Original Investigation

Implementation of a Regional Telephone Cardiopulmonary Resuscitation Program and Outcomes After Out-of-Hospital Cardiac Arrest

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IMPORTANCE Bystander cardiopulmonary resuscitation (CPR) significantly improves survival from out-of-hospital cardiac arrest but is provided in less than half of events on average. Telephone CPR (TCPR) can significantly increase bystander CPR rates and improve clinical outcomes.

OBJECTIVE To investigate the effect of a TCPR bundle of care on TCPR process measures and outcomes.

DESIGN, SETTING, AND PARTICIPANTS A prospective, before-after, observational study of adult patients with out-of-hospital cardiac arrest not receiving bystander CPR before the 9-1-1 call between October 1, 2010, and September 30, 2013.

INTERVENTIONS A TCPR program, including guideline-based protocols, telecommunicator training, data collection, and feedback, in 2 regional dispatch centers servicing metropolitan Phoenix, Arizona. Audio recordings of out-of-hospital cardiac arrest calls were audited and linked with emergency medical services and hospital outcome data.

MAIN OUTCOMES AND MEASURES Survival to hospital discharge and functional outcome at hospital discharge.

RESULTS There were 2334 out-of-hospital cardiac arrests (798 phase 1 [P1] and 1536 phase 2 [P2]) in the study group; 64% (1499) were male, and the median age was 63 years (age range, 9-101 years; interquartile range, 51-75 years). Provision of TCPR increased from 43.5% in P1 to 52.8% in P2 ($P < .001$), yielding an increase of 9.3% (95% CI, 4.9%-13.8%). The median time to first chest compression decreased from 256 seconds in P1 to 212 seconds in P2 ($P < .001$). All rhythm survival was significantly higher in P2 (184 of 1536 [12.0%]) compared with P1 (73 of 798 [9.1%]), with an adjusted odds ratio (aOR) of 1.47 (95% CI, 1.08-2.02; $P = .02$) in a logistic regression model and an adjusted difference in absolute survival rates (adjusted rate difference) of 3.1% (95% CI, 1.5%-4.9%). Survival for patients with a shockable initial rhythm significantly improved in P2 (107 of 306 [35.0%]) compared with P1 (42 of 170 [24.7%]), with an aOR of 1.70 (95% CI, 1.09-2.65; $P = .02$) and an adjusted rate difference of 9.6% (95% CI, 4.8%-14.4%). The rate of favorable functional outcome was significantly higher in P2 (127 of 1536 [8.3%]; 95% CI, 6.9%-9.8%) than in P1 (45 of 798 [5.6%]; 95% CI, 4.1%-7.5%), with an aOR of 1.68 (95% CI, 1.13-2.48; $P = .01$) and an adjusted rate difference of 2.7% (95% CI, 1.3%-4.4%).

CONCLUSIONS AND RELEVANCE Implementation of a guideline-based TCPR bundle of care was independently associated with significant improvements in the provision and timeliness of TCPR, survival to hospital discharge, and survival with favorable functional outcome.

JAMA Cardiol. doi:10.1001/jamacardio.2016.0251
Published online May 4, 2016.

Invited Commentary and **Editor's Note**

Supplemental content at jamacardiology.com

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Out-of-hospital cardiac arrest (OHCA) is a major public health problem in the United States.[1] Successful resuscitation requires a synchronized set of interdependent rescuer actions (the "chain of survival"), of which the initial links are immediate recognition of cardiac arrest and activation of the emergency response system, early cardiopulmonary resuscitation (CPR) with an emphasis on chest compressions, and rapid defibrillation.[2] Bystander CPR (BCPR) has been shown to double or even triple survival from OHCA.[3-7] Despite decades of public CPR training, in most communities fewer than half of all individuals with cardiac arrest receive any BCPR, and bleak survival rates persist.[8] In response, both the American Heart Association[2,9] and the Institute of Medicine[10] have emphasized the importance of telecommunicators (9-1-1 call takers and dispatchers) identifying cardiac arrest and assisting lay rescuers in providing BCPR to improve survival.

