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Clinical paper

Large urban center improves out-of-hospital cardiac arrest survival

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Abstract

Background: Large cities pose unique challenges that limit the effectiveness of system improvement interventions. Successful implementation of integrated cardiac resuscitation systems of care can serve as a model for other urban centers.

Methods: This was a retrospective analysis of prospectively collected data of adult cases of non-traumatic cardiac arrest who received treatment by Chicago Fire Department EMS from September 1, 2013 through December 31, 2016. We measured temporal OHCA outcomes during implementation of system-wide initiatives including telephone-assisted and community CPR training programs; high performance CPR and team based simulation training; new post resuscitation care and destination protocols; and case review for EMS providers. Outcomes measured included bystander CPR rates, return of spontaneous circulation (ROSC), hospital admission and survival, and favorable neurologic outcomes (CPC 1–2). Relative risk was determined by logistic regression model where observed group-specific outcomes are expressed as odds ratios (OR).

Results: We included 6103 adult OHCA cases occurring outside of health care facilities from September 1, 2013 through December 31, 2016. Significantly improved outcomes ($p < 0.05$) were observed between 2013 and 2016 for bystander CPR (11.6% vs 19.4%), ROSC (28.6% vs 36.9%), hospital admission (22.5% vs 29.4%), survival (7.3% vs 9.9%), and CPC 1–2 (4.3% vs 6.4%). Utstein survival increased from 16.3%–35.4% and CPC 1–2 survival from 11.6%–29.1% ($p < 0.05$). After adjustment for OHCA characteristics, survival with CPC 1–2 increased over time (OR 1.15, $p = 0.0277$).

Conclusions: Densely populated cities with low survival rates can overcome systematic challenges and improve OHCA survival.

Keywords: Out of hospital cardiac arrest, Systems of care, Prehospital, Resuscitation, Neurological outcomes, Quality improvement

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Introduction

Nearly 400,000 cases of out-of-hospital cardiac arrest (OHCA) occur in the United States (US) every year.[1] While the average rate of OHCA survival to hospital discharge is 11.4%, survival varies greatly by geography.[1–6] Survival rates vary from close to 0% and as high as 50% for shockable rhythms.[7] Model communities have demonstrated improved survival outcomes by establishing integrated resuscitation systems of care, which provide key interventions at the community, pre-hospital, and hospital levels.[8–11] However, large cities pose unique challenges that limit the effectiveness of system improvement interventions.[12] Many large urban centers consistently report OHCA survival rates in the single digits.[13]

Chicago is the third largest and one of the most racially and socioeconomically diverse cities in the US.[14] Often cited as an example of a city with poor survival outcomes, the last study of OHCA in Chicago reported survival rates of 2% (the Chicago CPR Project, 1987–1988).[3,13,15] Survival remained at stagnant rate of 3% as of a 2011 Joint Commission Report[16] due to the absence of a citywide cardiac arrest database and a coordinated effort to improve OHCA prehospital care.

Chicago has since comprehensively restructured the city's approach to the treatment of OHCA by implementing evidence-based interventions throughout the OHCA system of care (Supplementary file, Table S1).[17] First, the Chicago Fire Department's (CFD) Emergency Medical Services (EMS) call takers and dispatchers were trained to improve recognition of OHCA and provide telephone-assisted CPR (T-CPR) instructions to bystanders making the 911 call.[18] Second, 911 dispatchers activate a tiered response for OHCA calls including a 4-person basic or advanced life support non-transport fire truck and a two-person advanced life support transport ambulance.[19,20] Third, simulation-based training sessions in Incident Command for Cardiac Arrest management defined high-performance CPR quality metrics and resuscitation roles, emphasizing high quality chest compressions with early defibrillation.[21,22] Fourth, a new OHCA transport protocol directed patients with return of spontaneous circulation (ROSC) to regional STEMI centers.[23] Finally, in September 2013, systematic OHCA data collection was introduced using the Cardiac Arrest Registry to Enhance Survival (CARES).[24]

During the same time period, a state-wide initiative known as Illinois Heart Rescue (ILHR) implemented an audit and feedback program using funded data coordinators. Like the National Heart-Rescue Project,[25] ILHR aimed to improve OHCA survival by increasing public awareness and response to OHCA, aligning prehospital care with OHCA treatment guidelines set by the American Heart Association and International Liaison Committee on Resuscitation (ILCOR), and standardizing post-resuscitation care for ROSC patients. ILHR prioritized initiatives to increase OHCA recognition, early activation of the 911 system, and bystander CPR training in communities with the highest incidence of OHCA and lowest bystander CPR rates.[26–28] Between January of 2013 and December of 2016, close to 30,000 people participated in nearly 300 bystander CPR community trainings conducted by ILHR in underserved communities of Chicago.

