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Changes in out-of-hospital cardiac arrest survival rates among patients with and without bystander intervention in the Cardiac Arrest Registry to Enhance Survival (CARES) program from 2010 to 2012

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Bachelor of Science
University of New Hampshire
2010

Faculty Thesis Advisor: Lyndsey Darrow, PhD

An abstract of
a thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
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in Epidemiology
2014

Abstract

Changes in out-of-hospital cardiac arrest survival rates among patients with and without bystander intervention in the Cardiac Arrest Registry to Enhance Survival (CARES) program from 2010 to 2012

By Katelyn Coutts

Background: Out-of-hospital cardiac arrest (OHCA) is a leading cause of death among adults in the U.S. While many factors influence the outcome for a patient experiencing OHCA (e.g., age, sex, and arrest location), bystander intervention is one that has potential for improvement, thus providing an opportunity to increase survival.

Objective: This analysis aimed to assess the changes in survival rates over time and to examine if the increase in survival was greater among the patients who received bystander intervention than among patients who did not receive bystander intervention.

Methods: Sites voluntarily participating in the Cardiac Arrest Registry to Enhance Survival (CARES) program for the entirety of January 1, 2010 to December 31, 2012 that reported at least five cardiac arrest events during that time were included in the study population (n=61 sites). All patients who experienced a witnessed OHCA event of confirmed cardiac etiology that occurred prior to EMS arrival and were found in an initial shockable cardiac rhythm were considered for inclusion (n=4,751). Multivariate logistic regression was performed to identify whether changes in the survival rate between 2010 and 2012 differed between those who received bystander intervention and those who did not.

Results: After controlling for patient age, sex, race/ethnicity, and event location (public or private), a 26% increase in survival when comparing 2010 to 2012 was observed among the patients who received bystander intervention (OR 1.26; 95% CI 1.01, 1.57). This trend in survival rate was not found among patients who did not receive bystander intervention (OR 0.89; 95% CI 0.71, 1.12).

Conclusion: These results suggest an improvement in bystander intervention among the participating agencies. Future survey and investigation of the 61 participating agencies will attempt to identify interventions and improvements that occurred during this timeframe that may have contributed to this change. This provides an opportunity to influence OHCA care and increase survival rates nationwide.

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Chapter I: Background

Cardiac Arrest

Sudden cardiac arrest is defined as the sudden loss of heart function, breathing, and consciousness, resulting from an electrical disturbance in the heart caused by an arrhythmia(1). The most common arrhythmia that causes cardiac arrest is ventricular fibrillation, or erratic electrical impulses that prevent the heart from contracting as a whole. Additional arrhythmias resulting in cardiac arrest include pulseless ventricular tachycardia (a rhythm that becomes too rapid to sustain cardiac output), pulseless electrical activity (electrical activity without a palpable pulse), and asystole (the lack of any electrical activity)(2). While the root cause of cardiac arrest can be a number of factors including trauma, drowning, drug overdose, respiratory arrest, and other noncardiac etiologies, 70%-85% of cases have a known cardiac cause (3). Although cardiac arrest can occur in anyone, individuals with preexisting cardiac conditions are at a greater risk, as well as individuals with family history, high blood pressure, diabetes, and high blood cholesterol. In addition, men are two to three times more likely to experience cardiac arrest than women(1).

Out-of-hospital cardiac arrest (OHCA), defined as a sudden cardiac arrest event that takes place outside of a medical setting, occurs in approximately 300,000 people per year in the United States (3). The overall survival to hospital discharge rate in patients who experience OHCA is 7.6% (95% CI. 6.7 to 8.4), based on a pooled, meta-analysis performed by Sasson et al. consisting of 79 studies and 142,740 patients (4). This rate, however, varies depending on a number of factors that can influence patient outcome. For example, the range of survival was higher among patients who experienced a bystander witnessed arrest (6.4% to 13.5% depending on baseline survival rates), received bystander cardiopulmonary resuscitation (CPR) (3.9% to 16.1%), or were found in a ventricular fibrillation or ventricular tachycardia cardiac rhythm (14.8% to 23.0%)(4). Although the rates vary by these and other factors, the overall OHCA survival rate has remained virtually unchanged for approximately 30 years, despite advancement in the medical field and substantial research efforts.

Chain of Survival

As shown, OHCA outcome is influenced by a network of factors relating to patient demographics, arrest etiology, bystander intervention, CPR and automated external defibrillator (AED) use, and many factors within the emergency medical system including 911 dispatch, emergency medical technician (EMT) treatment, and advanced care in the hospital setting. A concept known as the “chain of survival” ties many of these aspects together in an attempt to identify essential factors following OHCA that optimize survival. This concept was originally proposed by the American Heart Association (AHA) in 1991 (5), and has since be used as a model for both the medical response and research fields. The chain of survival consists of five key links: early access, early CPR, rapid defibrillation, effective advanced care, and integrated post-cardiac arrest care – each of which contains essential steps to optimize the patient’s outcome (6). The first link in the chain of survival is early access, which consists of immediate recognition of cardiac arrest and activation of the emergency response system.

The second link in the chain of survival is early CPR, ideally initiated by bystanders as soon as possible. In a multivariable logistic regression performed in the Ontario Prehospital Advanced Life Support (OPALS) study, researchers determined that bystander-witness status, bystander CPR, CPR by fire or police, and ambulance response time were all independently associated with survival (5). Further, they concluded that bystander CPR was the potentially modifiable factor with the strongest association to survival (OR 2.98 95% CI. 2.07, 4.29)(5). Based on the previously mentioned meta-analysis performed by Sasson et al., bystander witnessed arrests occurred 53% (95% CI. 45.0 to 59.9) of the time, but only 32% (95% CI. 26.7 to 37.8) of patients received bystander CPR (4).

