Statewide Regionalization of Postarrest Care for Out-of-Hospital Cardiac Arrest: Association With Survival and Neurologic Outcome

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Study objective: For out-of-hospital cardiac arrest, authoritative, evidence-based recommendations have been made for regionalization of postarrest care. However, system-wide implementation of these guidelines has not been evaluated. Our hypothesis is that statewide regionalization of postarrest interventions, combined with emergency medical services (EMS) triage bypass, is associated with improved survival and neurologic outcome.

Methods: This was a prospective before-after observational study comparing patients admitted to cardiac receiving centers before implementation of the interventions ("before") versus those admitted after ("after"). In December 2007, the Arizona Department of Health Services began officially recognizing cardiac receiving centers according to commitment to provide specified postarrest care. Subsequently, the State EMS Council approved protocols allowing preferential EMS transport to these centers. Participants were adults (≥18 years) experiencing out-of-hospital cardiac arrest of presumed cardiac cause who were transported to a cardiac receiving center. Interventions included (1) implementation of postarrest care at cardiac receiving centers focusing on provision of therapeutic hypothermia and coronary angiography or percutaneous coronary interventions (catheterization/PCI); and (2) implementation of EMS bypass triage protocols. Main outcomes included discharged alive from the hospital and cerebral performance category score at discharge.

Results: During the study (December 1, 2007, to December 31, 2010), 31 hospitals were recognized as cardiac receiving centers statewide. Four hundred forty patients were transported to cardiac receiving centers before and 1,737 after. Provision of therapeutic hypothermia among patients with return of spontaneous circulation increased from 0% (before: 0/145; 95% confidence interval [CI] 0% to 2.5%) to 44.0% (after: 300/682; 95% CI 40.2, 47.8). The post return of spontaneous circulation catheterization PCI rate increased from 11.7% (17/145; 95% CI 7.0, 18.1) before to 30.7% (210/684; 95% CI 27.3, 34.3) after. All-rhythm survival increased from 8.9% (39/440) to 14.4% (250/1,734; adjusted odds ratio [aOR]=2.22; 95% CI 1.47 to 3.34). Survival with favorable neurologic outcome (cerebral performance category score=1 or 2) increased from 5.9% (26/439) to 8.9% (153/1,727; aOR=2.26 [95% CI 1.37, 3.73]). For witnessed shockable rhythms, survival increased from 21.4% (21/98) to 39.2% (115/293; aOR=2.96 [95% CI 1.63, 5.38]) and cerebral performance category score=1 or 2 increased from 19.4% (19/98) to 29.8% (87/292; aOR=2.12 [95% CI 1.14, 3.93]).

Conclusion: Implementation of a statewide system of cardiac receiving centers and EMS bypass was independently associated with increased overall survival and favorable neurologic outcome. In addition, these outcomes improved among patients with witnessed shockable rhythms. [Ann Emerg Med. 2014;64:496-506.]

Please see page 497 for the Editor's Capsule Summary of this article.

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INTRODUCTION

Background

For decades, out-of-hospital cardiac arrest has been a major focus of emergency medical services (EMS) systems, and several bystander and EMS interventions have been shown to improve outcomes.[1-10] In contrast, inhospital postarrest care of out-of-hospital cardiac arrest has historically received little attention. The consensus was that, if a patient was not "saved" in the field, the likelihood that hospital care would make any significant difference was very low.[11,12] However, in the late 1990s, major interest in postarrest care was sparked by observational studies showing a potential effect of inhospital interventions, even in

[†]Arizona Cardiac Receiving Center Consortium participants are listed in the Appendix.

Editor's Capsule Summary

What is already known on this topic

Expert postarrest care improves out-of-hospital cardiac arrest outcomes.

What question this study addressed

Does regionalization of postarrest care improve out-of-hospital cardiac arrest outcomes?

What this study adds to our knowledge

In this before-after analysis, a statewide strategy of EMS bypass to specialized postarrest care centers resulted in improved neurologically intact out-of-hospital cardiac arrest survival.

How this is relevant to clinical practice

If the results can be replicated, communities should consider out-of-hospital cardiac arrest care regionalization strategies.

some patients with major neurologic deficits.[13-16] There is an increasing amount of literature and consensus that specialized postarrest care, including therapeutic hypothermia and targeted temperature management, improves out-of-hospital cardiac arrest outcomes.[17-19] In response, international recommendations for the use of therapeutic hypothermia were published.[20-22] There is also an increasing amount of literature reporting that a wide range of interventions, combined with standardized comprehensive critical care, may improve outcome.[15,23-38]

Importance

The literature showing that inhospital care significantly influences outcomes after out-of-hospital cardiac arrest has resulted in discussions in support of regionalizing postarrest care through EMS triage to specialized centers[39-42] and ultimately led to the American Heart Association policy statement on regionalization.[43] However, direct evidence for the effect of widespread, multisystem regionalization on patient outcomes is lacking.