In this study, we describe the temporal association of OHCA survival outcomes with systems-wide evidence-based interventions guided by a cardiac arrest registry in Chicago.

Methods

Study design

This is a retrospective analysis of prospectively collected data of non-traumatic cardiac arrests in adults (ages 18 years and older) occurring outside of nursing homes and healthcare facilities and who received treatment by CFD EMS from September 1st 2013 through December 31st 2016. The study was approved by the Office for the Protection of Research Subjects of the University of Illinois at Chicago.

Setting and population

Chicago, Illinois extends 228.4 square miles westward on a plain along the southwest shore of Lake Michigan.[29] CFD is the single EMS provider agency for more than 1000 medical emergency calls per day received by the Chicago's 911 dispatch center. CFD's EMS system provides service to ˜2.9 million people who live and/or commute to Chicago (2,722,389 residents plus 177,457 commuters).[30,31] CFD has 33 receiving hospitals, 24 of which are ST elevation myocardial infarction (STEMI) Receiving Centers with 24/7 interventional cardiology and targeted temperature management (TTM) capabilities. CFD's EMS treats ˜2500 victims of OHCA every year.

Study outcomes

Our primary outcome of interest was survival to hospital discharge. As secondary outcomes, we analyzed temporal trends in bystander CPR rates, ROSC prior to hospital arrival, survival to hospital admission, and survival with good neurologic outcome as defined by cerebral performance category score of 1 or 2 (CPC 1–2).[32,33] Bystander CPR was defined as CPR initiated by a person who was present and intervened but was not part of the organized EMS response.[34] We conducted separate analysis for Utstein survival with and without bystander CPR. Utstein survival is defined as the rate of survival among persons whose arrests were witnessed by a bystander and who had an initial rhythm of ventricular fibrillation or pulseless ventricular tachycardia (shockable rhythms) as documented by first responding EMS provider. Utstein survival provides a standardized benchmark for determining the effectiveness of the cardiac arrest system of care.[34] Utstein bystander survival is defined as survival among Utstein patients who also received bystander CPR and/or use of an automated external defibrillator (AED).

Data source

Data for all consecutive cases occurring in Chicago was obtained from CARES, a multicenter registry developed by the Centers for Disease Control and Prevention and Emory University. The CARES registry collects data on all victims of non-traumatic OHCA in whom resuscitation is attempted by EMS providers.[24] Data were collected from three sources: 911 dispatch centers, EMS providers, and receiving hospitals. Dispatch data were automatically downloaded into the prehospital electronic patient care report (E-PCR). Prehospital data was collected by treating EMS providers and entered into custom fields in their E-PCR. Data from the E-PCR were automatically uploaded to the CARES registry. Hospital treatment and outcomes data were entered into CARES by trained hospital personnel at all 33 EMS receiving facilities. Prehospital and hospital data were then merged within the registry to create a complete record on each OHCA. When missing or incomplete documentation, individual EMS providers or hospitals were contacted by phone and missing data were entered by a regional system data coordinator.

Statistical analysis

Descriptive statistics are presented as overall and by calendar year using percentages for categorical variables and means with standard deviations for continuous variables. All outcomes were coded as binary variables where 1 represented event and 0–no event. A generalized estimating equation (GEE) with logit link was used to estimate the association between binary outcomes and covariates. GEE model produces estimates at the population level with robust standard errors that correctly controls for subjects clustered in census tract. The main independent variable for analysis of temporal trends was calendar year.