Rapid defibrillation, the third link in the chain of survival, is critical because the likelihood of successful defibrillation rapidly decreases in the minutes following cardiac arrest (5). This is due, in part, to the cardiac arrhythmia of the patient. "Shockable rhythms" are arrhythmias that can potentially be corrected by the shock delivered from an AED, and include ventricular fibrillation (VF) and pulseless ventricular tachycardia (pVT). As time passes when these rhythms are initially present in a patient, cardiac stores of oxygen and metabolic substrates are depleted, which reduces the effectiveness of the AED delivered shock (5). In data prospectively collected from 2005 to 2010 by the Cardiac Arrest Registry to Enhance Survival (CARES) program, researchers found that out of 31,689 OHCA events of cardiac etiology, 36.7% were witnessed by a bystander, however, bystanders only utilized an AED in 3.7% of the cases (3).

The fourth link in the chain of survival is effective advanced care, including advanced life support (ALS) interventions from paramedics in the pre-hospital setting. These interventions include advanced airways, intravenous medications, and 12-lead electrocardiograms (ECG) that providers can use to gain a better understanding of the heart's electrical activity (5). This can often be transmitted to the receiving hospital, allowing emergency room doctors to initiate their response prior to the arrival of the patient.

The last link, integrated post-cardiac arrest care, was added to the chain of survival with the release of the 2010 AHA Guidelines (6). This link focuses on a multidisciplinary approach to managing patient care after the return of spontaneous circulation in an effort to achieve normal or near-normal functional status upon recovery. Objectives identified by the AHA include optimizing cardiopulmonary function, access to an appropriate critical-care unit, and therapeutic hypothermia (6). The latter is a technique where the induction of mild hypothermia in comatose survivors of OHCA is used to improve neurological functionality upon recovery. A meta-analysis of randomized trials reported improved survival and neurological outcome in patients who received therapeutic cooling compared to those who remained at body temperature (5).

Survival Rates

Although there are numerous contributing factors that can affect the patient outcome of OHCA, there are sets of factors that combine to result in a survival rate much greater than the reported overall rate of 7.6%. For example, in a separate analysis utilizing the CARES data, researchers found that patients with an initial shockable rhythm (VF/pVT) had a significantly higher survival rate than patients with a converted shockable (originally non-shockable and converted to shockable during rescue efforts) or a non-shockable rhythm (26.9% vs. 4.7% and 4.1%, $p<0.001$) (2). Abrams, et al. used the same CARES data to conclude the survival rate to hospital discharge for OHCA of presumed cardiac etiology was 32% for bystander-witnessed VF/pVT cases, combining event characteristics that result in a survival rate substantially higher than the 7.6% overall rate (7).

Utilizing the CARES dataset, the CARES team performed a univariate analysis comparing the survival rates between 2010 and 2012 among bystander-witnessed OHCA events where the patient was found in an initial shockable rhythm (VF/pVT). This comparison showed no statistically significant increase in survival from 2010 to 2012 (31.6% vs. 33.5%, p=0.219); however, among the group where bystanders initiated CPR and/or applied an AED, there was a statistically significant increase in survival (34.7% vs. 40.6%, p=0.011). Based on the previously mentioned analyses and the comparison of survival rates between OHCA events with and without bystander intervention, we can conclude that individuals with the greatest chance of survival to hospital discharge following an OHCA event are those that are witnessed, found in a shockable rhythm, and received bystander intervention. Among these components, bystander intervention is the one aspect that has the greatest potential for improvement. As demonstrated in the univariate analysis, only the subgroup with bystander intervention had an increase in survival, suggesting that bystander CPR and AED use improved from 2010 to 2012 among the select communities used in the analysis. This, however, was an uncontrolled analysis, and thus, did not adjust for the numerous factors that can influence the outcome of OHCA. The purpose of this current study is to determine if this association remains after adjusting for appropriate confounding factors. If the adjusted analysis results in a statistically significant increase in the survival rate among the OHCA cases where bystander CPR was initiated or an AED was applied, future research can focus on determining what participating EMS agencies and communities changed between 2010 to

2012 that resulted in the improved success of bystander intervention. This information can then be used to help EMS agencies and communities nationwide improve the quality of bystander CPR and AED use.

OHCA Research

An 18-year prospective cohort study in Sweden (n=7,187) using the Swedish Cardiac Arrest Register (SCAR) found the survival to one-month in OHCA patients who experienced a bystander-witnessed arrest of cardiac etiology and were found in a shockable rhythm almost doubled from 1990 to 2009 (8). Researchers from this study concluded that this marked increase in survival was highly associated with an increase in bystander CPR, which increased from 46% to 73% during the study time (8). While this study provides a thorough analysis of the increase in OHCA survival over time and the essential role bystander CPR plays, the analysis spans such a wide timeframe, that there are many other contributing factors to the increase in survival. This includes numerous advances in the medical field, protocol changes, and years of CPR promotion and training among the community. Additionally, researchers did not stratify the analysis to determine if there was a difference in the change in survival rate depending on the presence of bystander CPR, and thus, were only able to assess the rate, not the quality, of CPR.

In an additional study using the SCAR database in Sweden, researchers found the overall survival rate among individuals who received bystander CPR did not increase significantly ($p<0.05$) from 1992 to 2005 (8.0% to 8.8%) (9). Similarly, neither did the survival rate among individuals who did not receive bystander CPR (2.3% in 1992 and 2.7% in 2005) (9).

