-hospital cardiac arrest; CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation; CRC, cardiac receiving center; CPC, cerebral performance category

[a] median (interquartile range, IQR) for continuous variables and count (percentage) for categorical variables.

* Chi-squared test for categorical variables and Kruskal-Wallis test for continuous variables; the unknown category, if present, is excluded from the testing procedure.

Table 2
Logistic Regression for Survival at Discharge[a].

Variable	Levels	aOR	95% CI	P-value* (Category)	P-value# (Covariate)
CPR Status	No CPR	––	––	––	0.011
	Bystander-Initiated CPR	1.51	(1.04, 2.18)	0.029	
	Dispatcher-Initiated Telephone CPR	1.64	(1.16, 2.30)	0.005	
Gender	F	––	––	––	0.556
	M	1.1	(0.81, 1.48)	0.557	
Age		0.98	(0.97, 0.99)	––	<0.001
Location of OHCA	Residential	––	––	––	<0.001
	Public	2.26	(1.63, 3.15)	<0.001	
Witnessed	No	––	––	––	<0.001
	Yes	3.71	(2.79, 4.92)	<0.001	
EMS Arrival Time	4 min or below	––	––	––	0.161
	5 min	0.75	(0.52, 1.08)	0.124	
	6–7 min	1.09	(0.78, 1.53)	0.626	
	8 min or above	0.66	(0.42, 1.05)	0.079	
	Unknown	0.78	(0.22, 2.80)	0.709	

CPR indicates cardiopulmonary resuscitation; OHCA, out-of-hospital cardiac arrest; EMS, emergency medical services

[a] Model adjusted for age, gender, witness status, location and EMS arrival time.

* Wald test.

Likelihood ratio test.

aOR (TCPR) = 1.56; 95% CI: 1.06, 2.31, p = 0.025]. Dispatch centers and various dichotomizations of EMS response time were not statistically significant, and hence were not included in Tables 2 and 3.

Discussion

Our statewide analysis showed that survival and survival with favorable functional outcome were significantly higher among patients who received TCPR and BCPR than among patients who received no CPR. Compared to no CPR, the ORs for BCPR and TCPR were similar for both survival and survival with favorable functional outcome. However, methods and results of studies assessing its impact on survival and functional outcome are not uniform. Bohm, et al. reviewed related papers published between 1985 and 2009 and found that there is limited evidence supporting the survival benefit of TCPR instructions. All reviewed studies comparing patient outcomes when CPR is provided with or without telecommunicator CPR instructions lack the statistical power to draw significant conclusions [20]. Thus, we analyzed a large sample of patient data to compare survival and functional outcomes among those receiving TCPR, BCPR and no CPR in order to determine whether TCPR improved outcomes.

Our findings are consistent with those in separate studies by Song et al. and Tanaka et al., both of which found that implementation of guideline-based TCPR protocols and/or quality-improvement programs was associated with increased survival and