The objective of this study was to investigate the effect of implementing a bundle of care, including a guideline-based telephone CPR (TCPR) protocol, interactive telecommunicator training, detailed data collection with 9-1-1 call auditing, and telecommunicator feedback for OHCA, in 2 regional dispatch centers serving metropolitan Phoenix, Arizona. We hypothesized that this implementation would be associated with (1) an increase in TCPR rates, (2) a decreased time to first chest compression, and (3) an increased likelihood of survival to hospital discharge and favorable functional outcome.

Key Points

Question Was implementation of a guideline-based bundle of telephone cardiopulmonary resuscitation (CPR) care associated with increased survival to hospital discharge and favorable functional outcome after out-of-hospital cardiac arrest?

Findings In this prospective, before-after, observational study, survival to hospital discharge and favorable functional outcome increased significantly from 9.1% to 12.0% and from 5.6% to 8.3%, respectively.

Meaning Guideline-based telephone CPR programs can help communities improve patient outcomes after out-of-hospital cardiac arrest.

Methods

Arizona has 6.7 million residents and is composed of 15 counties with urban, suburban, rural, and wilderness areas.[11] In 2004, the Arizona Department of Health Services, in conjunction with The University of Arizona, emergency medical services (EMS) agencies, and hospitals in the state, created the Save Hearts in Arizona Registry and Education (SHARE) program. SHARE was designed to measure the incidence of OHCA and the effect of public, EMS, and hospital resuscitation interventions.[12] This program and its results have been previously described in detail.[4,12-18]

Because OHCA has been designated a major public health problem in Arizona and because the objective of the SHARE program is to improve resuscitation quality and increase survival, the data collected were exempt from the Health Insurance Portability and Accountability Act. Permission to publish the deidentified patient, 9-1-1 center, EMS agency, and hospital data was obtained from the Arizona Department of Health Services' Human Subjects Review Board and The University of Arizona Institutional Review Board. The project is registered at clinicaltrials.gov (NCT01999036).

Because this project was foremost a public health quality improvement effort, 2 regional dispatch centers were selected because they collectively serve 30 incorporated districts in the metropolitan Phoenix area and cover approximately two-thirds of Arizona's population. Phase 1 (P1) was from October 1, 2010, through November 6, 2011, in one center and from February 1, 2011, through March 14, 2012, in the other center. The respective phase 2 (P2) start dates were November 7, 2011, and March 15, 2012. Phase 2 ended September 30, 2013, in both centers. The P1 and P2 periods started on different dates in the centers because of administrative and logistic constraints encountered in implementing the intervention.