Goals of This Investigation

In 2004, the Arizona Department of Health Services developed a statewide partnership with EMS agencies and researchers focusing on out-of-hospital cardiac arrest. The net effect was improvement in bystander and EMS care that led to a tripling of survival statewide.[7,44,45] In 2007, this partnership established criteria for a statewide network of specialized cardiac receiving centers that could provide therapeutic hypothermia, prompt percutaneous coronary interventions, and other guideline-based postarrest critical care. In 2008, protocols were developed allowing EMS to bypass local hospitals to preferentially transport patients to cardiac receiving centers.

The goal for this study was to evaluate whether statewide regionalization of postarrest interventions, combined with EMS triage, would be associated with improved survival and neurologic outcome. Here we report the outcomes of this effort.

MATERIALS AND METHODS

Study Design

This was a prospective, multicenter, multisystem, before-after observational cohort analysis comparing outcomes in patients admitted to cardiac receiving centers during the period before implementation versus those admitted to the same hospitals after implementation.

Setting

Arizona had 6.4 million residents in 2010 (http://quickfacts.census.gov/qfd/states/04000.html), with 62 licensed acute care hospitals. The Arizona Department of Health Services establishes EMS protocols, scope of practice, and provider certification. EMS crew configuration, vehicle deployment, dispatch, and response intervals vary widely across the state.[46]

There are 19,428 licensed out-of-hospital providers statewide (basic EMTs [12,901], EMT-intermediate-99 [39], and paramedics [6,488]). In the majority of locations, paramedics perform field resuscitation attempts and transport postarrest patients to cardiac receiving centers. At this analysis, 31 hospitals and 120 EMS agencies, responding to approximately 80% of the state's population, participated in the state-sponsored Save Hearts in Arizona Registry and Education (SHARE) program. SHARE provided the data collection and infrastructure for this study and has been previously described in detail.[7,44,46]

Data Collection and Processing and Methods of Measurement

Since 2004, more than 13,000 out-of-hospital cardiac arrests have been entered into the SHARE database. EMS data are obtained from the patient care reports and outcomes are obtained either directly from the hospitals or from the State Office of Vital Records. SHARE includes an Utstein-style out-of-hospital cardiac arrest EMS database linked with inhospital postarrest care and outcome data. Data collected from participating EMS systems and hospitals are manually entered into an Access 2007 (Microsoft, Redmond, WA) database by an experienced team of trained data coordinators who link and abstract the information. Consistent with Utstein methodology, every out-of-hospital cardiac arrest in which EMS documents an attempted resuscitation is included. Data are cross-referenced between first responding fire department-based EMS, private ambulance transport companies, and the cardiac receiving center database. For this effort, a data tool was developed to collect patient information for all out-of-hospital cardiac arrest patients brought to cardiac receiving centers (Appendix E1, available online at http://www.annemergmed.com). The data forms were completed by cardiac receiving center clinical personnel on

Table 1. Characteristics of study population stratified by before (pre) versus after (post) cardiac arrest protocol implementation by cardiac receiving centers.