A Norwegian study prospectively collected data on all OHCA events of cardiac etiology in adult patients where resuscitation was attempted and compared survival to hospital discharge in two time periods: 2001-2005 vs. 2006-2008 (10). In 2005, Norwegian EMS systems implemented the 2005 AHA guidelines, which modified the CPR algorithm to a chest compression to rescue breath ratio of 30:2 for the layperson rescuer, simplifying training and minimizing the time interruption of compressions (6). When comparing the two time periods (n=846), the number of patients receiving bystander CPR increased from 60% to 73% (p=0.0001) (10). Survival to hospital discharge also increased among witnessed OHCA events where patients were found in a shockable rhythm from 2001-2005 to 2006-2008 (37% vs. 52%, p=0.0105). Researchers concluded that the increase in bystander CPR was the primary factor for a statistically significant increase in survival over the study period (10).

While numerous studies have examined OHCA survival rates over time and have attempted to link changes in these rates to specific factors in the Chain of Survival, to our knowledge, there are none that have done so using U.S. data from EMS agencies and communities participating in passive surveillance. Furthermore, the results of this study will have immediate practical use. Having a motivated study population of healthcare professionals, researchers can take the results from our study and conduct surveys and interviews in an attempt to identify efforts the individual agencies have made that may have led to an improvement in bystander CPR, and thus survival rate. Additionally, our study is conducted in multiple states across the nation, increasing generalizability of the results to the United States. Lastly, our study period will range from 2010 to 2012, within which we will determine a survival trend analysis controlling for various factors that influence survival rate. With this short study period, we will be more likely to definitively pinpoint specific actions agencies have taken to improve OHCA care. Many of the previous studies conducted span a wide time frame, making it difficult to determine what is specifically attributed to the change in survival rate.

CARES

The Cardiac Arrest Registry to Enhance Survival was created in 2004 by the Centers for Disease Control and Prevention and Emory University Department of Emergency Medicine. CARES consists of over 400 voluntarily participating EMS agencies and over 900 hospitals in 28 states from across the U.S (11). Participating communities enter local data and have the capabilities to generate their own reports, which can be used to compare their EMS system performance to aggregate data at the local, state, or national level. This is a valuable resource that guides communities in identifying areas for improvement and practices that may lead to enhanced OHCA care. The CARES database is a HIPAA-compliant, web-based, prospective registry for OHCA cases that occur in the participating communities (11). Healthcare professionals record detailed information on each OHCA case, including patient demographics, arrest scene information, bystander intervention, EMS response times and care, receiving hospital treatment, and patient outcome. Because the CARES data is a composite of gathered information from three points in the response and treatment continuum (dispatch, EMS, and hospital data), the resulting database provides a thorough resource for arrest information.

Chapter II: Manuscript

Changes in out-of-hospital cardiac arrest survival rates among patients with and without bystander intervention in the Cardiac Arrest Registry to Enhance Survival (CARES) program from 2010 to 2012

By Katelyn Coutts

Abstract

Background: Out-of-hospital cardiac arrest (OHCA) is a leading cause of death among adults in the U.S. While many factors influence the outcome for a patient experiencing OHCA (e.g., age, sex, and arrest location), bystander intervention is one that has potential for improvement, thus providing an opportunity to increase survival.

Objective: This analysis aimed to assess the changes in survival rates over time and to examine if the increase in survival was greater among patients who received bystander intervention than among patients who did not receive bystander intervention.

Methods: Sites voluntarily participating in the Cardiac Arrest Registry to Enhance Survival (CARES) program for the entirety of January 1, 2010 to December 31, 2012 that reported at least five cardiac arrest events during that time were included in the study population (n=61 sites). All patients who experienced a witnessed OHCA event of confirmed cardiac etiology that occurred prior to EMS arrival and were found in an initial shockable cardiac rhythm were considered for inclusion (n=4,751). Multivariate logistic regression was performed to identify whether changes in the survival rate between 2010 and 2012 differed between those who received bystander intervention and those who did not.

Results: After controlling for patient age, sex, race/ethnicity, and event location (public or private), a 26% increase in survival when comparing 2010 to 2012 was observed among the patients who received bystander intervention (OR 1.26; 95% CI 1.01, 1.57). This trend in survival rate was not found among patients who did not receive bystander intervention (OR 0.89; 95% CI 0.71, 1.12).

Conclusion: These results suggest an improvement in bystander intervention among the participating agencies. Future survey and investigation of the 61 participating agencies will attempt to identify interventions and improvements that occurred during this timeframe that may have contributed to this change. This provides an opportunity to influence OHCA care and increase survival rates nationwide.

Introduction

Out-of-hospital cardiac arrest (OHCA) is a leading cause of death among adults in the U.S., occurring in approximately 300,000 people annually. The median reported rate of survival for cardiac arrest is 7.6%, a measure that has remained virtually unchanged for 30 years (3). The survival rate, however, is extremely variable depending on numerous factors including initial cardiac rhythm, whether it was a witnessed arrest, if bystander cardiopulmonary resuscitation (CPR) was performed, time before advanced care was received, patient demographics, and many other factors.

While numerous studies have examined cardiac arrest survival rates, very few have measured rates over time specifically investigating how changes in bystander intervention affect survival. These studies do not attempt to isolate bystander intervention as the cause for an increase in survival over time, but instead analyze the overall trend of survival. Two studies on this topic were completed using the Swedish Cardiac Arrest Register (SCAR), a national database that began collecting OHCA data in 1990. The first, an 18-year prospective study (n=7,187), identified the one-month OHCA survival rate among individuals who experienced a bystander-witnessed arrest of cardiac etiology and were found in a shockable rhythm (ventricular fibrillation or pulseless ventricular tachycardia) almost doubled from 12% in 1990 to 23% 2009 (8). Researchers concluded this change in survival was highly associated with the rate of bystander CPR, which increased from 46% to 73% over the span of the study (8).