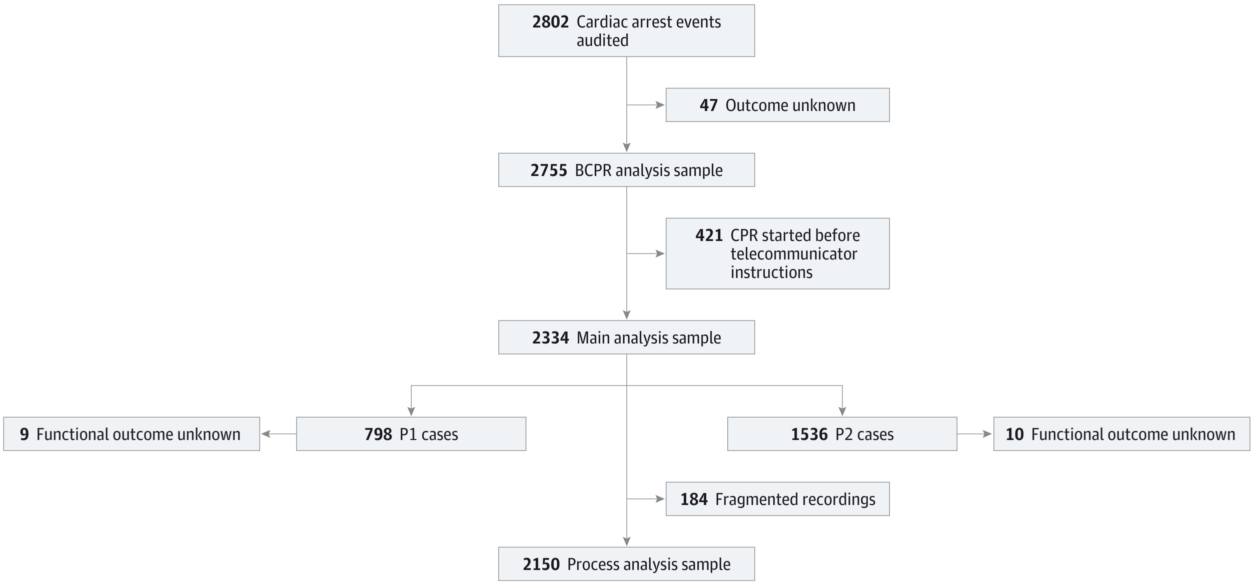
Study Population

This study was a prospective, before-after, observational analysis of patients with OHCA entered into the SHARE database. The study population (**Figure**) was composed of patients with an EMS-treated, non–EMS-witnessed OHCA of nontraumatic origin. Cases were excluded if patients showed evidence of obvious death or had do not resuscitate orders. Incidents in medical facilities (eg, physician's office or nursing home) and incidents in which CPR was started before telecommunicator instructions were also excluded. In addition, calls with incomplete or fragmented audio were excluded from the TCPR process analysis. Calls in which CPR was started before telecommunicator instructions were not excluded for the comparison of BCPR rates between P1 and P2. Bystander CPR was considered started if compressions were documented in either TCPR or EMS data.

Intervention

The TCPR program was designed as a statewide effort to measure and improve the process of TCPR. Because roughly two-thirds of the state's population (approximately 4 million citizens) reside in metropolitan Phoenix,[19] the formal data linkage (9-1-1 to EMS to hospital) and evaluation were focused here. The data for this region come from 2 public 9-1-1 emergency medical dispatch centers, 30 EMS agencies, and 22 cardiac receiving centers. The dispatch centers had provided prearrival CPR instructions to callers reporting potential OHCAs; however, they had not yet adopted guideline-based recommendations for identifying cardiac arrest, training, or quality improvement before the intervention. The intervention was a comprehensive bundle of care based on the latest American Heart Association[9] guidelines for TCPR (http://azdhs.gov/azshare/911/index.htm). The bundle included novel protocols, training modules, case and system-level data collection, reporting, and feedback to individual health care professionals. The protocols call for (1) compression-only CPR for adult arrests

Figure. Study Population Profile



BCPR indicates bystander cardiopulmonary resuscitation; CPR, cardiopulmonary resuscitation; P1, phase 1; and P2, phase 2.

of presumed cardiac origin and (2) compressions with rescue breaths for all other arrests.[9] The protocols direct telecommunicators to ask the following 2 questions as early as possible: (1) "Is the patient conscious?" and (2) "Is the patient breathing normally?" If the answer to both is no, then telecommunicators are advised to start TCPR instructions immediately. Live and web-based teaching modules trained approximately 250 telecommunicators, focusing on early arrest recognition, identifying agonal breathing (gasping), and starting prompt, assertive, and continuous TCPR instructions until professional rescuers assume care (http://ow.ly/Ui7E8). For the quality improvement aspect of the intervention, OHCA calls were audited, and system-level performance reports were provided on key process measures. The 9-1-1 center supervisors provided case-level feedback to individual telecommunicators on calls if coaching was needed. There were no other system-wide interventions to improve EMS or hospital resuscitation care during the TCPR intervention.

Main Outcome Measures

The main outcome measures were survival to hospital discharge and favorable functional outcome at hospital discharge. Secondary outcomes consisted of the 6 key TCPR process measures (described below) and a comparison of TCPR and overall BCPR rates between P1 and P2.

9-1-1 Data

The investigators developed a web-based data collection tool to capture relevant information on the telecommunicator to bystander interaction (eAppendix in the Supplement). This call review and data collection process has been reported in detail.[20] Audio recordings of cardiac arrest calls were collected from 2 regional 9-1-1 centers serving the metropolitan Phoenix area. These recordings were matched to EMS-confirmed OHCA reports through case-specific identifiers, such as incident number, incident location, and date and time of the call. Patient outcomes were obtained directly from participating hospitals or from the Arizona Office of Vital Records. Incident information is entered into the 9-1-1 dispatch centers' medical computer-aided dispatch systems for telecommunicators to assign emergency response units according to the nature of the call. Calls are assigned specific cardiac arrest codes when patients are recognized as not conscious and not breathing or not breathing normally.

