ORIGINAL RESEARCH

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Multistate 5-Year Initiative to Improve Care for Out-of-Hospital Cardiac Arrest: Primary Results From the HeartRescue Project

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***Background*—**The HeartRescue Project is a multistate public health initiative focused on establishing statewide out-of-hospital cardiac arrest (OHCA) systems of care to improve case capture and OHCA care in the community, by emergency medical services (EMS), and at hospital level.

***Methods and Results*—**From 2011 to 2015 in the 5 original HeartRescue states, all adults with EMS–treated OHCA due to a presumed cardiac cause were included. In an adult population of 32.8 million, a total of 64 988 OHCAs—including 10 046 patients with a bystander-witnessed OHCA with a shockable rhythm—were treated by 330 EMS agencies. From 2011 to 2015, the case-capture rate for all-rhythm OHCA increased from an estimated 39.0% (n=6762) to 89.2% (n=16 103; $P<0.001$ for trend). Overall survival to hospital discharge was 11.4% for all rhythms and 34.0% in the subgroup with bystander-witnessed OHCA with a shockable rhythm. We observed modest temporal increases in bystander cardiopulmonary resuscitation (41.8–43.5%, $P<0.001$ for trend) and bystander automated external defibrillator application (3.2–5.6%, $P<0.001$ for trend) in the all-rhythm group, although there were no temporal changes in survival. There were marked all-rhythm survival differences across the 5 states (8.0–16.1%, $P<0.001$) and across participating EMS agencies (2.7–26.5%, $P<0.001$).

***Conclusions*—**In the initial 5 years, the HeartRescue Project developed a population-based OHCA registry and improved statewide case-capture rates and some processes of care, although there were no early temporal changes in survival. The observed survival variation across states and EMS systems presents a future challenge to elucidate the characteristics of high-performing systems with the goal of improving OHCA care and survival. **(*J Am Heart Assoc*. 2017;6:e005716. DOI: 10.1161/JAHA.117.005716.)**

Key Words: automated external defibrillator • cardiac arrest • cardiopumonary resuscitation • public health initiative • quality improvement

An estimated 424 000 people suffer an out-of-hospital cardiac arrest (OHCA) each year in the United States.[1] Improving OHCA resuscitation and outcomes is challenging given its sudden unexpected nature and its complex physiology requiring time-sensitive multimodal care.[2–4] Survival to hospital discharge remains low and varies markedly across community emergency care systems, suggesting an opportunity to improve outcomes by addressing care differences and uniformly implementing best practices.[1,5–10] Consequently, improving OHCA survival requires effective community-based education, evidence-based care delivery, and a coordinated response from a diverse set of stakeholders along the chain of

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Accompanying Tables S1 through S3 are available at http://jaha.ahajournals.org/content/6/9/e005716/DC1/embed/inline-supplementary-material-1.pdf

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Clinical Perspective

What Is New?

- The HeartRescue Project created a large US population-based registry that captured an estimated 89% of all-rhythm out-of-hospital cardiac arrests.
- In this public health initiative, modest temporal increases in prehospital bystander cardiopulmonary resuscitation and bystander automated external defibrillator application were observed.
- Survival exceeded historical reports of out-of-hospital cardiac arrest survival among all-rhythm patients and the Utstein subgroup (bystander-witnessed out-of-hospital cardiac arrests with an initial shockable rhythm), but we did not observe a temporal change in survival rates.

What Are the Clinical Implications?

- Emergency medical services agencies and community and academic hospitals have successfully partnered in multiple US states to create a population-based registry that measures baseline out-of-hospital cardiac arrest survival with the collective goal of implementing best care practices and improving survival.
- The variability in survival variation among participating states and across emergency medical services agencies presents opportunities to understand why some systems are successful and some are not.

survival that includes laypersons, emergency telecommunicators, first responders, emergency medical services (EMS), and hospital personnel.[3,11]

There are few large-scale, population-based reports of resuscitation in the United States, and most OHCA recommendations and outcomes reports are derived from research networks or selected communities without complete population-based case ascertainment.[5,12] As detailed in the report from the Institute of Medicine, cardiac arrest is a public health problem that requires a public health model that should strive to develop a national population-representative registry.[3] Such a model would engage on a broad scale to achieve measurement, raise public awareness, improve accountability, and undertake programmatic improvement aimed at increasing survival following cardiac arrest and, in turn, improving public health.

The HeartRescue Project was established as a collaboration of academic institutions in 5 states in partnership with the Medtronic Foundation.[2] This quality-improvement initiative focused on engaging stakeholders across the participating states to establish a statewide resuscitation registry that can support comprehensive OHCA case capture and implementation of best practices in an effort to improve survival. In this investigation, we report on the extent to which the initial 5-state collective achieved representative statewide involvement and case capture and the temporal patterns in OHCA care and outcomes and outline future programmatic efforts to implement best practices and improve survival.

Methods

Study Design, Setting, and Population

The HeartRescue project is a multistate public health initiative that was first established in 5 states (Arizona, Minnesota, North Carolina, Pennsylvania, Washington) in 2010.[2] The data reported represent the initial observational cohort of persons aged ≥18 years treated for OHCA between January 1, 2011, and December 31, 2015, among the 5 original HeartRescue states. An eligible cardiac arrest case was defined as an adult in a nontraumatic pulseless state from a presumed cardiac etiology who received resuscitation, defined as the provision of EMS cardiopulmonary resuscitation (CPR) and/or defibrillation, or receipt of a shock by an automated external defibrillator (AED).[2] Cases were excluded if they had missing survival information. In 2015, the 5 states collectively had an estimated population of 42.3 million, including 32.8 million adults.[13] A total of 330 EMS agencies and 411 hospitals participated.

Data Elements and Collection

The HeartRescue Project used the Cardiac Arrest Registry to Enhance Survival (CARES) Web platform to serve as each state-based registry.[12] CARES is a prospective registry established in the United States in 2005 that collects demographic, dispatch, prehospital EMS, and hospital-based data on patients who suffer OHCA. CARES organizes information according to the Utstein template using standard data element definitions.[14] HeartRescue collected information through emergency dispatch information, EMS reports, hospital records, and vital statistics. HeartRescue coordinators facilitate and oversee data collection. The need for institutional review board approval was waived by the University of Washington because the HeartRescue Project was part of a public health initiative and contained deidentified data.