The second study utilizing the SCAR OHCA data measured the overall survival rate from 1992 to 2005 among two cohorts: individuals who received bystander CPR and individuals who did not receive bystander CPR. Researchers concluded that neither cohort had a statistically significant increase in survival rate over the study period (8.0% to 8.8% in the CPR cohort and 2.3% to 2.7% in the non-CPR cohort) (9).

A Norwegian study prospectively collected data on all OHCA events of cardiac etiology in adult patients where resuscitation was attempted and compared survival to hospital discharge in two time periods: 2001-2005 vs. 2006-2008 (10). In 2005, Norwegian EMS systems implemented the 2005 AHA guidelines, which modified the CPR algorithm to a chest compression to rescue breath ratio of 30:2 for the layperson rescuer, simplifying training and minimizing the time interruption of compressions (6). When comparing the two time frames (n=846), the percentage of patients receiving bystander CPR increased from 60% to 73% (p=0.0001) (10). Survival to hospital discharge also increased among witnessed OHCA events where patients were found in a shockable rhythm from 2001-2005 to 2006-2008 (37% vs. 52%, p=0.0105). Researchers concluded that the increase in bystander CPR was the primary factor for a statistically significant increase in survival over the study period (10).

A univariate analysis using the Cardiac Arrest Registry to Enhance Survival (CARES) data identified a statistically significant increase in the survival rate from 2010 to 2012 among patients who experienced a witnessed OHCA, were found in a shockable rhythm, and received bystander intervention of CPR and/or the application of an automated external defibrillator (AED) (34.7% vs. 40.6%, p=0.011). The survival rate in patients with the same criteria who did not receive bystander CPR or AED application did not show a statistically significant increase between 2010 and 2012 (31.6% vs. 33.5%, p=0.219). The comparison of these two groups indicates an improvement of bystander CPR and AED use between 2010 and 2012, which in turn had a statistically significant effect on the survival rate.

Using the results of this preliminary univariate analysis as the starting point, we performed a multivariate logistic regression analysis to determine if the change in survival from 2010 to 2012 was significantly different among the bystander intervention group compared to the group without bystander intervention, while controlling for factors that may confound the association. The results of this study will aid researchers in identifying aspects that changed from 2010 to 2012 among the participating EMS agencies that may have had an impact in the survival increase, providing useful information about the care continuum that may have potential to improve OHCA outcomes nationwide.

Methods

Data Collection

The Cardiac Arrest Registry to Enhance Survival was created in 2004 by the Centers for Disease Control and Prevention and Emory University Department of Emergency Medicine. CARES, consisting of over 400 voluntarily participating emergency medical services (EMS) agencies and over 900 hospitals in 28 states from across the U.S., is a web-based registry that prospectively collects OHCA event data from EMS logs and extracted hospital information (11). Details pertaining to the registry and data collection have been previously described (12). The CARES dataset contains de-identified health information and has received exempt status from the Emory University Institutional Review Board (IRB).

All OHCA events occurring between January 1, 2010 and December 31, 2012 (n=38,3807) among participating sites (n=70) that were recorded in the CARES registry were eligible for inclusion. In all cases, resuscitation was attempted and the arrest was of confirmed cardiac etiology. Excluded observations were those that were unwitnessed arrests (20,174), occurred after the arrival of rescue personnel (4,103), found in an unshockable rhythm (8,841) or took place in a health care setting (416). In addition, nine agencies were excluded from the analysis because each consisted of less than five OHCA events over the three-year period (20 observations). Lastly, 81 observations were missing information on whether bystander intervention occurred, whether the individual survived to hospital discharge, or a covariate, and were thus excluded from the modeling process. This resulted in an analysis of 4,670 observations used in the logistic regression modeling process.

Statistical Analysis

Statistical analysis was performed using SAS statistical software version 9.3 (SAS Institute Inc., Cary, NC). Chi-square tests were used to identify differences in the distributions of the covariates between patients who received bystander intervention and patients who did not receive bystander intervention. Multivariate logistic regression was performed to assess the association of bystander intervention and cardiac arrest event year with patient survival to hospital discharge. Interaction was assessed using the Likelihood Ratio Test to examine if the effect of year on survival was different among the bystander intervention group when compared with the non-intervention group. To adjust for predictors of survival, logistic regression models included age, sex, race/ethnicity, and arrest location (public or private). Regression models also controlled for agency/CARES site (n=61). Confounding was assessed by evaluating whether the absence of a predictor resulted in more than a 10% change in the estimates for year among either the bystander intervention or non-intervention groups. Precision was also considered in the determination of the final model. The Hosmer-Lemeshow test was used to assess the fit of the final model.

Results

Table 1 displays the event characteristics by bystander intervention group. Although p-values from the bivariate analysis showed statistical significance, the distributions did not vary dramatically. OHCA events were evenly distributed over the three-year period, with the highest proportion of events with bystander intervention occurring in 2012, when 37.7% of arrests received either bystander CPR or the application of an AED. The distribution of patient age was similar among the bystander intervention and non-bystander intervention groups, with the majority of cases occurring in patients ranging from 50 to 79 years of age. Approximately 75% of the patients were male, with similar distributions across the bystander intervention groups. Overall, 41.7% of OHCA events occurred in public, however this proportion was statistically significantly higher in the bystander intervention group (49.2% vs. 34.4%, p<.0001). The majority of patients were classified as white, with a greater proportion of bystander intervention arrests occurring in white patients, 50.1%, compared to 42.0% of non-bystander intervention arrests occurring in white patients. Similarly, 14.9% of bystander intervention events and 23.3% of non-bystander intervention events occurred in black patients. Approximately 28% of arrests were classified as an Unknown race because select agencies did not collect patient information regarding race. This proportion was similar in both bystander intervention groups.