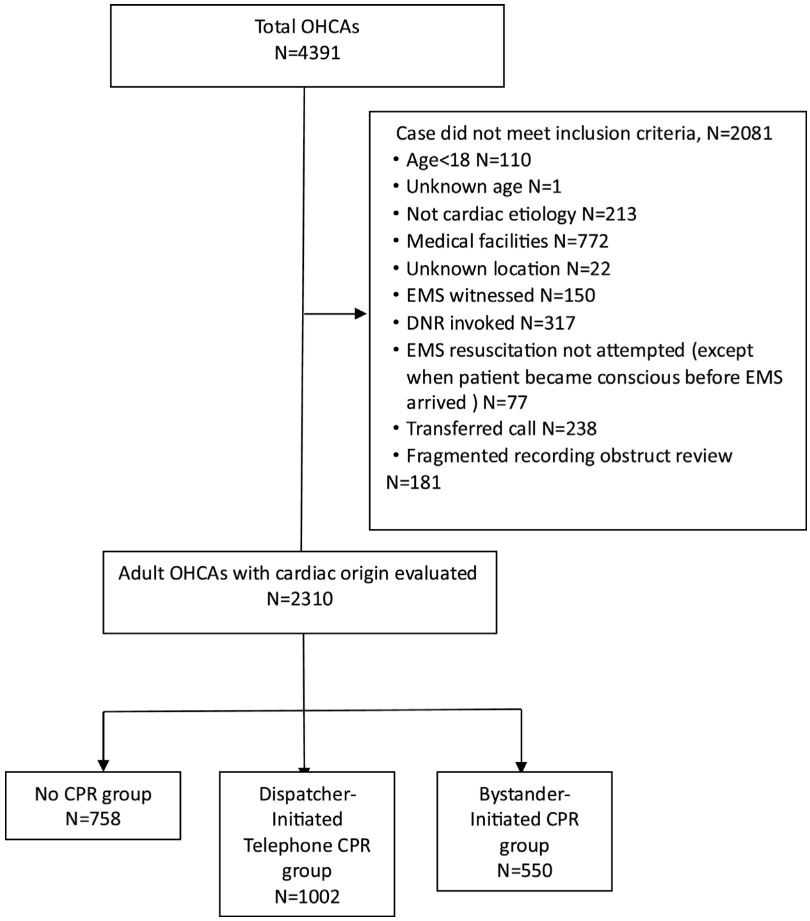

Fig. 1. Study Enrollment.
OHCA indicates out-of-hospital cardiac arrest; EMS, emergency medical services; DNR, do not resuscitate order; CPR, cardiopulmonary resuscitation.

Table 3
Logistic Regression for Favorable Functional Outcome at Discharge[a].

Variable[b]	Levels	aOR	95% CI	P-value[*] (Category)	P-value[#] (Covariate)
CPR Status	No CPR	--	--	--	0.037
	Bystander-Initiated CPR	1.58	(1.05, 2.39)	0.029	
	Dispatcher-Initiated Telephone CPR	1.56	(1.06, 2.31)	0.025	
Gender	F	--	--	--	0.267
	M	1.22	(0.86, 1.74)	0.271	
Age		0.98	(0.97, 0.99)	--	<0.001
Location of OHCA	Residential	--	--	--	<0.001
	Public	2.58	(1.79, 3.71)	<0.001	
Witnessed	No	--	--	--	<0.001
	Yes	3.76	(2.71, 5.20)	<0.001	
EMS Arrival Time	4 min or below	--	--	--	0.179
	5 min	0.74	(0.49, 1.12)	0.152	
	6–7 min	0.88	(0.59, 1.30)	0.513	
	8 min or above	0.54	(0.31, 0.93)	0.026	
	Unknown	0.7	(0.15, 3.16)	0.641	

CPR indicates cardiopulmonary resuscitation; OHCA, out-of-hospital cardiac arrest; EMS, emergency medical services.
[a] Model adjusted for age, gender, witness status, location and EMS arrival time.
[b] The model also adjusted for dispatch center (not shown; p = 0.0085).
[*] Wald test.
[#] Likelihood ratio test.

increased favorable functional outcome [21,22]. Vaillancourt, however, found a trend toward decreased survival in cases where TCPR instructions were provided [11] and Fujie found that survival and favorable functional outcome rates did not vary across cases where TCPR instructions were provided or not provided [23]. In addition, Akahane found that, though TCPR was associated with increased 1-month survival, it was not associated with increased favorable functional outcome [24]. Ro found that TCPR was associated with increased favorable functional outcome, but not with increased survival to discharge [25].

Our study is unique in several ways and adds additional information to the published literature. First, it draws on data collected from multiple emergency dispatch centers primarily prescribing compression-only CPR for adult OHCAs of cardiac origin. The 2015

AHA guidelines recommend the provision of compression-only instructions for adult OHCAs of cardiac origin [2]. Second, we evaluated functional outcomes for each CPR group in addition to evaluating survival. Third, our study utilized data from multiple, independent EMS systems participating in a statewide public health cardiac resuscitation program designed to improve all facets of OHCA care.

