Original Investigation

Association of Bystander and First-Responder Intervention With Survival After Out-of-Hospital Cardiac Arrest in North Carolina, 2010-2013

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IMPORTANCE Out-of-hospital cardiac arrest is associated with low survival, but early cardiopulmonary resuscitation (CPR) and defibrillation can improve outcomes if more widely adopted.

OBJECTIVE To examine temporal changes in bystander and first-responder resuscitation efforts before arrival of the emergency medical services (EMS) following statewide initiatives to improve bystander and first-responder efforts in North Carolina from 2010-2013 and to examine the association between bystander and first-responder resuscitation efforts and survival and neurological outcome.

DESIGN, SETTINGS, AND PARTICIPANTS We studied 4961 patients with out-of-hospital cardiac arrest for whom resuscitation was attempted and who were identified through the Cardiac Arrest Registry to Enhance Survival (2010–2013). First responders were dispatched police officers, firefighters, rescue squad, or life-saving crew trained to perform basic life support until arrival of the EMS.

EXPOSURES Statewide initiatives to improve bystander and first-responder interventions included training members of the general population in CPR and in use of automated external defibrillators (AEDs), training first responders in team-based CPR including AED use and high-performance CPR, and training dispatch centers in recognition of cardiac arrest.

MAIN OUTCOMES AND MEASURES The proportion of bystander and first-responder resuscitation efforts, including the combination of efforts between bystanders and first responders, from 2010 through 2013 and the association between these resuscitation efforts and survival and neurological outcome.

RESULTS The combination of bystander CPR and first-responder defibrillation increased from 14.1% (51 of 362; 95% CI, 10.9%-18.1%) in 2010 to 23.1% (104 of 451; 95% CI, 19.4%-27.2%) in 2013 ($P < .01$). Survival with favorable neurological outcome increased from 7.1% (82 of 1149; 95% CI, 5.8%-8.8%) in 2010 to 9.7% (129 of 1334; 95% CI, 8.2%-11.4%) in 2013 ($P = .02$) and was associated with bystander-initiated CPR. Adjusting for age and sex, bystander and first-responder interventions were associated with higher survival to hospital discharge. Survival following EMS-initiated CPR and defibrillation was 15.2% (30 of 198; 95% CI, 10.8%-20.9%) compared with 33.6% (38 of 113; 95% CI, 25.5%-42.9%) following bystander-initiated CPR and defibrillation (odds ratio [OR], 3.12; 95% CI, 1.78-5.46); 24.2% (83 of 343; 95% CI, 20.0%-29.0%) following bystander CPR and first-responder defibrillation (OR, 1.70; 95% CI, 1.06-2.71); and 25.2% (109 of 432; 95% CI, 21.4%-29.6%) following first-responder CPR and defibrillation (OR, 1.77; 95% CI, 1.13-2.77).

CONCLUSIONS AND RELEVANCE Following a statewide educational intervention on rescusitation training, the proportion of patients receiving bystander-initiated CPR and defibrillation by first responders increased and was associated with greater likelihood of survival. Bystander-initiated CPR was associated with greater likelihood of survival with favorable neurological outcome.

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Editorial page 231

Related article page 247

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Out-of-hospital cardiac arrest is a major public health issue accounting for approximately 200 000 deaths per year in the United States.[1] Despite more than 2 decades of evidence demonstrating significant benefits from early cardiopulmonary resuscitation (CPR) and defibrillation, wide variation in CPR training, bystander and first-responder intervention, and survival after out-of-hospital cardiac arrest remains.[2-5]

Prior training in CPR and use of automated external defibrillators (AEDs), as well as dispatcher-assisted CPR, may influence bystander interventions.[6-9] First-responder intervention is dependent on dispatcher recognition of cardiac arrest and timely activation of first responders.[10-12] Most improvements associated with increased survival were reported in metropolitan areas where multiple simultaneous improvements to emergency medical service (EMS) care for cardiac arrest patients were implemented.[2,10-12] In 2010, the American Heart Association issued a policy statement calling for regional systems of care for cardiac arrest patients.[13] As part of the HeartRescue project funded by the Medtronic Foundation,[14] the North Carolina Regional Approach to Cardiovascular Emergencies Cardiac Arrest Resuscitation System (RACE-CARS) program initiated multifaceted interventions for improving care for cardiac arrest in North Carolina in 2010. Interventions included statewide initiatives to improve bystander and first-responder intervention such as training the population in CPR and AED use and training dispatch centers in recognizing cardiac arrest symptoms in order to implement bystander CPR within 60 seconds of call receipt.[15] It is currently unknown whether these efforts have translated to improved use and outcomes.

The aims of this study were to examine temporal changes in the proportion of cardiac arrest patients who received resuscitative efforts before EMS arrival (CPR, defibrillation, or both) by bystanders, first responders, or both, including the combination of efforts between bystanders and first responders in North Carolina from 2010 through 2013; and to examine the association between these interventions and outcomes.