Quality improvement evaluators were formally trained in a call evaluation process that resulted in strong interrater agreement on 6 key performance metrics reported in this study. These included (1) percentage of TCPR-indicated calls in which the telecommunicator recognized the need for TCPR, (2) percentage of TCPR-indicated calls in which the telecommunicator started TCPR instructions, (3) percentage of TCPR-indicated calls in which bystanders started TCPR, (4) interval from call receipt until the telecommunicator recognized the need for TCPR, (5) interval from call receipt until start of TCPR instructions, and (6) interval from call receipt until the bystander performed the first chest compression.[20]

The need to perform CPR was indicated in the audio recordings when it was determined the patient was not conscious and was not breathing normally. Not breathing normally was defined as the caller describing either complete absence of breathing, agonal breathing, or a rapid or slow respiratory rate. Evaluator identification of audible agonal breaths during audio recording review was considered not breathing normally. Telecommunicator recognition of the need for TCPR was indicated when he or she used any of several key terms in the context of providing CPR instructions (eg, "CPR," "chest compressions," and "compressions"). Cardiopulmonary resuscitation instructions were defined as any portion of telecommunicator to bystander communication that detailed the delivery of chest compressions, rescue breaths, or both. Performance of TCPR was defined as any chest compressions delivered to the individual in response to TCPR instructions. If ventilations occurred without chest compressions, this occurrence was not counted as TCPR started.

EMS Data

Emergency medical services data were prospectively collected and entered into an existing Utstein-style database reflecting standardized international guidelines for the collection and reporting of OHCA data.[4,12,13] Data elements include sex, age, location of arrest, bystander-witnessed arrest, presumed etiology of arrest, EMS dispatch to scene arrival (response) interval, whether BCPR was provided, initial prehospital electrocardiographic rhythm, type of EMS protocol (minimally interrupted cardiac resuscitation vs conventional basic life support/advanced cardiac life support), prehospital intubation, whether the patient was transported to a cardiac receiving center, and clinical outcomes.

Hospital Data

The process for linking EMS and hospital postarrest data has been previously described in detail.[17] Data are cross-referenced between the first responding fire-based EMS, private ambulance transport agencies, and the Arizona Cardiac Receiving Center Database.[4,13,17] Outcome data were cross-referenced with the Arizona Hospital Discharge Database and the Arizona Office of Vital Records. Favorable functional outcome was defined through an in-person interview as a Cerebral Performance Category score of 1 (good cerebral performance) or 2 (moderate cerebral disability at hospital discharge).[21]

Statistical Analysis

Continuous variables were summarized by the median and range and were compared between the 2 periods (P1 vs P2) using the Wilcoxon rank sum test. Categorical variables were summarized by the frequency and proportion with 95% Clopper-Pearson CIs and were compared between the 2 periods by either the χ^2 test or Fisher exact test. Logistic regression models were used to compare the survival rates and the rates of favorable functional outcome between the 2 periods, while adjusting for potential confounders. Random effects for the EMS agencies were included in the models to account for any correlation between individuals cared for by the same EMS agency. The effect of the continuous variable age in the logistic regression models was examined nonparametrically using penalized thin plate regression splines through the generalized additive model and the Akaike information criterion. The logistic regression model was fitted for all individuals, as well as the subgroup with a shockable initial rhythm. Adjusted rate difference (aRD) in any event rates between P1 and P2 was estimated by averaging the predicted difference in event probabilities (P2 vs P1) across all patients using the fitted logistic model, and a 95% CI for the aRD was obtained by the bias-corrected and accelerated bootstrap approach. In the process analysis, the proportion of calls with telecommunicator recognition of the need for TCPR with TCPR instructions given or with compressions started was compared between the 2 periods. To compare the time to (1) telecommunicator recognition of the need for TCPR, (2) start of TCPR instructions, and (3) first compression, the generalized log-rank test[22] was used to compare interval-censored and right-censored data. The software environment R[23] and the R packages gamm4,[24] interval,[25] and Icens[26] were used for the analysis. All tests were 2-sided with α = .05.