We followed Rea et al. in defining three CPR groups among patients ≥ 18 years and in adjusting for age, gender, witness status, location and EMS response time [26]. They too found that both BCPR and TCPR increased survival compared to no CPR [aOR (BCPR) = 1.69; 95% CI: 1.42, 2.01; aOR (TCPR) = 1.45; 95% CI: 1.21, 1.73] [26]. In Rea's study, patient functional outcome was unclear due to incomplete data [26]. We found that BCPR and TCPR are about equally effective in promoting favorable functional outcomes as well, a result consistent with Goto's recent three-group study of patients <18 years [27].

These results are plausible even though BCPR has two presumed advantages over TCPR. The first is that, by the definition used in this study, BCPR starts sooner after arrest onset than TCPR. This timing is vital because of the degree to which patient outcomes deteriorate in the absence of CPR [28]. The second is that lay rescuers who perform BCPR on their own initiative are more likely to have had CPR training [29] and the confidence needed to start CPR.

Any advantage that accrues to TCPR, then, would do so (1) between the time TCPR is started and the time professional rescuers assume care and (2) despite the fact that these rescuers are less likely to have had CPR training than those who initiate CPR without telecommunicator assistance. Telecommunicators have the potential not only to help lay rescuers recognize cardiac arrest and start CPR, but also to help create and maintain appropriate compression rate, depth and fraction through continuous CPR coaching until professional rescuers assume care [2,30,31]. This is an essential function because lay rescuer CPR knowledge and skill erode quickly after training [32]. As a rule, telecommunicators in the present study direct lay rescuers to count their compressions out loud so telecommunicators can monitor and adjust the rate as needed. In this way, they can provide real-time audio feedback consistent with audiovisual feedback shown to improve compression quality among EMS professionals [33,34].

In addition, these telecommunicators are trained to provide psychological support throughout the emergency call, encouraging lay rescuers to continue compressions until professional help arrives. This is also an essential function – one simulation study showed that lay rescuers aged 50–75 could perform adequate compressions for at least 10 min when coached by a telecommunicator [35]. Furthermore, telecommunicators in the present study are encouraged to have bystanders switch rescuers if fatigue requires and more than one bystander is present (see http://cprlinktolife.com).

Finally, a TCPR continuous quality improvement program including standardized reviews of audio recordings and system and case level feedback to agencies and individual providers in the study region may have improved outcomes for patients receiving TCPR [8].

Our study has limitations. First, it is not a randomized trial. We did, however, control for known confounders. Second, we did not assess lay rescuer knowledge of CPR, CPR training history, socioeconomic status, or relationship to the patient which may impact the caller's willingness to perform CPR. Third, TCPR protocols varied across dispatch centers. About 75% of the audio recordings evaluated in this study were from dispatch centers that drafted their own protocols. The remainder were from centers using various versions of Medical Priority Dispatch or Association of Public-Safety Communications Officials systems [36]. Finally, this study is missing survival data on 68 patients and CPC score on 89 patients.

Future efforts investigating the potential benefits of TCPR should consider not only arrests of cardiac origin but also those that stem from respiratory causes such as drowning, drug overdose, and asphyxia. Such work could give 9-1-1 agencies impetus to improve and expand the provision of TCPR to a potentially growing group of patients.

Conclusion

In this statewide analysis involving multiple emergency dispatch centers and EMS systems, we found that TCPR was independently associated with increased survival and favorable functional outcome after OHCA and was as effective as BCPR.

Conflicts of interest

Drs. Bobrow and Spaite disclose that the University of Arizona received funding from the Medtronic Foundation through the Heart Rescue Grant to support community-based translation of resuscitation science. Dr. Zhixin Wu received support from Science and Technology Foundation of Foshan City, China (no.2015AB00355 and no. 2015AG10001), Guangdong Province Science and Technology Foundation (no. 2014A020212002).

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