Methods

Data Source

The Cardiac Arrest Registry to Enhance Survival (CARES) is a voluntary, prospective clinical registry of patients with out-of-hospital cardiac arrest in the United States. It was established by the Centers for Disease Control and Prevention and Emory University for public health surveillance and continuous quality improvement. The registry has been described in detail.[16,17] All patients with a confirmed out-of-hospital arrest (defined as apneic and unresponsive) for whom resuscitation is attempted, even those with termination of resuscitation before hospital arrival are included in the registry. Data are collected as cardiac arrests occur from 911 dispatch centers, EMS agencies, and receiving hospitals and are entered into the database. Standardized international Utstein definitions for defining clinical variables and outcomes are used to ensure uniformity.[18] A CARES analyst reviews every record for completeness and accuracy.[16] In North Carolina, a team of data consultants assisted with training, quality control, and data feedback to county EMS agencies regarding the CARES data. The Duke University Medical Center Institutional Review Board approved the current study for analyses and publication of the findings. A waiver of the requirement for written informed consent and Health Insurance Portability and Accountability Act (HIPAA) authorization was granted on the basis of (1) using existing central CARES registry data and under existing waivers of consent for CARES under the HeartRescue project and (2) using aggregated and deidentified data. The physical location of each cardiac arrest was assigned based on the address of the cardiac arrest., ArcGIS 10.2 software (Esri) was used to geocode each incident location to the street address level. The geocoding process assigns a latitude and longitude coordinate to each address. A 97% geocoding rate was achieved. Non-geocoded records included post office boxes and other non-physical locations. This process verified the county in which each cardiac arrest occurred. The total resident population and demographic characteristics in each county were determined through information reported by the US Census 2010 and the American Community Survey 5-year estimates for 2009 through 2013.

Study Population and Setting

To reduce the chance that our results were driven by changes in reporting, we included counties with complete case capture from 2010 through 2013. Thus, the study population included all out-of-hospital cardiac arrests from 11 counties in North Carolina (Camden, Catawba, Durham, Mecklenburg, Pasquotank, Stanly, Stokes, Surry, Transylvania, Wake, and Warren), covering a total population of approximately 2.7 million inhabitants (30% of the state's total population), with demographics varying from urban to rural areas served by 11 EMS agencies. The remaining 51 counties reporting data to CARES did not have complete countywide case capture for the study years. We included arrests of presumed cardiac cause and excluded cases witnessed by 911 responder or with "do not resuscitate" orders, following the Utstein guidelines for reporting cardiac arrests.[18] All EMS agencies included in this study had 2-tiered response systems with first responders equipped with AEDs.[19] In accordance with the CARES registry, a *first responder* was defined as personnel who responded to the medical emergency in an official capacity as part of an organized medical response team but who were not the designated transporter of the patient to the hospital.[19] First responders were police officers, firefighters, rescue squads, or life-saving crew members trained to perform basic life support until the EMS team arrives and who were called to the scene by emergency dispatch centers. *Bystanders* were defined as other persons who were present and had intervened but had not been dispatched, as defined by the Utstein guidelines for reporting cardiac arrest.[18] Of the 11 EMS agencies, 9 had implemented protocols for dispatch-assisted CPR instruction prior to the study period. Protocols for team-based CPR were implemented by 4 EMS agencies before January 2010 and 4 EMS agencies during the study period.

Intervention

The HeartRescue Project in North Carolina initiated a multifaceted, statewide quality-improvement program in 2010.[14] The project included intervention for community members, EMS staff, first responders, and hospital administrators and staff. For community members, chest compression-only training was offered at major civic events as well as to patients with cardiovascular disease and their family members before hospital discharge. School staff were trained in the use of AEDs, and community grants were provided to groups to implement CPR training programs. Medical EMS dispatchers were trained in recognizing when callers were describing cardiac arrest and in providing callers with CPR instruction and encouraged to use protocols to transport certain patients to specialized medical centers. First responders were instructed in team-based CPR, including AED use and high-performance CPR. Hospital administrators were encouraged to establish protocols for primary percutaneous coronary intervention for ST-segment elevation myocardial infarction, target temperature and hypothermia management, and goal-directed intensive unit care neurorehabilitation. The protocol is publicly available and the main interventions are listed in eTable 1 in the Supplement.[20]