Table 2 displays the unadjusted survival rate categorized by year and bystander intervention status. There is a crude trend of increasing survival among the bystander intervention group over the three-year period; the opposite is seen in the non-bystander intervention group. The highest survival rate was 42.3% and was measured among the

2012 bystander intervention group. The lowest survival rate, 25.8%, was in the same year among the non-bystander intervention group. The percentage of patients receiving bystander intervention increased from 44.3% in 2010 to 52.2% in 2012. The crude survival increase appears only in the bystander intervention group, indicating a potential improvement in the quality of bystander intervention.

Table 3 further categorizes the survival rate by event characteristic, bystander intervention, and year. Without respect to the presence of bystander intervention, the youngest age group (0-17 years) had the highest survival rate of 55.8% and the oldest group (>80 years) had the lowest survival rate of 16.2%. Sex and race resulted in similar survival rates among males and females and race/ethnicity groups, respectively. There was a large difference among private and public arrest locations with survival rates of 26.4% and 42.8%, respectively. These trends among the characteristics of events were similar over the three-year period and across bystander intervention groups.

Interaction assessment was performed to test whether the effect of year on survival differed by bystander intervention group. The overall test for interaction, likelihood ratio test with two degrees of freedom, resulted in borderline significant interaction terms (p=0.0898) in the direction anticipated. When comparing 2012 to 2010 alone, the interaction with bystander intervention was statistically significant (p=0.0294). This suggests the effect of year on survival rate varies significantly between the two bystander intervention groups.

Our logistic regression modeling strategy resulted in a final model including the interaction between year and bystander intervention, controlling for age, sex, race/ethnicity, arrest location, and agency. All variables, except for race (p=.755), were found to be strong predictors of survival. There was little difference between crude and adjusted odds ratios (Table 4) indicating none of the covariates were strong confounders of the association of interest. Although race was not a predictor of survival or a confounder, it was included in the final model for consistency with previous studies that have controlled for race; its inclusion did not harm precision (7, 2). Assessment of collinearity resulted in no variance inflation concerns. The Hosmer-Lemeshow test resulted in a failure to reject the null, indicating adequate model fit. As shown in Table 5, when comparing 2012 to 2010, the odds of survival among the bystander intervention group increased by 26% (OR 1.26; 95% CI 1.01, 1.57) whereas the odds of survival among the group without bystander intervention decreased by 11% (OR 0.89; 95% CI 0.71, 1.12).

Discussion

The results of this analysis indicate an interactive effect between year of arrest and presence of bystander intervention; the effect of year on survival varies depending on bystander intervention status. A statistically significant increase in survival was apparent from 2010 to 2012 among the bystander intervention group, but was not present among the group without bystander intervention. This suggests the quality of bystander intervention improved over the three-year period among the 61 agencies included in the analysis, resulting in the increase in survival.

While many factors influence survival, this analysis suggests a change in the quality of bystander involvement and motivates identification of specific interventions performed at the agency level that have improved OHCA care. One factor that may have influenced this increase in survival was the release of the 2010 American Heart Association Cardiac Arrest Guidelines, which removed rescue breathing from the CPR algorithm for the untrained rescuer (6). Based on research, CPR with only compressions ("Hands-Only CPR") results in similar survival rates as the previously recommended rescue breaths and CPR combination. While this method is similar in effectiveness to traditional CPR, officials believed simplifying the rescue technique would encourage more bystanders to perform CPR(6).

Limitations

Cardiac arrest data utilized in this analysis originated from a voluntary registry from 911 reports and EMS data. Due to the voluntary nature of program enrollment, participating agencies may differ from other U.S. EMS agencies in their survival rates, population demographics, response and treatment methods, and other unknown characteristics. Analysis methods involved dichotomously grouping OHCA cases according to bystander intervention, including bystander CPR and/or application of an AED. This did not allow for consideration of the total time or effectiveness of the bystander CPR, forcing the assumption that all bystander intervention provided the same benefit to the patient. In addition, the use of an AED was based solely on the application of the AED to the patient, regardless of whether a shock was advised or delivered.

Logistic regression models controlled for age, sex, race/ethnicity, location of arrest, and agency. However, control of additional potential predictors of survival (e.g., ALS treatment and medications given, response time intervals, and hospital interventions) was not possible due to missing data or the information was not collected in the registry system. To confound our results, these factors would have had to improve only among the bystander intervention group, as we observed no improvement in survival among the non-intervention group. In addition, some agencies did not collect patient information regarding race, resulting in approximately 28% of the observations being classified as an Unknown race. This proportion, however, was similar between the bystander intervention and non-intervention groups. Lastly, outcome was based on survival to hospital discharge, and did not account for resulting neurological function in the survivors.

Conclusion

The findings of this analysis demonstrate that the quality of bystander intervention improved from 2010 to 2012, contributing to an increase in OHCA survival rate among 61 EMS agencies and communities from across the U.S. This information, taken in the context with future plans to survey these agencies and identify influential factors, provides an opportunity for advancement in out-of-hospital cardiac arrest care and potential for a greater chance of survival among patients who suffer from this sudden, life-threatening medical emergency.