	Pre (N=440)			Post (N=1,737)		
Characteristic	**n/N**	**% (95% CI)**	**Missing n**	**n/N**	**% (95% CI)**	**Missing n**
Male sex	280/440	63.6 (58.9–68.1)	0	1,132/1,731	65.4 (63.1–67.6)	6
Age, mean (95% CI), y	440	63.9 (62.4–65.4)	0	1,728	63.0 (62.2–63.8)	9
Age, y			0			9
≥80	75/440	17.0 (13.6–20.9)		306/1,728	17.7 (15.9–19.6)	
60–79	192/440	43.6 (38.9–48.4)		744/1,728	43.1 (40.7–45.4)	
18–59	173/440	39.3 (34.7–44.1)		678/1,728	39.2 (36.9–41.6)	
Witnessed arrest	215/429	50.1 (45.3–54.9)	11	671/1,640	40.9 (38.5–43.3)	97
Initial rhythm on EMS arrival			9			76
VF/VT	147/431	34.1 (29.6–38.7)		468/1,661	28.2 (26.0–30.4)	
Asystole	168/431	39.0 (34.3–43.8)		815/1,661	49.1 (46.6–51.5)	
PEA	113/431	26.2 (22.1–30.6)		342/1,661	20.6 (18.7–22.6)	
Other, non-VF/VT rhythms	3/431	0.7 (0.1–2.0)		36/1,661	2.2 (1.5–3.0)	
Location of OHCA			10			114
Residential	298/430	69.3 (64.7–73.6)		1,157/1,623	71.3 (69.0–73.5)	
Medical facility	39/430	9.1 (6.5–12.2)		195/1,623	12.0 (10.5–13.7)	
Public	93/430	21.6 (17.8–25.8)		271/1,623	16.7 (14.9–18.6)	
Provision of bystander CPR	207/428	48.4 (43.5–53.2)	12	811/1,632	49.7 (47.2–52.1)	105
EMS use of MICR	182/430	42.3 (37.6–47.2)	10	1,061/1,652	64.2 (61.9–66.5)	85
Response interval, median (IQR), min	429	5 (4–6)	11	1,623	5 (4–7)	114
Intubated before ED arrival	308/433	71.1 (66.6–75.4)	7	1,185/1,715	69.2 (66.8–71.3)	22
Any out-of-hospital ROSC	111/439	25.3 (21.3–29.6)	1	418/1,735	24.1 (22.1–26.2)	2
Any ROSC (out-of-hospital or posthospital)	145/440	33.0 (28.6–37.6)	0	684/1,737	39.4 (37.1–41.7)	0
Went to catheterization laboratory						
All patients	17/440	3.9 (2.3–6.1)	0	210/1,737	12.1 (10.6–13.7)	0
Patients with any ROSC	17/145	11.7 (7.0–18.1)	0	210/684	30.7 (27.3–343)	0
Received therapeutic hypothermia						
All patients	0/440	0 (0–0.8)	0	300/1,735	17.3 (15.5–19.2)	2
Patients with any ROSC	0/145	0 (0–2.5)	0	300/682	44.0 (40.2–47.8)	2
Survival to hospital discharge						
All rhythms	39/440	8.9 (6.4–11.9)	0	250/1,734	14.4 (12.8–16.2)	3
Witnessed arrests with VF/VT	21/98	21.4 (13.8–30.9)	12	115/293	39.2 (33.6–45.1)	106
Any ROSC	39/145	26.9 (19.9–34.9)	0	250/681	36.7 (33.1–40.5)	3
Positive neurologic outcome (cerebral performance category score=1 or 2) at discharge						
All rhythms	26/439	5.9 (3.9–8.6)	1	153/1,727	8.9 (7.6–10.3)	10
Witnessed arrest with VF/VT	19/98	19.4 (12.1–28.6)	12	87/292	29.8 (24.6–35.4)	107
Any ROSC	26/144	18.1 (12.1–25.3)	1	153/674	22.7 (19.6–26.1)	10

VF, Ventricular fibrillation; *VT*, ventricular tachycardia; *PEA*, pulseless electrical activity; *OHCA*, out-of-hospital cardiac arrest; *MICR*, minimally interrupted cardiac resuscitation; *IQR*, interquartile range; *ROSC*, return of spontaneous circulation.

neurologic outcomes for all rhythms and in several patient subgroups.

Final logistic regression models for all-rhythms survival and positive neurologic outcome (primary analysis) had adequate fit according to the Hosmer-Lemeshow goodness-of-fit test (Tables 2 and 3), and the area under the receiver operating characteristic was greater than 0.8 for both outcomes (Tables 2 and 3). There were 40 cases representing potential outliers according to diagnostic statistics for both survival and positive neurologic outcomes. For survival, the largest change in the regression coefficient for before versus after, after removal of potential outliers, was 4.3%, well below our 20% threshold. For favorable neurologic outcome, the largest change in the regression coefficient for before versus after was 6.9%, also below the threshold. Thus, all cases were retained in the final analysis.

To control for potential secular trends occurring independently of implementation, a time component (year) was included in the analysis. aORs did not significantly change for any variable (no aOR changed by more than 5%) and time was not significantly associated with outcomes (survival aOR=0.95, 95% CI 0.75 to 1.20; neurologic outcome aOR=1.07, 95% CI 0.79 to 1.44). Neither survival nor neurologic outcome varied significantly across years in the before period (survival: Fisher's exact test P=.91, test for trend P=.86; positive neurologic outcome: Fisher's exact test P=.18, test for trend P=.74).