Two sets of models were estimated. First, we estimated unadjusted linear trend in outcomes by GEE model. Second, full GEE model estimated adjusted temporal trend controlling for the following covariates: age, sex, initial cardiac arrest rhythm (ventricular fibrillation, pulseless ventricular tachycardia, asystole, pulseless electric activity), location of arrest (private residence versus public areas), whether the arrest was witnessed, whether bystander CPR was provided, and presumed cardiac etiology. $P < 0.05$ was considered statistically significant. We checked if the assumption of linear trend was reasonable by estimating model with set of indicator variables for each calendar year in reference to the first year, 2013. The model allowed for flexible modeling of time trends in outcome, such as increase followed by flat trend or decrease in trend. The linear trend assumption was reasonable for all outcomes based on Quasi Information Criterion.[35] Finally, to discern whether the temporal trends in survival are mainly driven by pre-hospital changes, we constructed similar logistic regression models to examine survival trends to hospital admission compared to survival to discharge over time.

Additional analysis was performed to test for interactions of location and bystander CPR. A two-sided $P < .05$ was considered statistically significant. Finally, we conducted additional analysis which limited OHCA patients to those with presumed cardiac etiology to determine whether the survival trends differ in the subgroup as compared to the overall. All analyses were performed using SAS software (version 9.4; SAS Institute Inc.) and Stata (version 14.2; StataCorp LLC).

Results

CFD EMS treated 7765 persons with non-traumatic cardiac arrests from September 1st 2013 through December 31st 2016. For this analysis we included 6103 cases after excluding patients less than 18 years of age (N = 224), where age was missing (N = 5), survival outcomes not recorded (N = 23), cardiac arrest occurring at a healthcare facility and/or nursing home (N = 1408), and unknown location (N = 5) (Supplementary file Figure S1: Consort diagram).

Demographics and cardiac arrest variables

Patient characteristics are summarized in Table 1. No significant changes were observed over the study period with respect to demographics and resuscitation characteristics. The mean age of our study population was 62.8 years (SD 16.9) and 41% were female. Approximately 4 out of 5 OHCA events occurred in private locations, 1 out of 5 patientshad shockable rhythms, and 46% of OHCA were witnessed.

Temporal trends in survival by rhythm

Survival rates to hospital discharge increased from 7.3% in 2013 to 9.9% in 2016 (Fig. 1). Survival rates for OHCA attributable to shockable rhythms increased from 17.8% to 27.1%, whereas survival among OHCA presenting with non-shockable rhythms increased more modestly from 4.9% to 5.4%.

Bystander response

Bystander CPR rates (see Table 1) increased from 13.1% in 2013 to 23.8% in 2016 ($p < 0.0001$). Few had bystander applied AED from 2% (CI 0.8%–3.1%) in 2013 to 2.2 (1.6–2.9) in 2016 (p = 0.9195). Bystander CPR increased most significantly in private locations from 9.6% in 2013 to 17.4% in 2016 ($p < 0.0001$, see Supplementary file Table S2).

OHCA survival outcomes

Unadjusted rates (Table 2) of field ROSC increased significantly from 28.6% (CI 24.8%–32.3%) to 36.9% (CI 34.8%–39.1%) (p = 0.0001) and survival to hospital admission went from 22.5% (CI 19.1%–26.0%) to 29.4% (CI 27.4%–31.4%) from 2013 to 2016 (p = 0.0004). While the increase in unadjusted rates of survival to hospital discharge was not statistically significant from 7.3% (CI 5.1%–9.4%) to 9.9% (CI 8.6%–11.2%), (p = 0.09), there was a significant increase in patients with CPC 1–2, from 4.3% (CI 2.6%–5.9%) in 2013 to 6.4% (CI 5.3%–7.5%) in 2016 (p = 0.0198). Similar trends were observed in the subgroup of patients with presumed cardiac etiology (see Supplementary file Table S3).

Utstein survival (Table 2) significantly increased over the study period from 16.3% (CI 5.2%–27.3%) to 35.4% (CI 28.0%–42.9%), p = 0.0043. CPC 1–2 also increased among this subset from 11.6% (CI 2.1%–21.1%) to 29.1% (CI 22.0%–36.2%), p = 0.0028. Survival rates were higher among Utstein cases who received bystander CPR, increasing from 25.0% (CI 7.7%–42.3%) to 44.6% (CI 34.4%–54.7%), p = 0.0489. CPC 1–2 in Utstein cases with bystander CPR also increased from 20.8% (CI 4.6%–37.1%) to 40.2% (CI 30.2%–50.2%), p = 0.0451.