Figure 1. Exclusion criteria and determination of analysis cohort

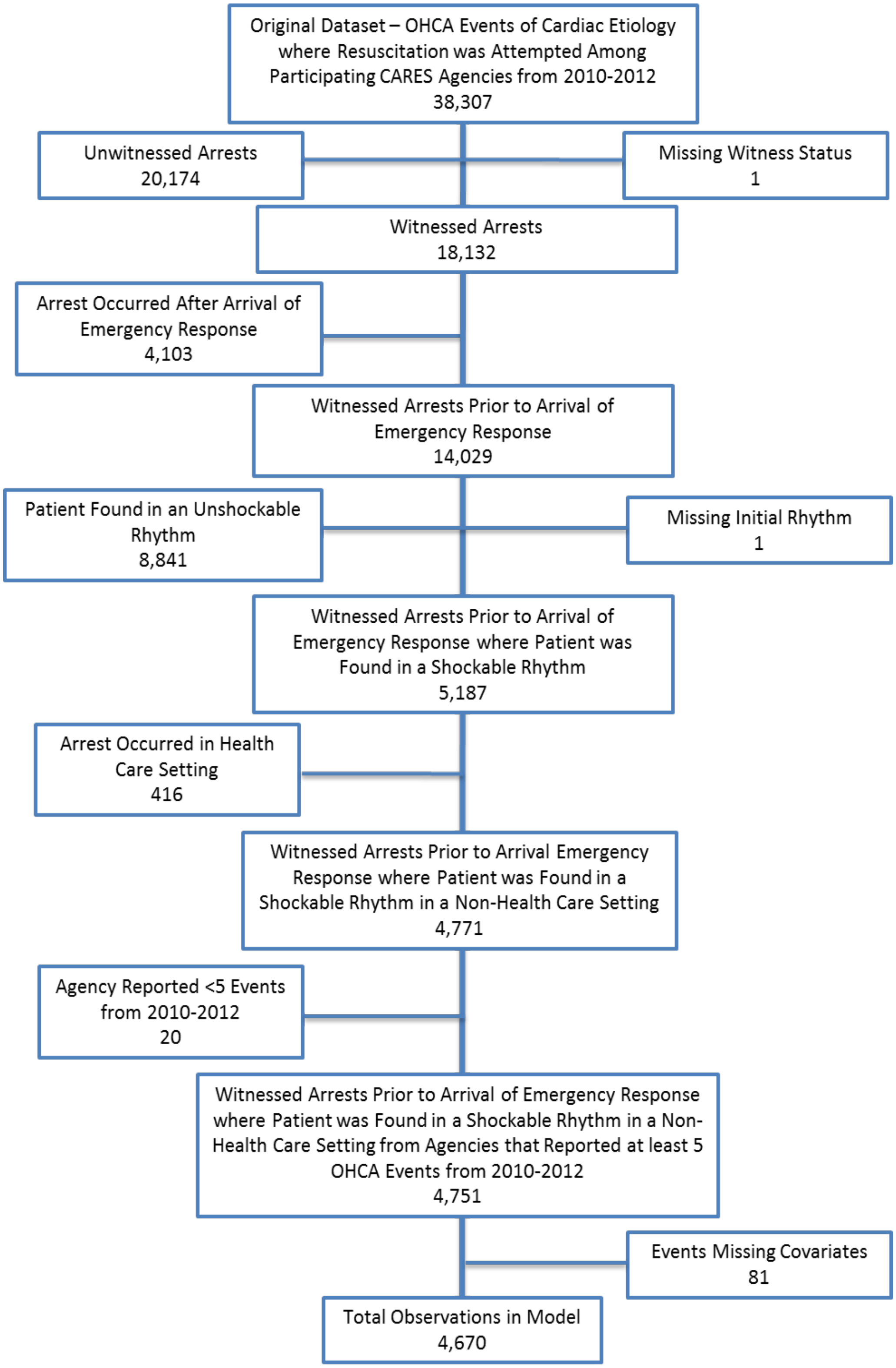

Table 1. Distribution of OHCA event characteristics by bystander intervention, 2010-2012 CARES data, n=4,751[a]

Characteristic	Overall		Bystander Intervention		No Bystander Intervention		p-Value
	N	%	N	%	N	%	
Year							
2010	1521	(32.0)	674	(28.6)	847	(35.4)	p=<.0001
2011	1529	(32.2)	795	(33.7)	734	(30.7)	
2012	1701	(35.8)	888	(37.7)	812	(33.9)	
Total	4751	(100.0)	2357	(100.0)	2393	(100.0)	
Age Group							
0-17	46	(1.0)	28	(1.2)	18	(0.8)	p=0.003
18-34	196	(4.1)	100	(4.3)	96	(4.0)	
35-49	805	(17.0)	372	(15.8)	432	(18.1)	
50-64	1837	(38.8)	956	(40.7)	881	(36.9)	
65-79	1295	(27.3)	648	(27.6)	647	(27.1)	
≥ 80	561	(11.8)	246	(10.5)	315	(13.2)	
Total	4740	(100.0)	2350	(100.0)	2389	(100.0)	
Sex							
Female	1149	(24.2)	519	(22.0)	630	(26.3)	p=0.0005
Male	3602	(75.8)	1838	(78.0)	1763	(73.7)	
Total	4751	(100.0)	2357	(100.0)	2393	(100.0)	
Location of Arrest							
Private	2769	(58.3)	1198	(50.8)	1570	(65.6)	p=<.0001
Public	1982	(41.7)	1159	(49.2)	823	(34.4)	
Total	4751	(100.0)	2357	(100.0)	2393	(100.0)	
Race/Ethnicity							
White	2185	(46.0)	1180	(50.1)	1004	(42.0)	p=<.0001
Black	910	(19.2)	352	(14.9)	558	(23.3)	
Hispanic/Latino	212	(4.5)	104	(4.4)	108	(4.5)	
Other	107	(2.3)	55	(2.3)	52	(2.2)	
Unknown	1337	(28.1)	666	(28.3)	671	(28.0)	
Total	4751	(100.0)	2357	(100.0)	2393	(100.0)	