The proportion of cases with missing variables was low (highest proportion of missing data was 5.8% for arrest location) (Table 1). The secondary sensitivity analysis showed that logistic regression results using imputed data for cases with missing

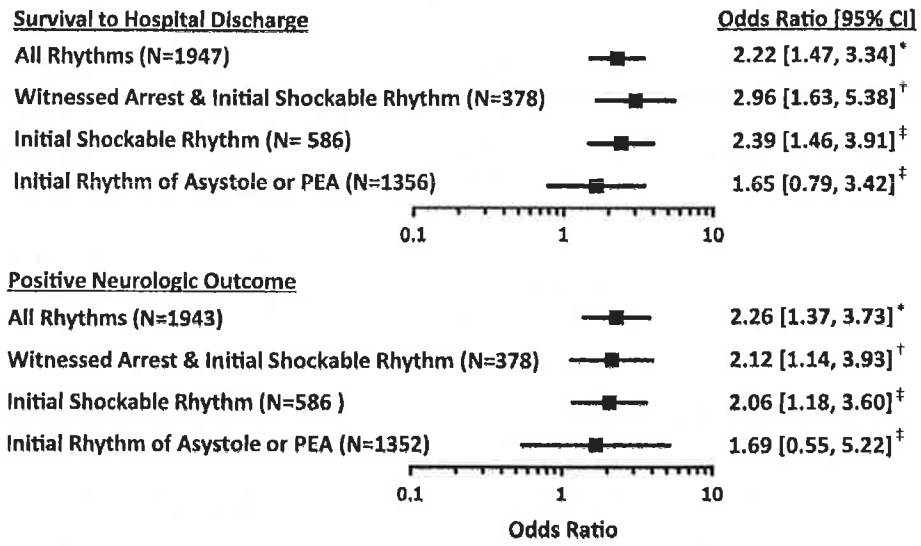

Figure. Comparison of outcomes for the after intervention period versus the before intervention period. Forest plots showing aOR for survival and survival with favorable functional outcome for the after intervention period versus the before intervention period (OR >1 favors the after period) for the entire study population (all rhythms) and several subgroups. *OR adjusted for the following: age, sex, EMS response interval, witnessed arrest, initial rhythm on EMS arrival, bystander CPR provision, location of OHCA, and EMS use of MICR. †OR adjusted for the following: age, sex, EMS response interval, bystander CPR provision, location of OHCA, and EMS use of MICR. ‡OR adjusted for the following: age, sex, EMS response interval, witnessed arrest, bystander CPR, location of OHCA, and EMS use of MICR.

interrupted cardiac resuscitation. The fact that EMS use of minimally interrupted cardiac resuscitation is higher in the postperiod is most likely a reflection of ongoing practice in Arizona as more EMS systems use minimally interrupted cardiac resuscitation over time. We have included this variable in our multivariable analysis to ensure that its influence on outcomes is accounted for (ie, controlled for) in our models so that the underlying effect of our main independent variable (before versus after period) can be accurately measured.

Finally, we are unable to prove that the EMS triage protocol actually led to preferential transport of patients to cardiac receiving centers. With scores of EMS agencies involved, logistic issues preclude us from knowing when the bypass protocol was invoked versus when the closest cardiac receiving center was also the closest "general hospital" (and would have received the patient whether it was a cardiac receiving center or not). However, the fact that there was a 60% increase in the rate at which out-of-hospital cardiac arrest patients were taken to cardiac receiving centers after implementation is consistent with the intent of the officially established triage protocols and with the concept of regionalization.

DISCUSSION

Implementation of this regionalized system of care was associated with improvement in overall survival (aOR=2.22), survival among patients with witnessed ventricular fibrillation or ventricular tachycardia (aOR=2.96), and the odds of favorable neurologic outcome for both the all-rhythm cohort (aOR=2.26) and those with witnessed ventricular fibrillation or ventricular tachycardia (aOR=2.12; Figure). In addition, although not statistically significant, the rates of both survival and favorable neurologic outcome increased in patients with nonshockable rhythms as well (Figure). The American Heart Association policy statement on regionalization recommends triaging patients with return of spontaneous circulation to cardiac receiving centers regardless of presenting rhythm.[43] Although our findings strongly support regionalization for patients with shockable rhythms, they also suggest that this recommendation is reasonable for patients with nonshockable rhythms.