Results

There were 2334 OHCAs (798 P1 and 1536 P2). Sixty-four percent (1499 of 2334) of the participants were male. The median age of participants was 63 years (age range, 9-101 years; interquartile range, 51-75 years). Inclusion and exclusion criteria are shown in the Figure. **Table 1** lists outcome measures and sample characteristics stratified by P1 and P2. Phase 2 had higher rates of sustained return of spontaneous circulation (*P* < .001), survival (*P* = .045), and favorable functional outcome (*P* = .03). The other sample characteristics were similar between P1 and P2 with the exception of location of arrest and prehospital intubation.

Survival was higher in P2 (12.0%; 95% CI, 10.4%-13.7%) than P1 (9.1%; 95% CI, 7.2%-11.4%) (*P* = .045), yielding a crude (unadjusted) rate difference of 2.8% (95% CI, 0.3%-5.4%) and a crude odds ratio (cOR) of 1.35 (95% CI, 1.02-1.80). After controlling for potential confounders and risk measures (**Table 2**), the logistic regression model identified a significantly higher odds of survival in P2 compared with P1 (adjusted odds ratio [aOR], 1.47; 95% CI, 1.08-2.02; *P* = .02) and higher survival rate in P2 (aRD, 3.1%; 95% CI, 1.5%-4.9%). The same was true for the rate of favorable functional outcome in P2 (8.3%; 95% CI, 6.9%-9.8%) vs P1 (5.6%; 95% CI, 4.1%-7.5%) (*P* = .03), with a cOR of 1.50 (95% CI, 1.05-2.13), crude rate difference of 2.6% (95% CI, 0.5%-4.8%), aOR of 1.68 (95% CI, 1.13-2.48), and aRD of 2.7% (95% CI, 1.3%-4.4%) (*P* = .01). The analysis of patients with a shockable initial rhythm also showed significant improvement in P2 vs P1: survival was 35.0% (107 of 306) vs 24.7% (42 of 170), with an aOR of 1.70 (95% CI, 1.09-2.65; *P* = .02) and an aRD of 9.6% (95% CI, 4.8%-14.4%), and the rate of favorable functional outcome was 28.8% (88 of 306) vs 17.1% (29 of 170), with an aOR of 2.13 (95% CI, 1.28-3.56; *P* = .004) and an aRD of 11.9% (95% CI, 4.7%-17.4%) (**Table 3**). A linear age effect was satisfactory in all 4 logistic regression models, and model discrimination was satisfactory, with the area under the receiver operating characteristic curve based on fixed effects only ranging from 70% to 85%. We conducted a sensitivity analysis of fitting all 4 models reported in Tables 2 and 3 without the "patient transported to a cardiac receiving center" variable. There was no notable difference in both the parameter estimates and the *P* values for all models. **Table 4** compares the TCPR process measures between P1 and P2. The proportion with TCPR started (both instructions and compressions) increased significantly from P1 (43.5% [321 of 738]) to

Table 1. Patient Characteristics and Clinical Outcomes by Phase

Variable	Phase[a] P1 (n = 798)	Phase[a] P2 (n = 1536)	*P* Value[b]
Patient characteristics			
Sex, No. (%)			
Male	512 (64.2)	987 (64.3)	>.99
Female	286 (35.8)	549 (35.7)	
Age, median (range), y	63 (14-99)	63 (9-101)	.85
Location of arrest, No. (%)			
Residential	713 (89.3)	1339 (87.2)	.09
Public	80 (10.0)	192 (12.5)	
Unknown	5 (0.6)	5 (0.3)	
Bystander-witnessed arrest, No. (%)			
No	540 (67.7)	1049 (68.3)	.68
Yes	258 (32.3)	480 (31.3)	
Unknown	0	7 (0.5)	
Presumed etiology of arrest, No. (%)			
Cardiac	774 (97.0)	1489 (96.9)	.83
Drowning	6 (0.8)	8 (0.5)	
Drug/alcohol overdose	10 (1.3)	23 (1.5)	
Respiratory	8 (1.0)	13 (0.8)	
Unknown	0	3 (0.2)	
Prehospital intubation, No. (%)			
No	276 (34.6)	648 (42.2)	<.001
Yes	522 (65.4)	888 (57.8)	
Shockable initial rhythm, No. (%)			
No	628 (78.7)	1230 (80.1)	.46
Yes	170 (21.3)	306 (19.9)	
Sustained return of spontaneous circulation, No. (%)			
No	602 (75.4)	1028 (66.9)	<.001
Yes	190 (23.8)	458 (29.8)	
Unknown	6 (0.8)	50 (3.3)	
Patient transported to cardiac receiving center, No. (%)			
No	343 (43.0)	660 (43.0)	>.99
Yes	455 (57.0)	876 (57.0)	
EMS dispatch to scene arrival time, median (range), min	5 (1-604)	5 (1-166)	.10
Clinical outcomes			
Survival, No. (%)			
Died	725 (90.9)	1352 (88.0)	.045
Lived	73 (9.1)	184 (12.0)	
Cerebral performance category at discharge, No. (%)			
Good, 1 or 2	45 (5.6)	127 (8.3)	.03
Poor, 3-5	744 (93.2)	1398 (91.0)	
Unknown	9 (1.1)	11 (0.7)	