Outcomes

The outcomes of interest were case-capture (described later), process of care measures (bystander CPR, bystander AED application, targeted temperature management [TTM]), and survival to hospital discharge. The project also collected information about functional status at hospital discharge. Good functional status was defined as cerebral performance category 1 or 2.[14,15] We evaluated outcomes in all-rhythm

OHCAs and in the Utstein subgroup defined as bystander-witnessed OHCAs with an initial shockable rhythm.

Statistical Methods

We used descriptive statistics to identify the characteristics, care processes, and outcomes for all eligible OHCA cases and in the Utstein subgroup. Trends in these variables were examined by calendar year using linear regression for continuous variables and the Mantel–Haenszel test of trend for categorical variables. We used US Census data and published estimates of North American adult EMS-treated all-rhythm (55 per 100 000 person-years) and adult ventricular fibrillation (14 per 100 000 person-years) OHCA incidence rates to calculate the extent of yearly case capture.[16] Annual case-capture rates were calculated as percentages based on the numbers of cases in the state-based CARES registry (the numerator) divided by the expected number based on the estimated incidence in the participating states (the denominator).

To assess a temporal pattern in OHCA survival, we fitted multilevel mixed-effects logistic regression models with random intercepts in which patients were nested within EMS agencies. These models account for both the correlation between observations within the same agency and the different participation patterns by agency, producing estimates that are conditional on EMS agency sites. For this analysis, we included calendar year as a set of dummy variables in the model with 2011 defined as our reference year. Models adjusted for age, sex, location of arrest, witnessed status, initial rhythm, whether the arrest occurred before EMS arrival, and state. These models enabled an assessment of whether survival differed across the 5 participating states and across the EMS agencies. Temporal trends were assessed in models that excluded and included bystander CPR and AED shock before EMS (includes laypersons, police, and first responders) because they were hypothesized to be potential mediators of any observed temporal trends.

We conducted sensitivity analyses to examine the robustness of the results. First, in an effort to mitigate the potential case-ascertainment biases associated with the increased participation in the HeartRescue Project over time, we restricted the observations to EMS agencies (n=64) that participated during all 5 years and had an average annual case volume of ≥20 cases. Second, we examined whether the overall temporal pattern in survival was similar across EMS agencies. Descriptive statistics and tests for univariate trends were conducted with SPSS version 23.0 (IBM Corp) Multivariate statistical analyses were conducted with STATA version 11.2 (StataCorp LP), and statistical significance was defined as $P \leq 0.05$.

Results

Among the 66 306 patients treated for OHCA from a presumed cardiac cause between 2011 and 2015, a total of 1318 were excluded, of which 153 had unknown survival status and 1165 were aged <18 years. The final all-rhythm OHCA study population was 64 988 patients and included 10 046 patients (15.5%) in the Utstein subgroup (bystander-witnessed OHCAs with an initial shockable rhythm).

Cardiac arrest characteristics, overall and by calendar year, are presented in Table 1. In the overall population, the median age was 65.7 years, 62.9% were male, and 41.2% of OHCAs were bystander witnessed. The baseline characteristics and processes of care of patients with known and unknown (n=153) outcomes are provided in Table S1. Briefly, patients with unknown outcomes were more frequently younger, had unknown race, had bystander- or EMS-witnessed OHCA in public locations, and had an initial shockable rhythm. Rates of all-rhythm OHCA case capture increased 2.3-fold between 2011 and 2015, increasing from 39.0% in 2011 to 68.6% in 2012, 80.9% in 2013, 88.3% in 2014, and 89.2% in 2015 ($P<0.001$ for trend; Figure 1). Over the 5 years, the number of participating EMS agencies increased from 125 in 2011 to >330 in 2015. Temporal changes in the Utstein subgroup are presented in Table S2.

The overall HeartRescue bystander CPR rate was 42.8%, bystander AED application was 4.6%, and AED application before EMS arrival (bystander, police, or first responder) was 21.9%. TTM was provided in 36.5% of all hospitalized patients and 55.4% of the Utstein subgroup. Table 2 summarizes rates of these processes of care and outcomes by calendar year for all-rhythm arrest and the Utstein subgroup. In the prehospital setting, there were increases in both bystander CPR, bystander AED, and AED application before EMS arrival over time. Prehospital termination of resuscitative efforts also increased over time. In the hospital setting, among all-rhythm OHCA with known procedure status, there was no change over time in the proportions of TTM use, angiography, or percutaneous coronary intervention. The proportion with any revascularization procedure declined significantly because of a decline in the proportion with reported coronary artery bypass grafting over time. In the Utstein subgroup, the proportion with TTM decreased significantly over time, whereas none of the other hospital procedures showed a significant trend over the 5-year period. These findings paralleled more complete ascertainment in procedural coding, shown by the declining proportions of unknown and missing values for each procedure over the 5-year period.

Unadjusted survival to hospital discharge and discharge with cerebral performance category 1 or 2 was 11.4% and 9.4%, respectively, for all-rhythm arrest and 34.0% and 30.4%,

Table 1. Characteristics of All OHCA Patients in HeartRescue Partner States From 2011 to 2015