[a] Bystander intervention information was missing for one OHCA event and age information was missing for 11 events

Table 2. Crude survival to hospital discharge percentages by year and bystander intervention groups, 2010-2012 CARES data, n=4,679[a]

	Survived to Hospital Discharge N (%)			
	Overall	2010	2011	2012
Overall (n = 4,679)	1574 (33.6)	485 (32.4)	513 (34.1)	576 (34.4)
Bystander Intervention (n = 2,319)	919 (39.6)	242 (36.6)	307 (39.3)	370 (42.3)
No Bystander Intervention (n = 2,359)	655 (27.8)	243 (29.1)	206 (28.5)	206 (25.8)

[a] Survival outcome was missing for 72 OHCA events and bystander intervention information was missing for one event

Table 3. Survival to hospital discharge percentages by year, bystander intervention, and event characteristic, 2010-2012 CARES data, n=4,679[a]

Overall

Characteristic	Survived to Hospital Discharge N (%)								
	N	Overall		2010		2011		2012	
Age Group									
0-17	43	24	(55.8)	8	(44.4)	5	(55.6)	11	(68.8)
18-34	192	90	(46.9)	29	(45.3)	27	(50.0)	34	(46.0)
35-49	794	286	(36.0)	76	(31.5)	104	(39.4)	106	(36.7)
50-64	1806	682	(37.8)	201	(34.6)	229	(39.0)	252	(39.5)
65-79	1280	399	(31.2)	140	(32.6)	116	(29.2)	143	(31.5)
≥ 80	556	90	(16.2)	31	(18.9)	30	(15.7)	29	(14.4)
Missing	80			24		27		29	
Sex									
Female	1133	373	(32.9)	118	(33.1)	124	(33.1)	131	(32.7)
Male	3546	1201	(33.9)	367	(32.2)	389	(34.4)	445	(34.9)
Missing	72			23		23		26	
Location of Arrest									
Private	2738	724	(26.4)	214	(24.5)	233	(27.0)	277	(27.7)
Public	1941	850	(43.8)	271	(43.5)	280	(43.6)	299	(44.3)
Missing	72			23		23		26	
Race/Ethnicity									
White	2162	750	(34.7)	208	(31.6)	254	(36.6)	288	(35.6)
Black	896	270	(30.1)	88	(30.8)	80	(27.4)	102	(32.1)
Hispanic/Latino	211	69	(32.7)	22	(27.9)	24	(37.5)	23	(33.8)
Other	106	35	(33.0)	15	(40.5)	10	(34.5)	10	(25.0)
Unknown	1304	450	(34.5)	152	(34.8)	145	(34.0)	153	(34.7)
Missing	72			23		23		26	

Table 3 Continued
Bystander Intervention

Characteristic		Survived to Hospital Discharge N (%)							
	N	Overall		2010		2011		2012	
Age Group									
0-17	27	17	(63.0)	7	(63.6)	2	(40.0)	8	(72.7)
18-34	98	51	(52.0)	16	(53.3)	16	(55.2)	19	(48.7)
35-49	368	156	(42.4)	36	(38.7)	56	(43.8)	64	(43.5)
50-64	938	394	(42.0)	100	(37.7)	128	(40.6)	166	(46.4)
65-79	638	241	(37.8)	69	(36.9)	81	(38.4)	91	(37.9)
≥ 80	244	57	(23.4)	14	(18.7)	22	(24.4)	21	(26.6)
Missing	44			13		17		14	
Sex									
Female	511	199	(38.9)	54	(35.1)	67	(37.9)	78	(43.3)
Male	1808	720	(39.8)	188	(37.0)	240	(39.7)	292	(42.0)
Missing	38			12		13		13	
Location of Arrest									
Private	1186	388	(32.7)	100	(29.6)	129	(32.8)	159	(35.0)
Public	1133	531	(46.9)	142	(43.8)	178	(45.8)	211	(50.2)
Missing	38			12		13		13	
Race/Ethnicity									
White	1168	482	(41.3)	124	(37.9)	162	(41.4)	196	(43.6)
Black	350	127	(36.3)	30	(31.3)	39	(33.3)	58	(42.3)
Hispanic/Latino	103	37	(35.9)	8	(29.6)	13	(40.6)	16	(36.4)
Other	54	21	(38.9)	9	(47.4)	7	(36.8)	5	(31.3)
Unknown	644	252	(39.1)	71	(36.8)	86	(38.6)	95	(41.7)
Missing	38			12		13		13	