Abbreviations: EMS, emergency medical services; P1, phase 1; P2, phase 2.

[a] Count (percentage) for categorical variables and median (range) for continuous variables.

[b] Fisher exact test or χ^2 test for categorical variables and Wilcoxon rank sum test for continuous variables. The unknown category, if present, is excluded from the testing procedure.

P2 (52.8% [746 of 1412]) ($P < .001$), yielding an RD of 9.3% (95% CI, 4.9%-13.8%) and an OR of 1.51 (95% CI, 1.26-1.82). The time to the beginning of TCPR instructions was reduced in P2 compared with P1 (median, 179 vs 205 seconds; $P = .004$), as was the time to first compression (median, 212 vs 256 seconds; $P < .001$).

The BCPR rate was analyzed on a sample of 2755 (adding in the 421 individuals who had CPR started before telecommunicator instructions were given but met all other inclusion criteria of the main analysis). The results showed that CPR was received before EMS arrival in 592 of 958 (61.8%) individuals in P1 compared with 1200 of 1797 (66.8%) individuals in P2, yielding an RD of 5.0% (95% CI, 1.2%-8.8%) ($P = .006$).

Discussion

Out-of-hospital cardiac arrest is a leading cause of death in the United States and is among the most time-sensitive medical emergencies.[1] Cardiopulmonary resuscitation is a simple, life-

Table 2. Fitted Logistic Regression Model for Survival and Favorable Functional Outcome

Variable	Survival OR (95% CI)	Survival P Value	Favorable Functional Outcome OR (95% CI)	Favorable Functional Outcome P Value
Phase				
P1	1 [Reference]	.02	1 [Reference]	.01
P2	1.47 (1.08-2.02)		1.68 (1.13-2.48)	
Sex				
Male	0.73 (0.54-0.99)	.046	0.71 (0.48-1.04)	.08
Female	1 [Reference]		1 [Reference]	
Age, 1-y increase	0.98 (0.97-0.99)	<.001	0.98 (0.97-0.99)	<.001
Bystander-witnessed arrest				
No	1 [Reference]	<.001	1 [Reference]	<.001
Yes	2.72 (2.02-3.66)		2.75 (1.91-3.96)	
Shockable initial rhythm				
No	1 [Reference]	<.001	1 [Reference]	<.001
Yes	5.94 (4.41-8.00)		8.37 (5.78-12.10)	
Location of arrest				
Residential	1 [Reference]	.07	1 [Reference]	.004
Public	1.41 (0.98-2.05)		1.86 (1.22-2.83)	
Patient transported to cardiac receiving center				
No	1 [Reference]	.007	1 [Reference]	<.001
Yes	1.53 (1.12-2.09)		2.23 (1.48-3.38)	

Abbreviations: OR, odds ratio; P1, phase 1; P2, phase 2.