Characteristic	Overall (n=64 988)	2011 (n=6762)	2012 (n=12 023)	2013 (n=14 314)	2014 (n=15 786)	2015 (n=16 103)	*P* Value*
OHCA by state, n (%)							<0.001
Arizona	12 022	2089 (17.4)	2489 (20.7)	2550 (21.2)	2421 (20.1)	2473 (20.6)	
Minnesota	6132	594 (9.7)	1189 (19.4)	1424 (23.2)	1464 (23.9)	1461 (23.8)	
North Carolina	19 715	1986 (10.1)	3508 (17.8)	4461 (22.6)	4933 (25.0)	4827 (24.5)	
Pennsylvania	14 612	491 (3.4)	2465 (16.9)	3509 (24.0)	4008 (27.4)	4139 (28.3)	
Washington	12 507	1602 (12.8)	2372 (19.0)	2370 (18.9)	2960 (23.7)	3203 (25.6)	
Participating EMS agencies, n	>330	125	206	271	308	>330†	
Age, y, mean (SD)	65.7 (15.6)	65.4 (15.8)	65.1 (15.9)	65.5 (15.7)	66.0 (15.5)	66.0 (15.4)	<0.001
Male sex, n (%)	40 907 (62.9)	4322 (63.9)	7498 (62.4)	8934 (62.4)	9980 (63.2)	10 173 (63.2)	0.72
Race, n (%)							0.007
White	29 569 (45.5)	2299 (34.0)	4950 (41.2)	6451 (45.1)	7880 (49.9)	7989 (49.6)	
Black	8099 (12.5)	674 (10.0)	1565 (13.0)	1772 (12.4)	2003 (12.7)	2085 (12.9)	
Other	1912 (2.9)	138 (2.0)	351 (2.9)	356 (2.5)	532 (3.4)	535 (3.3)	
Unknown	25 408 (39.1)	3651 (54.0)	5157 (42.9)	5735 (40.1)	5371 (34.0)	5494 (34.1)	<0.001‡
Arrest location, n (%)							0.13
Private residence	45 063 (69.3)	4634 (68.5)	8421 (70.0)	10 009 (69.9)	10 849 (68.7)	11 150 (69.2)	
Public	9301 (14.3)	942 (13.9)	1657 (13.8)	1957 (13.7)	2332 (14.8)	2413 (15.0)	
Nursing home/assisted living	7315 (11.3)	807 (11.9)	1373 (11.4)	1499 (10.5)	1823 (11.5)	1813 (11.3)	
Medical facility	3048 (4.7)	362 (5.4)	503 (4.2)	743 (5.2)	736 (4.7)	704 (4.4)	
Other	151 (0.2)	3 (0.0)	55 (0.5)	73 (0.5)	2 (0.0)	18 (0.1)	
Unknown	110 (0.2)	14 (0.2)	14 (0.1)	33 (0.2)	44 (0.3)	5 (0.0)	
Cardiac arrest before EMS arrival, n (%)	58 260 (89.7)	6080 (89.9)	10 779 (89.7)	12 738 (89.0)	14 213 (90.0)	14 450 (89.7)	0.63
Witnessed arrest, n (%)							0.001
Bystander witnessed	26 777 (41.2)	2673 (39.5)	4869 (40.5)	5825 (40.7)	6801 (43.1)	6609 (41.0)	
EMS witnessed	6721 (10.3)	682 (10.1)	1241 (10.3)	1574 (11.0)	1571 (10.0)	1653 (10.3)	
Unwitnessed	31 482 (48.4)	3407 (50.4)	5910 (49.2)	6913 (48.3)	7412 (47.0)	7840 (48.7)	
Unknown	8 (0.0)	0 (0.0)	3 (0.0)	2 (0.0)	2 (0.0)	1 (0.0)	
Shockable initial rhythm, n (%)							<0.001
Yes (all VF)	16 467 (25.3)	1855 (27.4)	3117 (25.9)	3546 (24.8)	4029 (25.5)	3920 (24.3)	
No	47 990 (73.8)	4839 (71.6)	8858 (73.7)	10 728 (74.9)	11 626 (73.6)	11 939 (74.1)	
Unknown	531 (0.8)	68 (1.0)	48 (0.4)	40 (0.3)	131 (0.8)	244 (1.5)	
Utstein subgroup, n (%)§	10 046 (61.0)	1083 (58.4)	1866 (59.9)	2111 (59.5)	2532 (62.8)	2454 (62.6)	<0.001
HeartRescue population, n	N/A	41 036 307	41 350 807	41 653 589	41 983 228	42 333 255	
HeartRescue population aged ≥18 y	N/A	31 509 788	31 849 733	32 165 945	32 490 688	32 833 394	
Expected incidence of all-rhythm OHCA (55/100 000)	N/A	17 330	17 517	17 691	17 870	18 058	
Case-capture rate, %	N/A	39.0	68.6	80.9	88.3	89.2	<0.001
Expected incidence of VF OHCA (14/100 000)	N/A	4411	4459	4503	4549	4597	
Case-capture rate, %	N/A	42.1%	69.9%	78.7%	88.6%	85.3%	<0.001

EMS indicates emergency medical services; N/A, not available; OHCA, out-of-hospital cardiac arrest; VF, ventricular fibrillation.
**P* values test for trend reported for cases with known values, unknowns shown for information.
†The total number of EMS agencies are not yet available.
‡*P* value for test for trend for increasing reporting of race.
§Utstein patients are a subgroup of shockable initial rhythm patients.

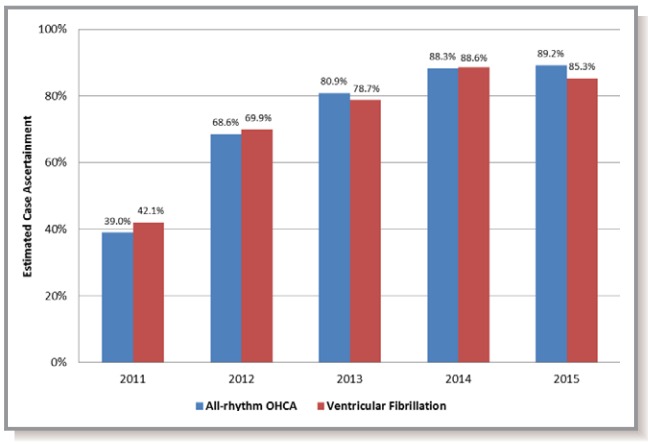

Figure 1. Trends in estimated all-rhythm and ventricular fibrillation case ascertainment in HeartRescue states. OHCA indicates out-of-hospital cardiac arrest.

respectively, in the Utstein subgroup. We observed survival differences across the 5 states in all-rhythm patients (8.0–16.1%, $P<0.001$) and in the Utstein subgroup (26.4–44.3%, $P<0.001$). Similarly, survival differed across EMS agencies (n=66) that exceeded 20 treated OHCA each year among the all-rhythm patients (2.7–26.5%, $P<0.001$) and in the Utstein subgroup (10.0–57.0%, $P<0.001$; n=64 agencies).