Association of prehospital factors and survival outcomes (Table 3)

Probability of OHCA survival decreased with every 10-year interval increase in patient age. Persons with OHCA had a better chance of surviving to discharge if their arrest was in a public location (OR 1.63, CI 1.33–2.00), was witnessed (OR 2.33, CI 1.91–2.85), and with bystander CPR (OR 1.46, CI 1.18–1.82). Public location (OR 2.02, CI 1.59–2.58), witnessed arrest (OR 2.34, CI 1.79–3.07), and bystander CPR (OR 1.84, CI 1.43–2.37) were also associated with improved CPC 1–2. Persons with OHCA had a better chance of receiving bystander CPR with each passing calendar year (OR 1.28, CI 1.19–1.37). There was no significant difference in bystander CPR rates by gender (OR for female gender 0.97, CI 0.85–1.11). Women were more likely to achieve ROSC (OR 1.47, CI 1.31–1.66), survive to hospital admission (OR 1.50, CI 1.31–1.70), and to hospital

Table 1 – Patient characteristics overall and by calendar year 2013–2016.

	Overall	2013[a]	2014	2015	2016	p Value[b]
Number of patients, no.	6103	564	1749	1838	1952	
Mean age in years (SD)	62.8 (16.9)	63.4 (16.1)	62.9 (16.7)	62.9 (16.9)	62.2 (17.3)	0.14
Age category, N (%)						
18–54	1851 (30.3)	156 (27.7)	529 (30.3)	549 (29.9)	617 (31.6)	0.14
55–64	1433 (23.5)	136 (24.1)	397 (22.7)	452 (24.6)	448 (23.0)	
65–74	1219 (20.0)	118 (20.9)	367 (21.0)	354 (19.3)	380 (19.5)	
≥75	1600 (26.2)	154 (27.3)	456 (26.1)	483 (26.3)	507 (26.0)	
Female gender, N (%)	2502 (41)	248 (44)	699 (40)	763 (41.5)	792 (40.6)	0.46
Race/ethnicity, N (%)[c]						
White	1797 (29.5)	161 (28.6)	529 (30.3)	539 (29.3)	568 (29.1)	0.65
Black	3410 (55.9)	330 (58.5)	965 (55.2)	1028 (55.9)	1087 (55.7)	
Hispanic	661 (10.8)	45 (8.0)	182 (10.4)	188 (10.2)	246 (12.6) 51 (2.6)	
Other	234 (3.8)	28 (5.0)	72 (4.1)	83 (4.5)		
First documented rhythm, N (%)						
Shockable rhythm	1117 (18.3)	89 (15.8)	331 (18.9)	357 (19.4)	340 (17.4)	0.89[d]
Asystole	2972 (48.7)	280 (49.7)	799 (45.7)	890 (48.4)	1003 (51.4)	
PEA	1660 (27.2)	149 (26.4)	454 (26.0)	512 (27.9)	545 (27.9)	
Location of arrest, N (%)						
Public	1205 (19.7)	95 (16.8)	354 (20.2)	352 (19.2)	404 (20.7)	0.28
Private	4898 (80.3)	469 (83.2)	1395 (79.8)	1486 (80.9)	1548 (79.3)	
Witnessed arrest, N (%)	2842 (46.6)	252 (44.7)	811 (46.4)	893 (48.6)	886 (45.4)	0.86
Presumed cardiac etiology, N (%)	5291 (86.7)	507 (89.9)	1532 (87.6)	1595 (86.8)	1657 (84.9)	0.0015
Bystander CPR, N (%)[e]	1028 (20.4)	61 (13.1)	224 (15.1)	365 (24.4)	378 (23.8)	<0.0001
Bystander AED, N (%)[e]	127 (2.1)	2.0 (0.8–3.1)	2.1 (1.4–2.8)	2.0 (1.3–2.6)	2.2 (1.6–2.9)	0.9195

[f] Missing 2 cases in 2014.
[a] Only 4 months of reporting period in 2013 (September–December).
[b] p Value for time trend estimated using unadjusted GEE models.
[c] Missing 1 case in 2014.
[d] p Value of shockable rhythm.
[e] Bystander CPR among the subset of cases unwitnessed or witnessed prior to EMS arrival (N = 5032).

discharge (OR 1.36, CI 1.11–1.67) compared to men. However, there was no significant advantage for women in CPC 1–2 (OR 1.16, CI 0.90–1.50). Similar trends were observed in the subgroup with presumed cardiac etiology (see Supplementary file Table S4).