Table 3. Fitted Logistic Regression Model for Survival and Favorable Functional Outcome in Patients With Shockable Initial Rhythm[a]

Variable	Survival OR (95% CI)	Survival P Value	Favorable Functional Outcome OR (95% CI)	Favorable Functional Outcome P Value
Phase				
P1	1 [Reference]	.02	1 [Reference]	.004
P2	1.70 (1.09-2.65)		2.13 (1.28-3.56)	
Sex				
Male	0.65 (0.40-1.07)	.09	0.53 (0.31-0.89)	.02
Female	1 [Reference]		1 [Reference]	
Age, 1-y increase	0.97 (0.96-0.99)	<.001	0.98 (0.97-1.00)	.01
Bystander-witnessed arrest				
No	1 [Reference]	<.001	1 [Reference]	<.001
Yes	2.33 (1.51-3.59)		2.44 (1.51-3.95)	
Location of arrest				
Residential	1 [Reference]	.03	1 [Reference]	.002
Public	1.73 (1.07-2.79)		2.27 (1.36-3.80)	
Patient transported to cardiac receiving center				
No	1 [Reference]	.60	1 [Reference]	.04
Yes	0.88 (0.56-1.40)		1.75 (1.02-2.99)	

Abbreviations: OR, odds ratio; P1, phase 1; P2, phase 2.

[a] Twenty individuals (9 in phase 1 and 11 in phase 2) with unknown Cerebral Performance Category score at discharge were excluded from the favorable functional outcome analysis.

saving intervention, but its effectiveness declines rapidly with each minute after collapse of the patient.[27] This time element explains, in part, why chest compressions by lay rescuers can double the chance of survival from OHCA.[3,4,28] Despite decades of large-scale public CPR training aimed at imparting this skill, BCPR rates remain unacceptably low, and there are immense regional, socioeconomic, and racial disparities in both CPR provision and survival.[29-31] The concept of prearrival TCPR, an intervention that has been shown to significantly improve both BCPR rates and survival, was first described in 1984 in King County, Washington.[32-37] Today, the ubiquitous presence of cell phones, along with the universal access to 9-1-1, presents a unique but underutilized opportunity to dramatically increase the frequency of BCPR and reduce the time to starting CPR.[9,38]

To our knowledge, this investigation is the first large-scale study of a TCPR program based on the latest guideline recommendations and implemented in multiple EMS systems. This project was associated with significant improvements in several important aspects of resuscitation care,

Table 4. Process Analysis

Variable	Phase[a] P1 (n = 738)	P2 (n = 1412)	*P* Value[b]
Telecommunicator knows TCPR indicated, No. (%)			
No	226 (30.6)	379 (26.8)	.11
Yes	509 (69.0)	1005 (71.2)	
Unknown	3 (0.4)	28 (2.0)	
TCPR instructions given, No. (%)			
No	368 (49.9)	612 (43.3)	.005
Yes	369 (50.0)	795 (56.3)	
Unknown	1 (0.1)	5 (0.4)	
Compressions started, No. (%)			
No	412 (55.8)	634 (44.9)	<.001
Yes	321 (43.5)	746 (52.8)	
Unknown	5 (0.7)	32 (2.3)	
Time to event, s[c]			
Telecommunicator's recognition of the need for TCPR	111	99.5	.02
Start of TCPR instructions	205	179	.004
First compression	256	212	<.001

Abbreviations: P1, phase 1; P2, phase 2; TCPR, telephone cardiopulmonary resuscitation.

[a] Count (percentage) for binary variables and estimated median for the time to any event.

[b] χ^2 Test for the binary variables, with the unknown category excluded from the testing procedure. Log-rank 2-sample test (permutation form) based on scores by Sun[22] for time-to-event variables.

[c] The estimated median time based on nonparametric maximum likelihood estimate for the event time distribution from interval-censored data using the self-consistent estimator.

including increased TCPR rates (from 43.5% to 52.8%), a reduction in the time to first bystander chest compression (from 256 to 212 seconds), and, most important, a 31.8% relative increase in survival (from 9.1% to 12.0%) and a 42.8% relative increase in favorable functional outcome (from 5.6% to 8.3%). In addition, we found that BCPR (lay rescuer CPR performed whether TCPR instructions were given or not) increased from 61.8% to 66.8%. While the proportions of BCPR in our study were slightly higher than those documented in some investigations, we believe that our method of using both 9-1-1 audio recordings and EMS first-care reports represents a more comprehensive representation of the BCPR intervention than previous use of either data source alone.