In analyses of temporal patterns, unadjusted survival to hospital discharge and discharge with cerebral performance category 1 or 2 declined over time from 13.7% to 10.5% ($P<0.001$ for trend) and from 10.4% to 8.9% ($P=0.002$ for trend), respectively, in the all-rhythm group. However, there was no evidence of temporal trend after multivariable adjustment (adjusted odds ratio: 0.98; 95% confidence interval, 96–1.00; $P=0.08$; Table 3, Figure 2). In the Utstein subgroup, there was no evidence of a temporal change in survival to hospital discharge (34.7–34.6%, $P=0.84$ for trend) and discharge with cerebral performance category 1 or 2 (28.2–31.5%, $P=0.42$). Similarly, we observed no evidence of temporal trend in survival among the Utstein subgroup after multivariable adjustment (odds ratio: 1.02; 95% confidence interval, 0.98–1.05; $P=0.34$).

In a sensitivity analysis restricted to the 64 EMS agencies with stable 5-year participation, overall all-rhythm survival (12.9%) and Utstein subgroup survival (37.2%) were higher in this restricted cohort, although there was no evidence of a temporal trend in survival (Table S3). We did, however, observe evidence of temporal change in survival according to individual EMS agencies. Among all-rhythm arrests, 23.4% of these EMS agencies experienced an absolute change (either increase or decrease) in survival of <5% between 2011 and 2015, 43.7% of EMS agencies experienced an absolute increase of ≥5%, and 32.8% experienced an absolute decrease of ≥5% in survival in the Utstein subgroup.

Discussion

In this multistate OHCA public health initiative, the HeartRescue Project was able to accrue participation of a substantial majority of each state to achieve an inclusive and large population-based registry representative of OHCA events. There were modest temporal increases in prehospital bystander CPR and bystander AED application but a potential decrease in hospital-based TTM. Outcomes exceeded historical reports of OHCA survival among all-rhythm patients and the Utstein subgroup, although we did not observe a temporal change in survival rates. The lack of temporal difference was contrasted by marked outcome variation among participating states and across EMS agencies.

With few exceptions, most reports of OHCA care and outcomes from the United States have involved selected communities or states; therefore, a true population-based registry with multiple diverse stakeholders representing a spectrum of emergency systems has generally been lacking.[5,12,17] Although data from these aforementioned consortia have clearly improved our understanding and treatment of OHCA, they typically derive from selected communities that may have a special interest in or resources to direct to OHCA resuscitation. In the first 5 years of implementation, the HeartRescue project successfully organized >330 EMS agencies and 411 hospitals in 5 states to achieve an estimated 90% OHCA case-capture rate. The high level of participation and the improvements in data fidelity indicate this type of foundational activity can be accomplished by most communities, providing important evidence to support the Institute of Medicine's goal to create a truly representative registry of OHCA resuscitation to benchmark and improve care.

In the prehospital phase of care, bystander CPR and public AED application can improve OHCA survival.[18–22] We observed bystander CPR in excess of 40% among all rhythm arrests and approaching 60% in the Utstein subgroup, results that surpass other North American and Asian reports and that compare favorably to European experiences.[23–25] We also observed modest temporal improvements in bystander CPR; however, the increase in bystander CPR was more modest than other programmatic initiatives that have corresponded to outcome improvements.[26–28] The rate of bystander AED increased over time, reaching 5% among all arrests and nearly 9% in the Utstein subgroup. Although this bystander AED involvement is still a small minority, there appears to be a slow and gradual increase compared with historical experiences.[29,30] Future studies might compare and contrast those communities that achieve especially high rates of bystander CPR and bystander/first-responder AED application to understand what characteristics best support this evidence-based care.

In the hospital phase of care, we observed a significant temporal decline in TTM in the Utstein subgroup. We

Table 2. Unadjusted Processes of Care and Outcomes in All OHCAs and the Utstein Subgroup