In order to discern whether the upward trend was attributable to the prehospital or in-hospital phase of resuscitation care, we examined temporal trends in survival to hospital admission compared to survival to hospital discharge among patients who survived to hospital

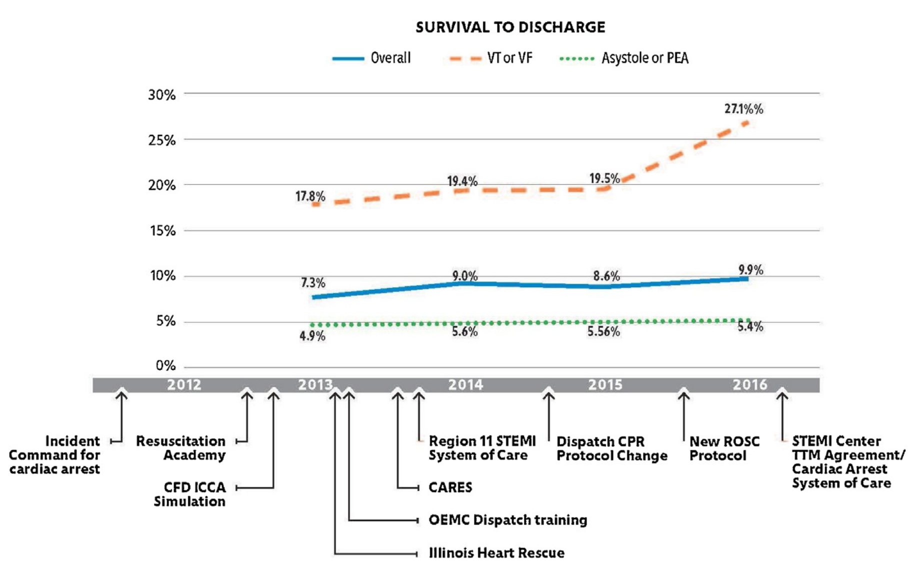

Fig. 1 – Observed rates for survival to discharge for the overall cohort (N = 6103) and by rhythm. Shockable (ventricular fibrillation [VF] and pulseless ventricular tachycardia [VT]) and non-shockable (asystole and pulseless electric activity [PEA]) cardiac arrest rhythms. Increased survival rates were observed for all rhythms in close temporal association with the implementation of multiple pre-hospital interventions (detailed in Supplementary file, Table S1: Timeline).

Table 2 – Trends of survival outcomes over time as percent with 95% confidence interval.[a]

	2013[b] N = 564	2014 N = 1749	2015 N = 1838	2016 N = 1952	p Value[c]
ROSC	28.6 (24.8–32.3)	32.0 (29.8–34.2)	32.9 (30.1–35.1)	36.9 (34.8–39.1)	0.0001
Hospital admission	22.5 (19.1–26.0)	25.3 (23.3–27.4)	26.8 (24.7–28.8)	29.4 (27.4–31.4)	0.0004
Hospital survival	7.3 (5.1–9.4)	9.0 (7.7–10.4)	8.6 (7.3–9.9)	9.9 (8.6–11.2)	0.09
Good and moderate CPC	4.3 (2.6–5.9)	5.2 (4.1–6.2)	5.3 (4.3–6.3)	6.4 (5.3–7.5)	0.0198
Aystole/PEA survival	3.7 (2.2–5.3)	4.0 (3.1–4.9)	4.2 (3.3–5.1)	4.3 (3.4–5.2)	0.50
Aystole/PEA survival with good/moderate CPC	1.6 (0.6–2.6)	1.7 (1.1–2.3)	1.7 (1.1–2.3)	1.7 (1.2–2.3)	0.76
Utstein survival	16.3 (5.2–27.3)	24.1 (17.8–30.1)	25.0 (18.7–31.3)	35.4 (28.0–42.9)	0.0043
Utstein bystander CPR survival	25.0 (7.7–42.3)	33.8 (23.2–44.3)	32.6 (23.0–42.2)	44.6 (34.4–54.7)	0.0489
Utstein good and moderate CPC	11.6 (2.1–21.1)	18.4 (12.6–24.2)	20.1 (14.3–25.9)	29.1 (22.0–36.2)	0.0028
Utstein bystander CPR good and moderate CPC	20.8 (4.6–37.1)	28.6 (18.5–38.7)	27.2 (18.1–36.3)	40.2 (30.2–50.2)	0.0451