Table 3 Continued
No Bystander Intervention

Characteristic	N	Survived to Hospital Discharge N (%)			
		Overall	2010	2011	2012
Age Group					
0-17	16	7 (43.8)	1 (14.3)	3 (75.0)	3 (60.0)
18-34	94	39 (41.5)	13 (38.2)	11 (44.0)	15 (42.9)
35-49	425	130 (30.6)	40 (27.0)	48 (35.3)	42 (29.8)
50-64	868	288 (33.2)	101 (32.0)	101 (37.1)	86 (30.7)
65-79	642	158 (24.6)	71 (29.3)	35 (18.8)	52 (24.3)
≥ 80	312	33 (10.6)	17 (19.1)	8 (7.9)	8 (6.6)
Missing	36		11	10	15
Sex					
Female	622	174 (28.0)	64 (31.5)	57 (28.8)	53 (24.0)
Male	1737	481 (27.7)	179 (28.3)	149 (28.3)	153 (26.5)
Missing	34		11	10	13
Location of Arrest					
Private	1551	336 (21.7)	114 (21.2)	104 (22.1)	118 (21.7)
Public	808	319 (39.5)	129 (43.1)	102 (40.2)	88 (34.5)
Missing	34		11	10	13
Race/Ethnicity					
White	993	268 (27.0)	84 (25.3)	92 (30.3)	92 (25.8)
Black	546	143 (26.2)	58 (30.5)	41 (23.4)	44 (24.3)
Hispanic/Latino	108	32 (29.6)	14 (26.9)	11 (34.4)	7 (29.2)
Other	52	14 (26.9)	6 (33.3)	3 (30.0)	5 (20.8)
Unknown	660	198 (30.0)	81 (33.2)	59 (29.1)	58 (27.2)
Missing	34		11	10	13

[a] Bystander intervention information was missing for one OHCA event, age information was missing for 11 events, and outcome information was missing for 72 events

Table 4. Logistic regression model selection process

Bystander Intervention - 2011 vs. 2010

Model	OR	Within 10%	95% CI	CI Width	CI Ratio
Fully Adjusted	1.1283	--	(0.8999, 1.4145)	0.5146	1.5718
Crude	1.1217	Yes	(0.9060, 1.3888)	0.4828	1.5329
Drop Race (p=.7545 in GS)	1.1300	Yes	(0.9014, 1.4165)	0.5151	1.5714

No Bystander Intervention - 2011 vs. 2010

Model	OR	Within 10%	95% CI	CI Width	CI Ratio
Fully Adjusted	0.9717	--	(0.7710, 1.2246)	0.4536	1.5883
Crude	0.9705	Yes	(0.7789, 1.2092)	0.4303	1.5524
Drop Race (p=.7545 in GS)	0.9728	Yes	(0.7720, 1.2259)	0.4539	1.5880

Bystander Intervention - 2012 vs. 2010

Model	OR	Within 10%	95% CI	CI Width	CI Ratio
Fully Adjusted	1.2635	--	(1.0144, 1.5738)	0.5594	1.5515
Crude	1.2716	Yes	(1.0334, 1.5647)	0.5313	1.5141
Drop Race (p=.7545 in GS)	1.2668	Yes	(1.0173, 1.5775)	0.5602	1.5507

No Bystander Intervention - 2012 vs. 2010

Model	OR	Within 10%	95% CI	CI Width	CI Ratio
Fully Adjusted	0.8895	--	(0.7070, 1.1191)	0.4121	1.5829
Crude	0.8479	Yes	(0.6820, 1.0541)	0.3721	1.5456
Drop Race (p=.7545 in GS)	0.8955	Yes	(0.7121, 1.1261)	0.4140	1.5813

Table 5. Odds ratios calculated from crude and fully adjusted logistic regression models comparing survival to hospital discharge from 2011 to 2010 and 2012 to 2010 among bystander intervention groups, 2010-2012 CARES data, n=4,670

	2011 vs. 2010		2012 vs. 2010	
	Bystander Intervention	No Bystander Intervention	Bystander Intervention	No Bystander Intervention
Crude	1.12 (0.91, 1.39)	0.97 (0.78, 1.21)	1.27 (1.03, 1.56)	0.85 (0.68, 1.05)
Fully Adjusted[a]	1.13 (0.90, 1.41)	0.97 (0.77, 1.22)	1.26 (1.01, 1.57)	0.89 (0.71, 1.12)

[a] Logistic regression model adjusted for age, sex, race, arrest location, and agency

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Chapter III: Summary and Implications

Summary

This analysis was performed using the Cardiac Arrest Registry to Enhance Survival (CARES) program and included all out-of-hospital cardiac arrest events occurring from January 1, 2010 to December 31, 2012 among CARES sites (EMS agencies and participating communities) that were enrolled for the entirety of that time. The objective was to determine whether cardiac arrest survival improved over the time period, and specifically whether the change in survival was different between those who received bystander intervention (CPR and/or defibrillation) and those who did not, after adjusting for covariates. Many factors predict survival including age, sex, race, witness status, and presenting arrhythmia. Unlike these factors, however, bystander intervention is one that can be improved with training and community involvement, providing a focus point of potential strengthening of the chain of survival.

A statistically significant increase in survival was apparent from 2010 to 2012 among the bystander intervention group, but was not present among the group without bystander intervention. This suggests the bystander intervention improved over the three-year period among the 61 agencies included in the analysis, resulting in the increase in survival.

Future Directions and Public Health Implications

This analysis will allow CARES researchers to further investigate the participating EMS agencies to determine what improvements they made in their care continuum between 2010 and 2012 that may have had an influence on the bystander CPR or AED use in their communities. This may include community outreach, increase of community CPR courses, dispatcher training, increase of public access AED's, and promotion of Hands-Only CPR for the untrained layperson. The next step for the CARES program is to survey the agencies in an attempt to identify these contributing factors. This may lead to advancements and recommendations that can be applied to communities throughout the U.S. Although there have been many advances in the medical field and extensive research on pre-hospital cardiac arrest care, survival rates have remained virtually stable for decades (3). This analysis and future investigation provides an opportunity to potentially influence survival rates and improve out-of-hospital cardiac arrest outcomes.