Process of Care	All OHCAs (n=64 988)						Utstein Subgroup (n=10 046)					
	2011 (n=6762)	2012 (n=12 023)	2013 (n=14 314)	2014 (n=15 786)	2015 (n=16 103)	*P* Value*	2011 (n=1083)	2012 (n=1866)	2013 (n=2111)	2014 (n=2532)	2015 (n=2454)	*P* Value
CPR initiation, n (%)						<0.001						0.003
Bystander	2825 (41.8)	4842 (40.3)	6161 (43.0)	6977 (44.2)	7003 (43.5)		607 (56.0)	1064 (57.0)	1201 (56.9)	1521 (60.1)	1471 (59.9)	
EMS	3921 (58.0)	7147 (59.4)	8139 (56.9)	8787 (55.7)	9088 (56.4)		473 (43.7)	799 (42.8)	909 (43.1)	1009 (39.8)	981 (40.0)	
Not applicable	16 (0.2)	30 (0.2)	22 (0.2)	20 (0.1)	9 (0.1)		3 (0.3)	3 (0.2)	1 (0.0)	2 (0.1)	1 (0.0)	
Unknown	0 (0.0)	4 (0.0)	2 (0.0)	2 (0.0)	3 (0.0)		0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)	
Bystander AED, n (%)	217 (3.2)	430 (3.6)	624 (4.4)	791 (5.0)	902 (5.6)	<0.001	77 (7.1)	145 (7.8)	142 (6.7)	197 (7.8)	8.5 (8.5)	<0.001
AED before EMS arrival†, n (%)	1483 (21.9)	3183 (26.5)	4090 (28.6)	4669 (29.6)	5010 (31.1)	<0.001	327 (30.2)	652 (34.9)	783 (37.1)	896 (35.4)	953 (38.8)	<0.001
EMS care disposition, n (%)						<0.001						0.005
Pronounced in field	1837 (27.2)	3151 (26.2)	4306 (30.1)	5138 (32.5)	5906 (36.7)		125 (11.5)	190 (10.2)	259 (12.3)	341 (13.5)	365 (14.9)	
Pronounced in ED	1060 (15.7)	1385 (11.5)	1798 (12.6)	1705 (10.8)	1655 (10.3)		123 (11.4)	181 (9.7)	243 (11.5)	245 (9.7)	216 (8.8)	
Ongoing resuscitation in ED	3865 (57.2)	7487 (62.3)	8210 (57.4)	8943 (56.7)	8539 (53.0)		835 (77.1)	1495 (80.1)	1609 (76.2)	1946 (76.9)	1873 (76.3)	
Hospital admission, n (%)	2712 (40.1)	4460 (37.1)	4975 (34.8)	5602 (35.5)	5475 (34.0)	<0.001	660 (60.9)	1114 (59.7)	1215 (57.6)	1475 (58.3)	1452 (59.2)	0.34
In hospital therapies, n (%)‡												
Therapeutic hypothermia	889 (34.1)	1545 (35.7)	1883 (39.0)	2019 (36.8)	1946 (36.0)	0.20	373 (58.7)	611 (56.6)	716 (61.3)	737 (51.2)	753 (52.3)	<0.001
Unknown§	102 (3.8)	129 (2.9)	141 (2.8)	122 (2.2)	67 (1.2)	<0.001	25 (3.8)	35 (3.1)	47 (3.9)	35 (2.4)	12 (0.8)	<0.001
Angiography	366 (33.8)	825 (33.9)	1162 (35.8)	1312 (33.4)	1318 (33.6)	0.47	188 (53.0)	459 (59.7)	623 (62.1)	715 (59.2)	757 (61.1)	0.09
Unknown	1628 (60.0)	2026 (45.4)	1731 (34.8)	1675 (29.9)	1556 (28.4)	<0.001	305 (46.2)	345 (31.0)	211 (17.4)	267 (18.1)	213 (14.7)	<0.001
Revascularization (PCI or CABG)	264 (27.2)	513 (23.4)	687 (22.4)	825 (22.7)	826 (22.4)	0.015	129 (39.9)	298 (41.6)	369 (38.8)	427 (37.8)	470 (40.0)	0.56
Unknown	1743 (64.3)	2272 (50.9)	1903 (38.3)	1960 (35.0)	1786 (32.6)	<0.001	337 (51.1)	397 (35.6)	264 (21.7)	346 (23.5)	276 (19.0)	<0.001
PCI	170 (19.0)	371 (17. 8)	538 (18.0)	631 (18.0)	625 (17.6)	0.48	86 (29.4)	220 (32.7)	282 (31.2)	316 (29.7)	345 (31.2)	0.79
Unknown	1817 (67.0)	2372 (53.2)	1994 (40.1)	2089 (37.3)	1921 (35.1)	<0.001	367 (55.6)	441 (39.6)	311 (25.6)	411 (27.9)	346 (23.8)	<0.001
CABG	95 (8.9)	147 (6.1)	156 (4.8)	204 (5.2)	219 (5.6)	0.004	44 (12.4)	82 (10.8)	90 (9.1)	114 (9.5)	137 (11.1)	0.74
Unknown	1643 (60.6)	2043 (45.8)	1746 (35.1)	1691 (30.2)	1558 (28.5)	<0.001	306 (46.4)	354 (31.8)	222 (18.3)	276 (18.7)	215 (14.8)	<0.001
ICD	186 (17.5)	373 (15.9)	456 (14.2)	481 (12.6)	487 (12.9)	<0.001	108 (31.7)	233 (30.9)	294 (29.9)	339 (29.0)	361 (30.1)	0.49
Unknown	1652 (60.9)	2121 (47.6)	1770 (35.6)	1792 (32.0)	1705 (31.1)	<0.001	319 (48.3)	359 (32.2)	232 (19.1)	308 (20.9)	254 (17.5)	<0.001

Continued

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Table 2. Continued

Process of Care	All OHCAs (n=64 988)						Utstein Subgroup (n=10 046)					
	2011 (n=6762)	2012 (n=12 023)	2013 (n=14 314)	2014 (n=15 786)	2015 (n=16 103)	*P* Value*	2011 (n=1083)	2012 (n=1866)	2013 (n=2111)	2014 (n=2532)	2015 (n=2454)	*P* Value
Outcome												
Survival to discharge, n (%)	924 (13.7)	1397 (11.6)	1576 (11.0)	1829 (11.6)	1698 (10.5)	<0.001	376 (34.7)	637 (31.4)	714 (33.8)	838 (33.1)	848 (34.6)	0.84
Discharged with CPC 1/2, n (%)	701 (10.4)	1141 (9.5)	1297 (9.1)	1512 (9.6)	1426 (8.9)	0.002	305 (28.2)	565 (30.3)	649 (30.7)	744 (29.4)	772 (31.5)	0.42
Unknown/missing	97 (1.4)	35 (0.3)	33 (0.2)	7 (0.0)	6 (0.0)	<0.001	42 (3.9)	16 (0.9)	7 (0.3)	2 (0.1)	3 (0.1)	<0.001

AED indicates automatic external defibrillator; CABG, coronary artery bypass grafting; CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; ED, emergency department; EMS, emergency medical services; ICD, implantable-cardioverter defibrillator; OHCA, out-of-hospital cardiac arrest; PCI, percutaneous coronary intervention.
**P* values test for trend among known values for procedures and outcomes.
†Includes layperson, police, and first responders.
‡Percentages for procedures performed are based on the cases with reported known values.
§Percentages and tests for "unknown" rows test for trend in provision of known procedure status vs missing or unknown.

hypothesize that the decline in these guideline-recommended therapies may reflect (1) inclusion of new communities that may have less clinical experience and/or fewer hospital-based resources to achieve more comprehensive evidence-based care or (2) misinterpretation of the results of the most recent multicenter randomized trial involving hospital-based TTM. The trial found no outcome differences for patients randomized to 36°C compared with 33°C. The CARES data set does not contain information on neurologic status after return of spontaneous circulation, thus the appropriateness of TTM cannot be adjudicated. This represents a potential future registry improvement. Importantly, both groups received TTM such that even the 36°C group required active as opposed to no TTM.[9] A decrease in revascularization was observed among all arrests, but there was no evidence of a change in the Utstein subgroup. Similarly, implantable-cardioverter defibrillator implantation in the Utstein subgroup remained stable over time. Although revascularization is recommended for OHCA patients with ST-segment–elevation myocardial infarction and predischarge implantable-cardioverter defibrillator implantation is recommended in clinically appropriate patients, the present data set does not permit the adjudication of the appropriateness of these procedures.[31–33]