ROSC: return of spontaneous circulation; CPC: cerebral performance category; PEA: pulseless electrical activity.
[a] Note different sample size in each year (refer CONSORT diagram).
[b] Only 4 months of reporting period in 2013 (from September to December).
[c] p Value for time trend from unadjusted GEE model.

admission (see Supplementary file, Table S5). Unadjusted rates of prehospital survival improved from 22.5% in 2013 to 29.4% in 2016. After multivariable adjustment, prehospital survival improved by 38% from 2013 to 2016 (p for trend 0.0111). There was no significant increase in temporal trends for improved in-hospital survival for patients who survived to hospital admission (p for trend of 0.4453).

Discussion

OHCA is a complex and lethal condition with numerous factors influencing survival. The Chicago experience suggests that systematic implementation of evidence-based, quality improvement initiatives coupled with focused community engagement and surveillance can improve survival outcomes in systems with historically low OHCA survival rates. There was >50% increase bystander CPR rates in close temporal association with bystander CPR training in priority neighborhoods and increased availability of T-CPR. Similarly, a 29% increase in ROSC and a 23% increase in survival to hospital admission support the positive effect of improvements made by CFD EMS. The most notable improvements were observed in witnessed, shockable rhythms where survival to hospital discharge increased by 150% and CPC 1–2 rates almost doubled. Our findings are important because they demonstrate an opportunity to advance implementation of evidence-based science to improve public health in communities long-challenged to achieve quality improvement.

Multifaceted community-wide approaches aimed at strengthening each link in the "chain of survival" have been successful at increasing OHCA survival in several model communities. Publications from North Carolina,[36] Arizona,[37] and Sweden[38] highlight how improved bystander CPR rates are associated with improved OHCA survival. In Denmark, mandatory resuscitation education, new resuscitation guidelines, introduction of health care professionals at dispatch centers, increased public AEDs, use of TTM, and other interventions led to large increases in the bystander CPR rates, survival to hospital discharge, and 30-day survival.[39] In Minnesota's "Take Heart America" survival doubled as a result of a similar community-wide approach to OHCA care.[40]

Our work stands out from previous studies as it represents significant improvement in OHCA survival outcomes reported by a city with historically poor outcomes and one of the most densely populated cities in the US. Large cities are often cited as examples of low

Table 3 – Summary of predictors of outcomes in fully adjusted models.

Covariate	Bystander CPR		ROSC		Hospital admission		Hospital survival		CPC1_2	
	Odds ratio	P value	Odds ratio	P value	Odds ratio	P value	Odds ratio	P value	Odds ratio	P value
Age (10-year increasing)	0.98 (0.94–1.03)	0.47	1.02 (0.99–1.05)	0.2798	0.96 (0.93–0.99)	0.0216	0.90 (0.85–0.96)	0.0005	0.89 (0.83–0.96)	0.0024
Female gender	0.97 (0.85–1.11)	0.67	1.47 (1.31–1.66)	<.0001	1.50 (1.31–1.70)	<.0001	1.36 (1.11–1.67)	0.0026	1.16 (0.90–1.50)	0.26
Public location (ref: private)	1.60 (1.34–1.91)	<0.0001	1.22 (1.07–1.40)	0.0036	1.49 (1.30–1.71)	<.0001	1.63 (1.33–2.00)	<.0001	2.02 (1.59–2.58)	<.0001
Witnessed arrest	0.92 (0.80–1.07)	0.28	1.99 (1.79–2.21)	<.0001	2.18 (1.93–2.46)	<.0001	2.33 (1.91–2.85)	<.0001	2.34 (1.79–3.07)	<.0001
Bystander CPR			1.02 (0.87–1.19)	0.8210	1.08 (0.93–1.24)	0.3233	1.46 (1.18–1.82)	0.0007	1.84 (1.43–2.37)	<.0001
Shockable rhythm	1.90 (1.62–2.22)	<0.0001	2.06 (1.78–2.39)	<.0001	2.18 (1.86–2.55)	<.0001	3.97 (3.28–4.81)	<.0001	6.93 (5.40–8.90)	<.0001
Presumed cardiology etiology	1.71 (1.35–2.17)	<0.0001	0.75 (0.63–0.88)	0.0007	0.52 (0.43–0.62)	<.0001	0.65 (0.50–0.86)	0.0023	0.53 (0.37–0.77)	0.0007
Term (calendar year – 1-year increasing)	1.28 (1.19–1.37)	<0.0001	1.12 (1.06–1.19)	0.0002	1.11 (1.04–1.18)	0.0013	1.07 (0.98–1.18)	0.1408	1.15 (1.02–1.30)	0.0277