These results suggest that the TCPR bundle, deliberately implemented and measured as part of a system-wide public health intervention, was an effective method to increase BCPR rates and survival on a large scale. This observation is a key finding because most previous work evaluating the effect of TCPR has been done in high-performance systems in the setting of strict research randomization protocols, where the investigators were closely linked to the functioning of the local systems.[39-41] Therefore, our findings add momentum to the current literature by being implemented in the real world across a large number of EMS agencies and communities and thus may carry optimism that successful implementation is possible in typical EMS systems.

Our findings highlight the benefit of using an existing 24/7 telecommunication infrastructure and training a small number of personnel. Therefore, we were able to deploy this strategy across a large metropolitan area with minimal incremental cost. The improved outcomes in this study suggest that our approach to implementing a comprehensive TCPR program is a feasible, efficient, and cost-effective method to increase BCPR rates and improve outcomes after OHCA.

In 2012, the American Heart Association[9] published its recommendations for TCPR. Our aim was to fully implement these recommendations and measure the effect on outcomes in multiple, diverse EMS jurisdictions. The results from this evaluation are consistent with previous prospective clinical studies[32-35] evaluating the effect of implementing a structured TCPR program within individual EMS systems with a single 9-1-1 center. In King County, Washington, Rea et al[32] found an OR for survival to hospital discharge from TCPR of 1.45 (95% CI, 1.21-1.73) compared with no CPR. Tanaka et al[33] observed that, when a TCPR program was implemented in conjunction with a continuous quality improvement program, BCPR rates increased from 41% to 56%, with an OR of 1.81 for improved survival with favorable functional outcome. In our analysis, the TCPR bundle (protocol, training, and continuous quality improvement program) was associated with significant improvements in survival (aOR of 1.47 and aRD of 3.1%) and favorable functional outcome (aOR of 1.68 and aRD of 2.7%).

Our study has some noteworthy differences from previous reports. First, our investigation was carried out as part of a statewide public health cardiac resuscitation program designed to improve all facets of OHCA care. Second, unlike the previous observational investigations, we specifically collected, audited, and linked each 9-1-1 call with both EMS and hospital process data (eg, EMS intervals, postarrest targeted temperature management, and coronary angiography) and with outcomes. Third, this study demonstrated that it is feasible to measure and benchmark key TCPR metrics and use these data to improve TCPR process and outcomes.

A limitation of our study is that, while it was a prospective controlled study (before-after analysis), it was not a randomized clinical trial. We believe that randomization of TCPR is not ethical given the previous positive randomized clinical trials. However, even if it could be argued that equipoise still exists, it is clear that no 9-1-1 emergency dispatch systems would consent to randomization after full disclosure of the extant evidence. While we controlled for all known confounders, unknown risk factors could be responsible for our findings. Therefore, although we cannot prove that the outcomes resulted directly from the process improvements, they are biologically plausible and not explained by confounding due to measured risk factors. Because EMS systems vary widely and because Arizona has focused on resuscitation quality improvement since 2004, it is unknown if other EMS systems would find similar results. However, the fact that our study encompassed two 9-1-1 centers, 30 distinct EMS systems, and 22 hospitals argues in favor of the idea that this approach and these findings are transportable to other diverse settings.

Conclusions

After implementation of a guideline-based, comprehensive, system-wide TCPR bundle of care, we observed an increase in telecommunicator CPR, a reduction in the time to first chest compression, and improved survival and functional outcome in patients with OHCA. The rates of survival and favorable functional outcome increased significantly in the subgroup of patients who were initially seen with a shockable rhythm.

ARTICLE INFORMATION

Accepted for Publication: February 12, 2016.

Published Online: May 4, 2016. doi:10.1001/jamacardio.2016.0251.

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Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Drs Bobrow and Spaite reported university support from Medtronic Philanthropy involving community-based translation of resuscitation science. No other disclosures were reported.

Additional Contributions: Paula R. Brazil, MA (Bureau of Emergency Medical Services & Trauma System, Arizona Department of Health Services), assisted in the writing and editing of the manuscript (without compensation). Mickey Eisenberg, MD, PhD, Thomas Rea, MD, MPH, and Cleo Subido (King County, Washington) provided study guidance. We are grateful to the 9-1-1 dispatch centers, emergency medical services agencies, and hospitals, whose collaboration made this project possible.

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