Whether OHCA survival in the United States is improving is uncertain.[4,6,7,17] Some studies have documented improvements in OHCA care delivery and survival, but these studies have thus far been limited to defined counties, states, or registries with selected—often urban—communities.[7,17,23] Importantly, no prior US studies have evaluated temporal trends in OHCA survival in the context of a public health program that concurrently introduces best-care practices to neighboring communities and comprehensive population-based case ascertainment. We observed overall (11.4%) and Utstein subgroup (34.0%) survival that is encouraging but still with the real opportunity for improvement. The aggregate mortality rate coupled with wide range of agency-specific outcomes highlight a need and opportunity for future quality and public health initiatives.[3]

Survival did not improve over time in this cohort.[6,8] The lack of temporal trends stands in contrast to a 10-year 7.3% absolute increase in 30-day OHCA survival in Denmark following national quality improvement initiatives and the 7-year 4.9% increase in neurologically intact survival in Japan that corresponded to significant increases in bystander CPR and AED use.[27,28] What explains the lack of temporal improvement in the current experience? First, the HeartRescue Program is a relatively new initiative. Effective implementation often requires years; even though there was modest improvement in some processes of care, a more coordinated and mature effort may be required to achieve measurable survival benefit. The most effective systems have often achieved improvement only after many years of sustained effort.[28] Second, improvements may have occurred simultaneously as

Table 3. Adjusted Predictors of Survival to Hospital Discharge Overall and Utstein Subgroup

	All OHCAs		Utstein Subgroup	
Variable	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Demographics				
Age, per y	0.98 (0.98–0.98)	<0.001	0.97 (0.97–0.97)	<0.001
Male	0.85 (0.80–0.91)	<0.001	0.85 (0.76–0.94)	0.002
Location of arrest (private residence reference)				
Public location	1.89 (1.77–2.02)	<0.001	2.20 (2.00–2.41)	<0.001
Nursing home or assisted living	0.85 (0.75–0.97)	0.017	0.56 (0.40–0.80)	0.001
Medical facility	2.03 (1.80–2.29)	<0.001	1.73 (1.39–2.14)	<0.001
Other location	0.90 (0.50–1.61)	0.717	1.35 (0.59–3.08)	0.473
Arrest variables				
Witnessed arrest	2.56 (2.39–2.74)	<0.001		
Shockable rhythm	6.70 (6.32–7.11)	<0.001		
EMS witnessed arrest	1.94 (1.80–2.10)	<0.001		
State (Arizona reference)				
Minnesota	1.03 (0.81–1.31)	0.796	1.26 (0.94–1.68)	0.120
North Carolina	0.79 (0.66–0.96)	0.016	0.85 (0.68–1.07)	0.170
Pennsylvania	0.83 (0.69–0.99)	0.043	0.91 (0.72–1.15)	0.424
Washington	1.43 (1.19–1.72)	<0.001	1.79 (1.43–2.25)	<0.001
Calendar year (2011 reference)				
2012	0.95 (0.85–1.05)	0.294	1.10 (0.93–1.30)	0.269
2013	0.95 (0.86–1.06)	0.360	1.17 (0.99–1.39)	0.064
2014	0.99 (0.90–1.10)	0.868	1.13 (0.96–1.33)	0.154
2015	0.91 (0.82–1.00)	0.061	1.16 (0.98–1.37)	0.080

CI indicates confidence interval; EMS, emergency medical services; OHCA, out-of-hospital cardiac arrest; OR, odds ratio.

communities implemented programmatic improvement simultaneous to case ascertainment and outcome measurement. Thus a true baseline OHCA survival rate in many communities may be lacking. This hypothesis is supported by the survival rates that exceed those reported in other contemporary US publications and the lower baseline survival rates reported in the aforementioned Danish and Japanese studies.[6,7,23,27,28] Third, such a broad-based initiative may not be able to consistently advance outcomes across variable settings so that improvements may occur only in selected regions or systems. The overall lack of a temporal change may belie the temporal differences in survival at the individual EMS agency level, suggesting that the collective lack of temporal change may not represent agency-level efforts and outcomes.

Although we did not observe outcome changes over time, we did find 2-fold variability in survival across HeartRescue partner states. Similarly, we observed nearly 5-fold survival differences across higher volume EMS agencies. These results are consistent with previous studies and highlight outcome disparities that suggest opportunities for public health improvement.[5] These data differ from a previous study by Girotra and colleagues that describes regional variations in OHCA care insofar as the prior study used selected US CARES data and did not examine temporal trends in survival.[10] In contrast, HeartRescue was designed to achieve population-based, statewide participation. To address outcome disparities and to improve OHCA survival, future HeartRescue investigations will focus on examining patient differences and processes of care between EMS agencies with high and low OHCA survival rates and EMS agencies with improving, no change, or declining OHCA survival. Understanding the heterogeneity observed herein provides opportunities to identify characteristics that account for these differences and in turn specifically target disparity with the goal of improving OHCA survival in future phases of the HeartRescue Project.

Limitations

Our findings should be considered in the context of the study's limitations. First, comprehensive information about patient, circumstance, and system factors was not available. Complete information about, for example, the quality of CPR or the timing