performing resuscitation systems of care.[13,41] Poor survival rates observed in large cities have been attributed to lower bystander CPR rates compared to mid-size urban and suburban areas, heavy traffic congestion, and inconsistencies in data collection and management.[12,41,42] Since half of the US population resides in large metropolitan areas, this public health problem is of considerable magnitude.[37] Despite these challenges, Chicago witnessed improved overall OHCA survival rates between 2013 and 2016, with a most significant increase in prehospital survival outcomes. The CFD's new approach to education and training on OHCA and systematic surveillance using CARES coupled with the statewide quality improvement program known as Illinois Heart Rescue led to encouraging survival trends in the challenging environment of the third largest city in the US.

More recent work supports our assertion that challenges to successful OHCA resuscitation in urban centers can be overcome. Detroit, often cited with Chicago as a city with dismal OHCA survival rates,[13] recently reported improved overall survival from 3.7% to 5.4% after directing rigorous surveillance of cardiac arrest and new dispatch and medical first responder training protocols.[43] Our report stands out from the Detroit experience in two important ways. First, Chicago saw a more significant increase in bystander CPR rates (50% increase over the study period compared to <10% increase in the Detroit report). ILHR's focused CPR training efforts in priority neighborhoods coupled with implementation of dispatch T-CPR protocols may explain this difference. Second, neurological outcomes were not reported in the Detroit publication. According to the Core Outcome Set for Cardiac Arrest (COSCA), developed by patients and clinicians, survival with a CPC 1–2 is of higher priority than survival alone.[44] Chicago not only experienced a significant improvement in overall survival from 2% (estimated in 2011) to 9.9% in 2016, but also a significant increase in survival with CPC 1–2 from 4.3%–6.4%. Our findings provide impetus to other emergency systems that have long believed that improving resuscitation is not feasible to re-engage in attempts to improve OHCA outcomes.

Limitations

Our study is limited by its retrospective observational design. Research in OHCA requires careful planning as decisions need to be made rapidly, making randomization and trial design more difficult. An alternative to a double-blinded randomized control trial is to use a step-wedge randomization design where new interventions are delivered using a staged approach, starting with a random small number of units, and eventually including all units in the implementation. However, randomization is not always feasible nor acceptable. One way to overcome the inability to randomize is to compare with historical data. Chicago did not have an OHCA surveillance system in place prior to starting to contribute data to CARES in 2013, therefore no comparable historical data source is available. Another limitation is lack of access to detailed clinical information on other factors that influence survival (such as comorbidity, delays in calling 911, and hospital care variables such as rate and timing of TTM, when CPC score was measured, and rate and timing of cath lab interventions). CARES is a public health surveillance system designed to be minimally burdensome and only essential data elements are included. EMS time intervals including EMS response times and time to first defibrillation were not assessed due to limitations of EMS provider computer aided dispatch software. While EMS providers were trained on HP-CPR, we have no reliable data on CPR quality metrics. Another limitation is the inability to determine direct causal relationships because of the co-occurrence of multiple interventions. Nevertheless, this is one of the largest EMS systems in the US to report a significant improvement in OHCA care, survival, and neurological outcomes.

Conclusions

Chicago observed significant improvements in OHCA survival outcomes in close temporal association with community and prehospital initiatives aimed at strengthening the chain of survival. Improved prehospital outcomes were associated with improved overall survival and survival with good neurologic outcome. The city of Chicago and, in particular, the Chicago Fire Department's EMS have made great strides towards demonstrating that systematic challenges to OHCA care in large, densely populated urban centers can be overcome.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resuscitation.2019.04.019.

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