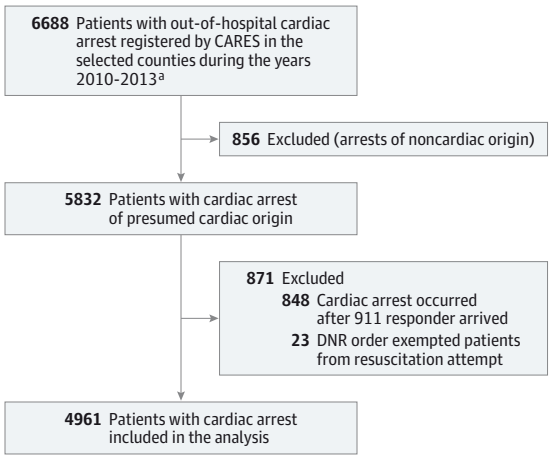
Outcome Measures

The main outcome parameters were resuscitative efforts through CPR, defibrillation, or both from bystanders and first responders, including the combination of efforts between bystanders and first responders, and patient survival to discharge and survival with favorable neurological outcome, which was measured by cerebral performance category 1 or 2, with 1 representing full recovery or mild disability and 2, moderate disability but independent in activities of daily living.[21]

Statistical Analyses

Proportions were calculated for categorical data. The mean and standard deviation, or median and interquartile range (IQR), as appropriate, were calculated for continuous data. Statistical significance for categorical data was assessed using Fisher exact test or χ^2 test. Temporal trends for categorical data were assessed using Cochran-Armitage trend test for trends across ordered groups (by year) if the Fisher exact test or χ^2 was statistically significant. Analyses regarding the combination of efforts from bystanders, first responders, and EMS (CPR and defibrillation) included only patients who were defibrillated before hospital arrival. Poisson regression analyses were used to analyze temporal trends based on changes in the number of patients with (1) a cardiac arrest, (2) return of spontaneous circulation, (3) survival to discharge, and (4) survival with favorable neurological outcome per 100 000 population (denominator). The Poisson assumptions were met. Odds ratios (ORs) with 95% confidence intervals were calculated by logistic regression analyses to examine the association between bystander and first-responder intervention and survival to discharge and favorable neurological outcome for the entire study period. Estimates are presented as unadjusted and adjusted for age and sex. We found no significant interactions. Missing data on study variables were no more than 1%. To test whether missing data may have introduced bias into the study, missing data were imputed using multivariate imputation by chained equations (MICE) methods estimated from sequential multivariable models with fully conditional specifications.[22-24] Results from the mean imputation methods were compared with results from listwise deletion. A P value of <.05 was considered statistically significant; all statistical tests were 2-sided; and age- and sex-adjusted results should be interpreted in context of lack of adjustment for multiple comparisons and, thus, are exploratory rather than confirmatory. All analyses were performed using SAS statistical software versions 9.2 and 9.4 (SAS Institute Inc) and Stata version 13.0 (StataCorp).

Figure 1. Selection of Population With Out-of-Hospital Cardiac Arrest



DNR indicates do not resuscitate; CARES, Cardiac Arrest Registry to Enhance Survival.

[a] The included counties are Camden, Catawba, Durham, Mecklenburg, Pasquotank, Stanly, Stokes, Surry, Transylvania, Wake, and Warren.

Results

Cardiac Arrests

The population selection is depicted in **Figure 1**. A total of 4961 out-of-hospital cardiac arrest patients were included in the study. Patient characteristics are reported in **Table 1**. Baseline and cardiac arrest characteristics were stable throughout the study period. Demographic characteristics for the included and excluded counties are shown in eTable 2 in the Supplement. The incidence of cardiac arrests per year was higher in the included counties (47.5 per 100 000 vs 27.2 per 100 000) and unknown in the remaining counties that did not report to CARES during the study period.

Bystander- and First Responder–Initiated CPR

For the whole study period, a total of 86.3% patients received CPR before EMS arrival, 45.7% by bystanders and 40.6% by first

Table 1. Changes in Characteristics of Patients With Out-of-Hospital Cardiac Arrest From 2010-2013