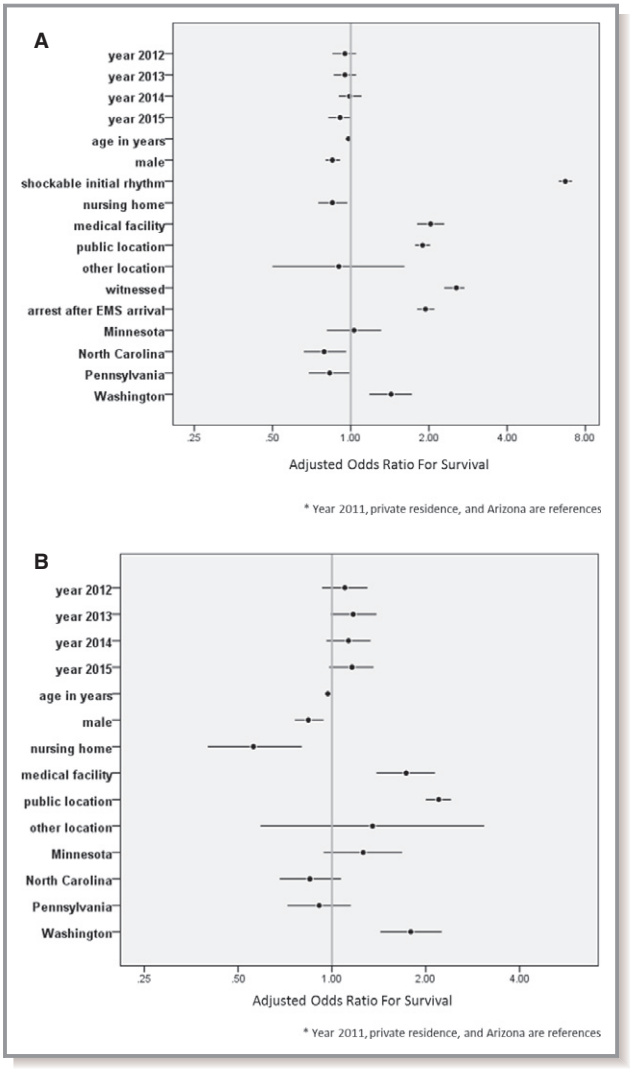

Figure 2. Adjusted odds ratio plot of predictors of survival in the (A) all-rhythm and (B) Utstein subgroup out-of-hospital cardiac arrest populations.

of care was not routinely available and would likely help explain relationships; however, the goals of the project favored broad participation, and detailed comprehensive data collection was not feasible for many stakeholders because many systems were new to case capture and reporting. Classification of etiology can be difficult to determine in some cases, and variable approaches to classification could produce bias, although investigations of etiology suggest that cardiac etiology accounts for the large majority of arrests in North America, and etiology is not associated with outcome.[34] We acknowledge the variability in published OHCA incidence estimates; however, our case ascertainment rates were based on estimates developed through a systematic review of published literature.[16,35] Program implementation was deferred to local leadership, given the goals of large-scale involvement and the quality-improvement initiative, thus we cannot rigorously assess which of these programs provided the optimal delivery approach. We evaluated the HeartRescue experience using a variety of analytical methods, but the results may be confounded by the temporal decrease in covariate missingness or the expanding denominator of EMS agencies, hospitals, and OHCAs as a consequence of HeartRescue expansion.

Conclusion

In the initial 5-year phase of this population-based initiative designed to measure and improve OHCA care, the HeartRescue Project achieved a nearly comprehensive state-based OHCA case-capture and demonstrated a high level of evidence-based care with modest increases in prehospital best-care practices of bystander CPR and AED application, although there was no evidence of a temporal improvement in survival. There was, however, substantial variability in survival according to EMS agency and state. As a consequence of the initiative, the HeartRescue Project created an inclusive, population-based OHCA registry within a public health model that can be used to support future programmatic implementation and the goal of community-based best practices. Future studies should evaluate distinguishing characteristics of both high-performing and temporally improving agencies with the goal of determining how such characteristics can be cultivated across more emergency systems to improve OHCA survival.

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Supplemental Material

Table S1. Characteristics and process of care of all rhythm out-of-hospital cardiac arrest patients with known and unknown outcomes

Characteristic	Known Outcome (n=64,988)	Unknown Outcome (n=153)	p value
Year, n (%)			0.28
2011	6762 (10.4)	15 (9.8)	
2012	12023 (18.5)	23 (15.0)	
2013	14314 (22.0)	45 (29.4)	
2014	15786 (24.3)	45 (29.4)	
2015	16103 (24.8)	25 (16.3)	
OHCA by State, n (%)			
Arizona	12022 (18.5)	0 (0)	<0.001
Minnesota	6132 (9.4)	4 (2.6)	
North Carolina	19715 (30.3)	29 (19.0)	
Pennsylvania	14612 (22.5)	47 (30.7)	
Washington	12507 (19.2)	73 (47.4)	
Age, mean (SD), years	65.7 (15.6)	61.4 (15.2)	<0.001
Male sex, n (%)	40907 (62.9)	104 (68.9)	0.199
Race, n (%)			0.009
Caucasian	29569 (45.5)	54 (35.3)	
African American	8099 (12.5)	14 (9.2)	
Other	1912 (2.9)	6 (3.9)	
Unknown	25408 (39.1)	79 (51.6)	
Arrest Location, n (%)			<0.001
Private residence	45063 (69.3)	94 (61.4)	
Public	9301 (14.3)	51 (33.3)	
Nursing home / Assisted living	7315 (11.3)	6 (3.9)	
Medical facility	3048 (4.7)	2 (1.3)	

Other	151 (0.2)	0 (0)	
Unknown	110 (0.2)	0 (0)	
Cardiac arrest before EMS arrival, n (%)	58260 (89.7)	129 (84.3)	0.03
Witnessed arrest, n (%)			
Bystander witnessed	26777 (41.2)	79 (51.6)	<0.001
EMS witnessed	6721 (10.3)	24 (15.7)	
Unwitnessed	31482 (48.4)	50 (32.7)	
Unknown	8 (0.0)	0 (0)	
Shockable initial rhythm, n (%)			
Yes (All VF)	16467 (25.3)	59 (38.6)	<0.001
No	47990 (73.8)	94 (61.4)	
Unknown	531 (0.8)	0 (0)	
Utstein OHCA, n (%)	10046 (61.0)	40 (67.8)	0.286
Processes of Care			
CPR initiation, n (%)			0.007
Bystander	27789 (42.8)	49 (32.0)	
EMS	37082 (57.1)	104 (68.0)	
Not applicable	97 (0.1)	0(0)	
Unknown	11 (0.02)	0(0)	
Bystander AED, n (%)	2964 (4.6)	2 (1.3)	0.054
Unknown	21 (0.03)	0 (0)	
AED prior to EMS arrival, n (%)	18435 (28.4)	33 (21.6)	0.062
EMS care disposition, n (%)			<0.001
Pronounced in field	20338 (31.3)	0 (0)	
Pronounced in ED	7606 (11.7)	0 (0)	
Ongoing resuscitation in ED	37044 (57.0)	153 (100)	