To our knowledge, this is the first statewide report showing an association between improved outcomes and regionalization. This effort involved 55 EMS agencies and 31 hospitals of widely varying size (case numbers per agency/cardiac receiving center ranged from 1 to 197), representing a vast array of organizational and demographic characteristics. Despite these variations, we found significant improvements in outcomes even after controlling for various confounders and independent risk factors, as well as the effects of cluster sampling by hospitals and EMS agencies. Previous investigations were smaller, generally reported implementation in 1 or 2 major regional hospitals with close linkages between the investigators and the clinical care, and did not include officially approved, system-wide EMS triage.[13,14,23,25,26,43,57-60] For instance, Engdahl et al[25] evaluated the inhospital care provided in 2 hospitals in Göteborg, Sweden, and found an association between improved outcome and receiving care at the hospital providing higher rates of specified postarrest interventions. However, EMS did not preferentially

triage patients to a specified hospital. Thus, this was not a regionalized approach to out-of-hospital cardiac arrest care because EMS was agnostic to destination hospital.

The concept of regionalization in health care has been described as "the direction of patients with select medical conditions to specially skilled, experienced, and equipped treatment centers."[60] This statewide effort was aimed at implementing both aspects of regionalization: guideline-based inhospital care and EMS triage.[43,60] We did not have data on the patients who were transported to noncardiac receiving centers, and thus we are ultimately unable to completely assess the effect of redirecting patients within the system. However, our findings are consistent with the intent of regionalization. First, we predicted that the implementation of the EMS triage protocols would significantly increase the rate of out-of-hospital cardiac arrest patients arriving at cardiac receiving centers compared with the preprogram rates. Indeed, the number of arrest patients arriving at cardiac receiving centers increased by 60% after protocol implementation. Second, this effort was associated with significant increases in use of guideline therapies at the cardiac receiving centers. Among potentially eligible patients, provision of therapeutic hypothermia increased from 0% to 44.0% and coronary angiography (with or without percutaneous coronary intervention) increased from 11.7% to 30.7%.

The literature has discussed a potential association between outcomes and the volume of patients cared for by cardiac receiving centers.[43,61] In our study, individual hospital volume ranged from 14 to 197 and overall survival varied widely among hospitals. However, when cardiac receiving centers were stratified by number of patients (<50, 50 to 100, and 101 to 197), there were no statistical differences across these groups in overall survivorship (15.3% [95% CI 12.3% to 18.7%] versus 13.2% [95% CI 10.1% to 16.7%] versus 12.5% [95% CI 10.7% to 14.5%], respectively). In addition, when the number of patients cared for at a given cardiac receiving center was added into the final LR model for survival, it had no effect on the OR for survival (regression coefficient changed by less than 5%) for after versus before and it was not significantly associated with survival. This is consistent with previous findings from the Cardiac Arrest Registry to Enhance Survival that showed no association between cardiac receiving center patient volume and outcome.[61]

Although our study does not prove that regionalization of EMS and inhospital care caused the doubling of survival, we believe our findings support the concept of widespread regionalization for the following reasons: First, bypass of local hospitals to take patients to cardiac receiving centers is likely safe. Our large preimplementation evaluations of transport time intervals and distance (in Arizona and Ontario, Canada) identified no association between longer transport intervals and higher mortality.[39,40] Second, there is widespread and growing evidence for a positive effect of intentional, guideline-based, postarrest, inhospital care. This strongly supports the theoretical plausibility for regionalization.[13-15,17-19,23,25-27,29,31,32,38,43,57-59,62] Third, our regionalization program was implemented across a vast demography in a wide variety of local systems and hospitals. This finding is particularly meaningful because the health care system in Arizona is decentralized—the "lead agency" can coordinate and collaborate, but does not mandate changes in care. Thus, it appears that an EMS jurisdiction can lead effective implementation of out-of-hospital cardiac arrest regionalization even if it does not have authority to require the necessary organizations to participate. This may mean that the "transportability" of regionalization to other EMS jurisdictions has the potential for success through a collaborative process even if they do not possess "control" of the system. Fourth, our findings are consistent with the nationally vetted recommendations for implementation of regionalized systems of care.[43]

In summary, implementation of a voluntary, statewide specialty hospital recognition program and EMS bypass protocols directing postarrest patients to these centers was independently associated with improvements in overall survival and the likelihood of favorable neurologic survival. In addition, survival from bystander-witnessed shockable rhythms improved, as did the rate of favorable neurologic outcome in this subgroup.

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