Characteristics	No./Total (%) of Patients					No. (%) of Patients	
	2010	2011	2012	2013	Total	Missing	*P* Value
Cardiac arrests							
No.	1167	1136	1317	1341	**4961**		
Per 100 000 population	46.2	43.9	49.9	49.8	47.5		<.01
Age, median (IQR), y	66 (54.0-78.0)	66 (54.0-78.0)	65 (53.0-77.0)	65 (54.0-77.5)	65 (54.0-78.0)	10 (0.2)	.64
Missing	0	7 (0.06)	2 (0.02)	1 (0.01)	10 (0.2)		
Age, y						10 (0.2)	
0-44	139/1167 (11.9)	136/1129 (12.1)	163/1315 (12.4)	156/1340 (11.6)	594/4951 (12.0)		.95
45-59	270/1167 (23.1)	256/1129 (22.7)	328/1315 (24.9)	334/1340 (24.9)	1188/4951 (24.0)		.42
60-74	388/1167 (33.3)	377/1129 (33.4)	420/1315 (31.9)	441/1340 (32.9)	1626/4951 (32.8)		.87
≥75	370/1167 (31.7)	360/1129 (31.9)	404/1315 (30.7)	409/1340 (30.5)	1543/4951 (31.2)		.85
Men	757/1166 (64.9)	690/1136 (60.7)	812/1317 (61.7)	802/1341 (59.8)	3061/4960 (61.7)	1 (0.02)	.06
Witnessed	502/1167 (43.0)	526/1136 (46.3)	574/1317 (43.6)	620/1341 (46.2)	2222/4961 (44.8)	0	.22
First recorded rhythm VF/pVT	276/1167 (23.7)	266/1136 (23.4)	286/1317 (21.7)	291/1340 (21.7)	1119/4960 (22.6)	1 (0.02)	.50
EMS response time, median (IQR), min	7.9 (6.1-10.0)	8.0 (6.2-10.1)	8.1 (6.2-10.3)	7.8 (6.0-10.1)	8.0 (6.1-10.1)	431 (8.7)	.10
Missing	205	115	99	25	431 (8.7)		
CPR initiated							
Bystander	458/1166 (39.3)	505/1135 (44.5)	640/1314 (48.7)	662/1341 (49.4)	2265/4956 (45.7)	5 (0.1)	<.01
Dispatch-assisted[a]	451/1139 (39.6)	501/1121 (44.7)	631/1294 (48.8)	653/1315 (49.7)	2236/4869 (45.9)	5 (0.1)	<.01
No dispatch-assisted	7/27 (25.9)	4/14 (28.6)	9/20 (45.0)	9/26 (34.6)	29/87 (33.3)	0	.37
First responder	511/1166 (43.8)	461/1135 (40.6)	499/1314 (38.0)	541/1341 (40.3)	2012/4956 (40.6)		.03
EMS	197/1166 (16.9)	169/1135 (14.9)	175/1314 (13.3)	138/1341 (10.3)	679/4956 (13.7)		<.01
Defibrillated[b]						1 (0.06)	
Total	364/1167 (31.2)	386/1136 (34.0)	444/1317 (33.7)	454/1340 (33.9)	1648/4960 (33.2)		.42
Bystander	34/364 (9.3)	28/386 (7.3)	25/444 (5.6)	27/454 (6.0)	114/1648 (6.9)		.16
First responder	149/364 (40.9)	189/386 (49.0)	200/444 (45.1)	236/454 (52.1)	774/1648 (47.0)		<.01
EMS	181/364 (49.7)	169/386 (43.8)	219/444 (49.3)	190/454 (41.9)	759/1648 (46.1)		.05
CPR and defibrillation[c]	362/1165 (31.1)	384/1134 (33.9)	441/1314 (33.6)	451/1338 (33.7)	1638/4951 (33.1)	10 (0.2)	.43
EMS-initiated CPR and EMS defibrillation	53/362 (14.6)	51/384 (13.3)	53/441 (12.0)	41/451 (9.1)	198/1638 (12.1)		.09
First responder-initiated							
CPR and EMS defibrillation	54/362 (14.9)	53/384 (13.8)	61/441 (13.8)	44/451 (9.8)	212/1638 (12.9)		.12
CPR and first-responder defibrillation	96/362 (26.5)	104/384 (27.1)	98/441 (22.2)	130/451 (28.8)	428/1638 (26.1)		.15
Bystander initiated							
CPR and EMS defibrillation	74/362 (20.4)	64/384 (16.7)	105/441 (23.8)	105/451 (23.3)	348/1638 (21.3)		.05
CPR and first-responder defibrillation	51/362 (14.1)	84/384 (21.9)	102/441 (23.1)	104/451 (23.1)	341/1638 (20.8)		<.01
CPR and bystander defibrillation	34/362 (9.4)	28/384 (7.3)	22/441 (5.0)	27/451 (6.0)	111/1638 (6.8)		.08

(continued)

Table 1. Changes in Characteristics of Patients With Out-of-Hospital Cardiac Arrest From 2010-2013 (continued)

Characteristics	No./Total (%) of Patients					No. (%) of Patients	
	2010	2011	2012	2013	Total	Missing	*P* Value
Not declared dead in field	788/1167 (67.5)	741/1136 (65.2)	834/1317 (63.3)	742/1341 (55.3)	3105/4961 (62.6)	0	<.01
Transported to PCI-capable hospital[d]	574/783 (73.3)	577/740 (78.0)	630/834 (75.5)	575/741 (77.6)	2356/3098 (76.0)	7 (0.2)	.11
Admitted to hospital ward	263/1167 (22.5)	298/1136 (26.2)	372/1317 (28.2)	366/1341 (27.3)	1299/4961 (26.2)	0	<.01
Received temperature management therapy[e]	100/180 (55.6)	170/291 (58.4)	219/362 (60.5)	236/361 (65.4)	725/1194 (60.7)	105 (8.1)	.02

Abbreviations: CPR, cardiopulmonary resuscitation; EMS, emergency medical services; IQR, interquartile range; VF/pVT, ventricular fibrillation/pulseless ventricular tachycardia; PCI, percutaneous coronary intervention.