Abbreviations: ED, emergency department; EMS, emergency medical services; N/A: not available; OHCA, out-of-hospital cardiac arrest; SD, standard deviation; VF, ventricular fibrillation

Table S2. Characteristics of bystander-witnessed out-of-hospital cardiac arrest patients with a shockable rhythm in HeartRescue partner states from 2011-2015

Characteristic	Overall (n=10,046)	2011 (n= 1,083)	2012 (n=1,866)	2013 (n=2,111)	2014 (n=2,532)	2015 (n=2,454)	p value*
OHCA by State, n (row %)							0.001
Arizona	1564	246 (15.7)	298 (19.1)	304 (19.4)	389 (24.9)	327 (20.9)	
Minnesota	1181	105 (8.9)	221 (18.7)	300 (25.4)	284 (24.0)	271 (22.9)	
North Carolina	2969	310 (10.4)	541 (18.2)	668 (22.5)	714 (24.0)	736 (24.8)	
Pennsylvania	1961	71 (3.6)	323 (16.5)	463 (23.6)	584 (29.8)	520 (26.5)	
Washington	2371	351 (14.8)	483 (20.4)	376 (15.9)	561 (23.7)	600 (25.3)	
Age, mean (SD), years	63.0 (14.1)	62.7 (14.2)	62.3 (14.3)	62.8 (14.5)	63.6 (14.1)	63.0 (13.5)	0.05
Male sex, n (%)	7642 (76.1)	821 (75.8)	1407 (75.4)	1600 (75.8)	1941 (76.7)	1873 (76.3)	0.42
Race, n (%)							0.76
Caucasian	5065 (50.4)	429 (39.6)	883 (47.3)	1078 (51.1)	1365 (53.9)	1310 (53.4)	
African American	973 (9.7)	73 (6.7)	182 (9.8)	223 (10.6)	238 (9.4)	257 (10.5)	
Other	284 (2.8)	23 (2.1)	54 (2.9)	48 (2.3)	80 (3.2)	79 (3.2)	
Unknown	3724 (37.1)	558 (51.5)	747 (40.0)	762 (36.1)	849 (33.5)	808 (32.9)	< 0.001†
Arrest Location, n (%)							0.21
Private residence	6035 (60.1)	639 (59.0)	1129 (60.5)	1264 (59.9)	1537 (60.7)	1466 (59.7)	
Public	3252 (32.4)	354 (32.7)	591 (31.7)	686 (32.5)	794 (31.4)	827 (33.7)	
Nursing home or assisted living	298 (3.0)	29 (2.7)	50 (2.7)	69 (3.3)	86 (3.4)	64 (2.6)	
Medical facility	415 (4.1)	57 (5.3)	80 (4.3)	75 (3.6)	110 (4.3)	93 (3.8)	
Other	30 (0.3)	0 (0.0)	13 (0.7)	13 (0.6)	0 (0.0)	4 (0.2)	
Unknown	16 (0.2)	4 (0.4)	3 (0.2)	4 (0.2)	5 (0.2)	0 (0.0)	
Cardiac arrest on EMS arrival, n (%)	10046 (100)	1083 (100)	1866 (100)	2111 (100)	2532 (100)	2454 (100)	N/A
Bystander witnessed arrest, n (%)	10046 (100)	1083 (100)	1866 (100)	2111 (100)	2532 (100)	2454 (100)	N/A
Shockable initial rhythm, n (%)	10046 (100)	1083 (100)	1866 (100)	2111 (100)	2532 (100)	2454 (100)	N/A

Abbreviations: ED, emergency department; EMS, emergency medical services; SD, standard deviation

* p-value test for trend, unknowns excluded from testing;† p-value test for trend in known versus unknown values

Table S3. Adjusted predictors of survival to hospital discharge in the overall and Utstein populations in EMS agencies with 5 year participation and average annual OHCA case volume ≥20

Variable	All Out-of-Hospital Cardiac Arrests		Utstein Population	
	Odds Ratio (95% CI)	p value		p value
Demographics				
Age, per year	0.98 (0.98, 0.98)	<0.001	0.97 (0.97, 0.97)	<0.001
Male	0.86 (0.79, 0.92)	0.001	0.84 (0.73, 0.96)	0.010
Location of arrest (private residence reference)				
Public location	1.76 (1.62, 1.91)	<0.001	2.02 (1.79, 2.27)	<0.001
Nursing home or assisted living	0.83 (0.71, 0.97)	0.021	0.53 (0.34, 0.82)	0.005
Medical facility	1.93 (1.62, 2.30)	<0.001	1.30 (0.99, 1.72)	0.058
Other location	0.75 (0.40, 1.43)	0.391	1.26 (0.52, 3.10)	0.609
Arrest variables				
Witnessed arrest	2.49 (2.29, 2.71)	<0.001		
Shockable rhythm	6.11 (5.65, 6.61)	<0.001		
EMS witnessed arrest	1.76 (1.58, 1.95)	<0.001		
Bystander CPR	1.23 (1.14, 1.33)	<0.001	1.23 (1.14, 1.88)	<0.001
AED shock prior to EMS	1.33 (1.20, 1.48)	<0.001	1.36 (1.20, 1.52)	<0.001
State (Arizona reference)				
Minnesota	0.98 (0.74, 1.30)	0.892	1.34 (1.16, 1.54)	<0.001
North Carolina	0.91 (0.73 , 1.12)	0.372	0.95 (0.72, 1.25)	0.698
Pennsylvania	0.87 (0.66, 1.15)	0.329	1.03 (0.71, 1.25)	0.893
Washington	1.52 (1.23, 1.88)	0.004	1.86 (1.41, 2.46)	<0.001
Calendar year (2011 reference)				
2012	0.97 (0.86, 1.08)	0.538	1.18 (0.98, 1.42)	0.085
2013	0.96 (0.86, 1.08)	0.497	1.24 (1.03, 1.50)	0.025
2014	0.96 (0.86, 1.07)	0.681	1.10 (0.91, 1.32)	0.324
2015	0.87 (0.78, 0.98)	0.017	1.04 (0.86, 1.26)	0.672

Abbreviations: CI, confidence interval

* Private residence as reference; † Arizona as reference; ‡ 2011 as reference

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