[a] Cardiac arrests were classified as *dispatch-assisted* or *no dispatch-assisted* CPR in accordance with whether the county where the cardiac arrest occurred had implemented protocols for dispatch-assisted CPR at the time of cardiac arrest.

[b] Percentages of patients who were defibrillated by bystanders, first responders, and EMS are relative to all patients who were defibrillated (n = 1648).

[c] Percentages of CPR and defibrillation are relative to all patients who received CPR and defibrillation corresponding to 1 of the 6 presented categories (n = 1638); 10 patients who were defibrillated but were not included in this category either due to missing status for who initiated CPR (n = 2), who performed defibrillation (n = 1), or who did not belong in the presented categories (n = 7).

[d] Percentages of patients transported to PCI-capable hospital are relative to those who were not declared dead in the field (n = 3105).

[e] Percentages of patients who received temperature management therapy are relative to patients who were admitted to a hospital ward (n = 1299).

responders. Throughout the study period, a significant increase in the proportion of patients receiving bystander-initiated CPR was observed from 39.3% (95% CI, 36.5%-42.1%) in 2010 to 49.4% (95% CI, 46.7%-52.0%) in 2013 ($P < .01$), whereas both first-responder- and EMS-initiated CPR decreased (Table 1).

Bystander and First-Responder Defibrillation

Of 1648 patients who had been defibrillated, 53.9% had received it before the arrival of the EMS, 6.9% by bystanders, and 47.0% by first responders. Although no significant changes were observed for bystander defibrillation during the study period (9.3% [95% CI, 6.8%-12.8%] in 2010 to 6.0% [95% CI, 4.1%-8.6%] in 2013; $P = .16$), first-responder defibrillation increased significantly from 40.9% (95% CI, 36.0%-46.1%) in 2010 to 52.1% (95% CI, 47.5%-56.7%) in 2013 ($P < .01$).

CPR and Defibrillation

Bystander-initiated CPR and bystander defibrillation was low with no significant variation over time. The proportion of patients who received bystander-initiated CPR and first-responder defibrillation increased from 14.1% (95% CI, 10.9%-18.1%) in 2010 to 23.1% (95% CI, 19.4%-27.2%) in 2013 ($P < .01$), whereas the proportion of patients who received first responder-initiated CPR and first-responder defibrillation remained stable.

Bystander and First-Responder Intervention and Survival

For the entire study period, patients who received bystander- and first-responder-initiated CPR were more likely to achieve sustained return of spontaneous circulation, survive to discharge and survive with favorable neurological outcome: 31.8% (717 of 2258) of patients who had received CPR initially from bystanders, 27.0% (542 of 2009) from first responders, and 26.3% (178 of 676) from EMS teams achieved sustained return of spontaneous circulation ($P < .01$ for difference between groups); 11.8% (266 of 2250) of patients who received CPR initially from bystanders, 8.9% (178 of 1994) from first responders, and 7.6% (51 of 672) from EMS teams survived to discharge ($P < .01$); and 10.5% (237 of 2250) of patients who received CPR initially from bystanders, 7.7% (153 of 1994) from first responders, and 7.0% (47 of 672) from EMS teams survived with a favorable neurological outcome ($P < .01$).

Overall, a significant improvement in outcomes was observed during the study period (**Table 2**). When stratified by who initiated CPR, the increase in favorable outcome throughout the study period was only present for those who received bystander-initiated CPR.

Compared with those who received EMS-initiated CPR and EMS defibrillation, patients who received bystander-initiated CPR and defibrillation, bystander-initiated CPR and first-responder defibrillation, and first responder-initiated CPR and defibrillation were more likely to survive to discharge. Survival among those who received EMS-initiated CPR and defibrillation was 15.2% (95% CI, 10.8%-20.9%); bystander-initiated CPR and defibrillation, 33.6% (95% CI, 25.5%-42.9%); bystander-initiated CPR and first-responder defibrillation, 24.2% (95% CI, 20.0%-29.0%); and first-responder CPR and defibrillation 25.2% (95% CI, 21.4%-29.6%). **Figure 2** shows unadjusted and age- and sex-adjusted estimates.

Estimates from the observed data set were consistent with estimates from the imputed data sets (eTable 3 in the Supplement). Throughout the study period, the increase among survivors who had been defibrillated was mainly observed among patients who had received bystander or first-responder intervention (eTable 4 in the Supplement).

Changes in Absolute Incidence of Out-of-Hospital Cardiac Arrests and Number of Survivors

An overall increase in the absolute incidence was observed during the study period from 46.2 per 100 000 persons (95% CI, 43.5-48.9) in 2010 to 49.8 per 100 000 persons (95% CI,47.2-52.6) in 2013 ($P < .01$). The number of patients who achieved

Table 2. Outcomes Overall and Stratified by Bystander-Initiated CPR According to Year

	2010		2011		2012		2013		Total			
	No./Total of Patients	% (95% CI)	No./Total of Patients	% (95% CI)	No./Total of Patients	% (95% CI)	No./Total of Patients	% (95% CI)	No./Total of Patients	% (95% CI)	Missing, No. (%)	*P* Value[a]
All patients (n = 4961)	1167/4961		1136/4961		1317/4961		1341/4961					
Sustained return of spontaneous circulation	285/1165	24.5 (22.1-27.0)	333/1136	29.3 (26.7-32.0)	414/1308	31.7 (29.2-34.2)	406/1339	30.3 (27.9-32.8)	4961/4961		13 (0.3)	<.01
Survival to discharge	96/1149	8.4 (6.9-10.1)	116/1130	10.3 (8.6-12.2)	144/1308	11 (9.4-12.8)	140/1334	10.5 (9.0-12.3)	1438/4948	29.1 (27.8-30.3)	40 (0.8)	.06
Favorable neurological outcome	82/1149	7.1 (5.8-8.8)	102/1130	9.0 (7.5-10.8)	126/1308	9.6 (8.1-11.4)	129/1334	9.7 (8.2-11.4)	496/4921	10.1 (9.3-11.0)	40 (0.8)	.02
Bystander-initiated CPR (n = 2265)	458/1166		505/1135		640/1314		662/1341		439/4921	8.9 (8.1-9.7)	5 (0.1)	
Sustained return of spontaneous circulation	122/458	26.6 (22.8-30.9)	158/505	31.3 (27.4-35.5)	213/634	33.6 (30.0-37.4)	224/661	33.9 (30.4-37.6)	2265/4956		7 (0.3)	.01
Survival to discharge	41/454	9 (6.7-12.0)	53/502	10.6 (8.2-13.6)	80/636	12.6 (10.2-15.4)	92/658	14 (11.5-16.9)	717/2258	31.8 (29.9-33.7)	15 (0.7)	<.01
Favorable neurological outcome	35/454	7.7 (5.6-10.6)	43/502	8.8 (6.6-11.6)	74/636	11.6 (9.4-14.4)	85/658	12.9 (10.6-15.7)	266/2250	11.8 (10.6-13.2)	15 (0.7)	<.01
No bystander-initiated CPR (n = 2691)	708/1166		630/1135		674/1314		679/1341		237/2250	10.6 (9.4-11.9)	5 (0.1)	
Sustained return of spontaneous circulation	163/706	23.1 (20.1-26.3)	175/630	27.8 (24.4-31.4)	200/671	29.8 (26.4-33.4)	182/678	26.8 (23.6-30.3)	2691/4956		6 (0.2)	.07
Survival to discharge	55/694	7.9 (6.1-10.2)	63/627	10 (7.9-12.7)	63/669	9.4 (7.4-11.9)	48/676	7.1 (5.4-9.3)	720/2685	26.8 (25.2-28.5)	25 (0.9)	.53
Favorable neurological outcome	47/694	6.8 (5.1-8.9)	58/627	9.3 (7.2-11.8)	51/669	7.6 (5.8-9.9)	44/676	6.6 (4.9-8.6)	229/2666	8.6 (7.6-9.7)	25 (0.9)	.60

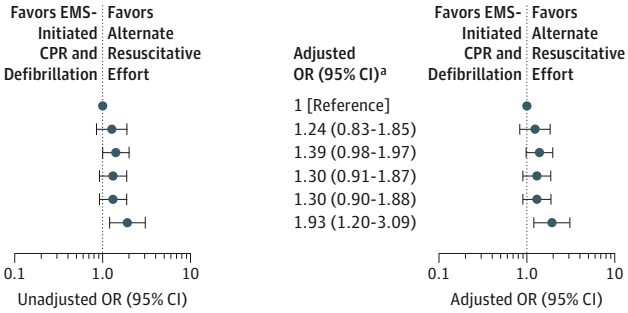
Abbreviations: CPR, cardiopulmonary resuscitation; EMS, emergency medical service.

[a] *P* value for trend across years.

Figure 2. Outcomes Among Patients Who Received Out-of-Hospital Cardiopulmonary Resuscitation and Defibrillation

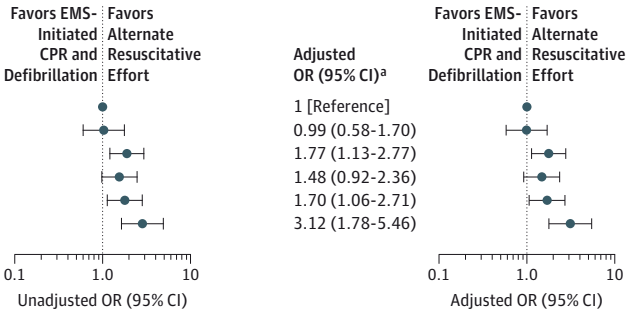
A Return of spontaneous circulation

Resuscitation					
Initiated CPR	Defibrillation	No. of Patients	No. of Events	Unadjusted OR (95% CI)	Adjusted OR (95% CI)[a]
EMS	EMS	198	72	1 [Reference]	1 [Reference]
First responder	EMS	212	89	1.27 (0.85-1.89)	1.24 (0.83-1.85)
First responder	First responder	432	193	1.41 (1.00-2.00)	1.39 (0.98-1.97)
Bystander	EMS	350	150	1.31 (0.92-1.88)	1.30 (0.91-1.87)
Bystander	First responder	343	147	1.31 (0.92-1.88)	1.30 (0.90-1.88)
Bystander	Bystander	113	59	1.91 (1.20-3.06)	1.93 (1.20-3.09)



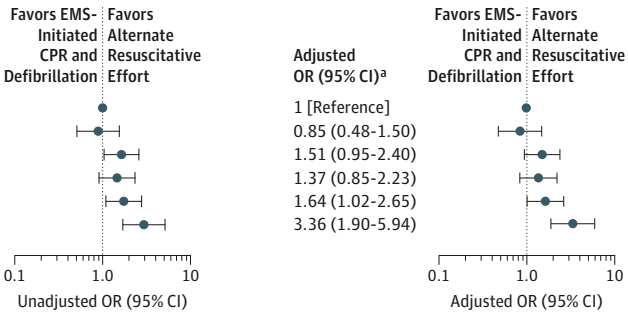
B Survival to discharge

Resuscitation					
Initiated CPR	Defibrillation	No. of Patients	No. of Events	Unadjusted OR (95% CI)	Adjusted OR (95% CI)[a]
EMS	EMS	198	30	1 [Reference]	1 [Reference]
First responder	EMS	212	33	1.03 (0.60-1.77)	0.99 (0.58-1.70)
First responder	First responder	432	109	1.89 (1.21-2.95)	1.77 (1.13-2.77)
Bystander	EMS	350	76	1.55 (0.98-2.47)	1.48 (0.92-2.36)
Bystander	First responder	343	83	1.79 (1.13-2.83)	1.70 (1.06-2.71)
Bystander	Bystander	113	38	2.84 (1.64-4.92)	3.12 (1.78-5.46)



C Favorable neurological outcome

Resuscitation					
Initiated CPR	Defibrillation	No. of Patients	No. of Events	Unadjusted OR (95% CI)	Adjusted OR (95% CI)[a]
EMS	EMS	198	29	1 [Reference]	1 [Reference]
First responder	EMS	212	28	0.89 (0.51-1.55)	0.85 (0.48-1.50)
First responder	First responder	432	95	1.64 (1.04-2.59)	1.51 (0.95-2.40)
Bystander	EMS	350	70	1.46 (0.91-2.34)	1.37 (0.85-2.23)
Bystander	First responder	343	79	1.74 (1.09-2.78)	1.64 (1.02-2.65)
Bystander	Bystander	113	38	2.95 (1.70-5.14)	3.36 (1.90-5.94)



CPR indicates, cardiopulmonary resuscitation; EMS, emergency medical services. The odds ratios (ORs) were generated from the imputed data sets and therefore correspond to all patients who were defibrillated (n = 1648).

[a] Adjusted for age and sex.

return of spontaneous circulation increased from 11.3 (95% CI, 10.0-12.7) per 100 000 persons in 2010 to 15.1 (95% CI, 13.7-16.6) per 100 000 persons in 2013 ($P < .01$); the number of those discharged alive increased from 3.8 per 100 000 persons (95% CI, 3.1-4.6) in 2010 to 5.2 per 100 000 persons (95% CI, 4.4-6.1) in 2013 ($P < .01$); and the number of patients discharged with favorable neurological outcome increased from 3.2 per 100 000 persons (95% CI, 2.6-4.0) in 2010 to 4.8 per 100 000 persons (95% CI, 4.0-5.7) in 2013 ($P < .01$).

Discussion

This study of out-of-hospital cardiac arrests that occurred from 2010 through 2013 in urban, suburban, and rural communities in North Carolina following a statewide quality-improvement initiative to increase bystander and first-responder intervention had 2 major findings: (1) the proportion of patients who received bystander-initiated CPR and also who were defibrillated by first responders increased from 14.1% in 2010 to 23.1% in 2013 and was associated with greater likelihood of survival (OR, 1.70 [95% CI, 1.06-2.70]) compared with patients who received EMS-initiated CPR and defibrillation; (2) survival with favorable neurological outcome increased and bystander-initiated CPR was associated with this increase.

Our study presents novel findings indicating that improvements in bystander and first-responder CPR and defibrillation are both associated with increased survival. Importantly, our study included analyses to assess cardiac arrest counts and survivor counts over time to add confidence that temporal results related to proportions are "true-true" and not

a consequence of ascertainment bias.[2] During the past decade, much focus has been drawn to increasing bystander CPR. Our findings suggest the possibility of improving outcomes by strengthening first-responder programs, in addition to increasing the number of bystanders who could then provide CPR, including those assisted by emergency dispatchers, and by improving EMS systems. This is particularly important for cardiac arrests that occur in residential areas and in areas with a long EMS response time, where public access defibrillation programs are unlikely to be implemented.[12,26]

The significant increase in bystander-initiated CPR and first-responder defibrillation in conjunction with the increase in numbers of patients surviving to hospital admission underscore the improvements made in the prehospital setting. The importance of the improvement in bystander CPR is also supported by the significant increase in survival to discharge and survival with favorable neurological outcome only observed in patients who received bystander CPR, but not in patients who did not receive bystander CPR. This is concordant with other studies including a recent Danish study, which also found an association between nationwide quality-improvement initiatives and an increase in bystander CPR and survival.[12,25,27] A study from 2005 through 2012 of all CARES sites also found improved rates of bystander CPR. Compared with that study, our study included information on initiatives to strengthen the chain of survival including first-responder intervention, more rural representation, consistency in reporting across years, and stable patient characteristics. Patient characteristics, EMS care, and survival are known to vary dramatically according to region.[2,5] While the reason for improved survival in our study is probably multifactorial and most likely related to improvements in each link in the chain of survival, our results support previous findings that improvements in the prehospital setting and systems of care are of great importance for cardiac arrest outcomes.[9,12,25,28] Although our study does not allow us to ascertain which factors have contributed most to improve survival, the substantial increase in bystander CPR and first-responder defibrillation together with the positive association between bystander CPR and first-responder defibrillation and survival likely reflect a positive effect of increasing rates of bystander CPR and first-responder defibrillation, and subsequently, survival.[8,9,29-33]

Although bystander CPR increased, bystander defibrillation remained low, with no significant change over time. Low rates of bystander defibrillation in the United States and other countries have been reported.[5,9] Patients who received bystander CPR and bystander defibrillation had a more than 30% chance of survival with favorable neurological outcome, in accordance with the Public Access Defibrillation Trial[34] and other studies.[35,36] These results support the importance of increasing bystander AED use.[36,37] Several initiatives can be taken to facilitate bystander AED use, such as crowd sourcing to identify AED locations, linking AEDs to emergency dispatch centers, and establishing lay first-responder programs in local communities.[27,36,38,39]

We observed a small increase in the incidence of cardiac arrests over time. We performed separate analyses focusing only on changes in absolute numbers of survivors (numerator) as dependent on population size (denominator) to adjust for the possibility that the improved survival could be driven by changes in reporting. Because these analyses did not change the main findings, we did not find any indication that the observed improvement in survival was driven by changes in reporting.

Limitations

The main limitation is the observational nature of the study such that there is no randomized control group, and inferences based on outcomes must be made with great caution. However, registration of cardiac arrests was prospective and uniform, following the standardized Utstein style for reporting out-of-hospital cardiac arrest and revised for data quality assurance by the RACE-CARS team.[18] Our results support efforts of other communities seeking to improve bystander and first-responder intervention, since they come from a quality-improvement database of a substantial portion of the state of North Carolina, with stable reporting over a 4-year period during a broad implementation program that used a standardized protocol, as recommended by the American Heart Association.[13,20,40]

We only report results from selected counties in North Carolina; however, these represent nearly half of the cardiac arrests captured in the state. Limiting the population enabled us to pursue complete case capture with data granularity as well as describe the organization of the EMS systems, emergency dispatch centers, and protocols used during the study period. Additionally, it was possible to review individual cases for quality assurance.[40] There is one potentially important difference in the included counties, in that the cardiac arrest rate is substantially higher in the included counties than in the excluded ones. This could be due to the nature of the CARES registry that allows EMS agencies to start reporting at any time, including in the middle of the year, or to other underreporting in these counties. In some counties the lower incidence might be due to fewer cases being eligible to enter the CARES registry due to longer EMS response times (if bystanders did not initiate CPR), in which case the lower incidence would be due to geographical differences rather than reporting bias. This has potential implications for understanding how geographical and logistical differences can influence the denominator of cardiac arrest populations. The remaining demographic characteristics in the included counties are comparable with the state of North Carolina and with the United States, and the incidence of out-of-hospital cardiac arrest as well as baseline characteristics in our study were stable throughout the study period and in agreement with previous studies.[2,9,25] Finally, we do not have information on several important factors that may influence outcome, such as percentage of dispatcher-identified cardiac arrests, quality of CPR given, whether CPR was compression only, how much time expired between cardiac arrest and administration of CPR and defibrillation, or what type of advanced care patients received. However, our study was not designed to assess causality, and the relationship between bystander and first-responder intervention and outcomes should be viewed as associations and not causal effect.

Conclusions

Following statewide interventions in North Carolina, the proportion of patients with out-of-hospital arrest receiving bystander-initiated CPR and first-responder defibrillation increased and was associated with greater likelihood of survival. During this time, bystander-initiated CPR was associated with greater likelihood of survival with favorable neurological outcome.

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