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# RHODE ISLAND MEDICAL JOURNAL



## SPECIAL SECTION

### OUT-OF-HOSPITAL CARDIAC ARREST (OHCA)

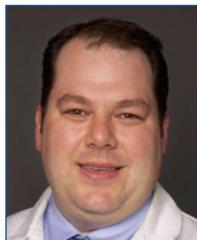
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**On the cover:** Members of the Cumberland Fire and Police Departments assist Cumberland EMS paramedics and physicians during a simulated out-of-hospital cardiac arrest.  
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## Out-of-Hospital Cardiac Arrest (OHCA) in Rhode Island: Can We Do Better?

NICHOLAS ASSELIN, DO, MS

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GUEST EDITORS

In this month's issue of the *Rhode Island Medical Journal* (RIMJ) we have gathered local experts in the management of Out-of-Hospital Cardiac Arrest (OHCA) to present the current state of affairs and a timely assessment of new frontiers in this dynamic field. No Emergency Medical Services (EMS) complaint touches as many parts of our health system like OHCA. The stakes are literally life and death, and yet the

outcome in OHCA varies dramatically in the United States health system.<sup>1</sup> Successful management of OHCA requires a series of events described by the American Heart Association as the "Chain of Survival"<sup>2</sup> that starts well before the victim collapses with prevention, system design, training (of bystanders, dispatchers, first responders, EMS and hospital staff), data fidelity and the prepositioning of resources including response assets, defibrillators, and trained bystanders.

March of 2017 proved to be an important moment for EMS in Rhode Island (RI) as it saw the rollout of a total reimagining of the RI Statewide EMS Protocols and Standing Orders.<sup>3</sup> This revamp touched every level of provider and every disease state, and represented years of effort by committed volunteers and public servants. The EMS Protocols were reformat ted and scope of practice and treatments were modified to reflect current best evidence. Traditionally, EMS has focused on the stabilization and rapid transport of life-threatening presentations; however, recent trends in the management of some disease states (like OHCA) have focused on providing timely, high quality care on scene, rather than the prior mantra of "scoop and run" in the severely ill or injured patient.

Following the "chain of survival" concept we open with **JASON RHODES**, et al. and their take on the use of EMS data to plan for, respond to and debrief events like OHCA. Next in the chain, **HEATHER RYBASACK-SMITH**, et al. review the evidence for using dispatchers as "the 1st, first responders" through the delivery of just-in-time CPR instruction for bystanders of OHCA. One of the driving factors behind changes in the OHCA protocol for EMS providers was a realization that the care they provided on scene was in many ways equal to what is provided in the emergency department, and that the quality of these interventions degraded during transport operations, making scene management essential. **LEO KOBAYASHI**, et al. present a subset of data from their STORM Resuscitation trial that demonstrates improved management of OHCA using mechanical adjuncts during transport of the patient.

Changes in EMS Protocols provide unique opportunities to assess their impact across a system. **JONATHAN THORNDIKE**, et al. performed a pilot study of OHCA outcomes comparing the first month of system-wide protocol with the same month the year before. **JOSEPH LAURO**, et al. discuss a case report of a success story from the RI EMS system; a woman who collapsed in her home, was treated there by



Members of the Cumberland Fire and Police Departments assist Cumberland EMS paramedics and physicians during a simulated out-of-hospital cardiac arrest. [PHOTO: JOHN PLIAKAS]

EMS providers, and later a community ED, a critical care EMS agency and an academic medical center, going home after a successful outcome. Finally, **TANYA SUTCLIFFE**, et al. review the literature on the management of pediatric OHCA, with particular focus on the differences in arrest etiology, as well as the challenges of managing this population at the scene of their arrest.

We look forward to generating a robust discussion over the management of OHCA in RI and invite our colleagues to share their experiences with these protocol changes. EMS management of OHCA is a dynamic field, and as the science advances nationally, so will our EMS system locally. By embracing a "chain of survival" approach to system design and operations and by gathering and reviewing the relevant data, we hope Rhode Island will join other high performing systems in delivering outstanding care for our patients who need us most, those in cardiac arrest.

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#### Disclaimers

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the Department of Emergency Medicine, Alpert Medical School of Brown University.

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# Data Utilization in Emergency Medical Services

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**KEYWORDS:** Informatics, Out-of-Hospital Cardiac Arrest, Emergency Medical Services

## INTRODUCTION

Emergency Medical Services (EMS) can be defined as a system that provides acute, urgent care and transportation for the sick and injured. EMS practitioners include professionals at many levels, both volunteer and paid, who are trained in the operational and clinical aspects of EMS. Physicians, nurses, respiratory therapists, pilots, dispatchers, managers, educators, maintenance staff, information technology professionals and others all contribute to the EMS system. Increasingly, EMS practitioners also work in other settings where their training is an advantage, such as hospital and other clinical settings, military and law enforcement, preventive and follow-up care systems, safety and security.

These activities generate data of interest to many, ranging from traffic safety scientists and automotive engineers to epidemiologists and economists. This article reviews some EMS data sources and tools available with a focus on using cardiac arrest data to improve system outcomes.

## EMS DATA SOURCES

Sources of EMS data can be grouped into three categories:

- 1] Logistic data, such as time, date and location of events, names of practitioners and services, patient demographics, health insurance information, etc.
- 2] Clinical data, such as patient assessment, vital signs, treatment and response, etc.
- 3] Operational data, such as response time, transport distance, communications recordings, practitioner skill logs, quality assurance reviews, patient safety audits, etc.

Much of this data is available from EMS ambulance responses as they are recorded electronically, instead of by prior paper and audio recording tape systems. Electronic recording, dispatch, and patient charting systems have been the long-term industry standard in EMS. Software vendors offer systems for computer-aided dispatch (CAD), patient charting, quality assurance review, personnel management, GIS mapping of EMS incidents, and other functions. Digital audio recording software now offers transcription and search

functions. These advances make EMS data more available for analysis. For most patients, however, outcome data remains separate from the EMS dataset, and requires abstraction or query from hospital databases.

## EMS DATA HISTORY

In 1973, state EMS directors realized that there was no standard format or process for gathering and comparing data from one state, one service, one provider, or one patient to another. There was increasing interest in such comparisons as hospital networks and speciality centers developed, ambulances more often crossed state lines, and large ambulance services formed. The emergency medical services system act of 1973 identified 15 essential components of an EMS system, thus creating a rudimentary framework for EMS data collection.<sup>1</sup>

Some systems began extracting data from paper reports or using early scannable paper database systems. Rhode Island had one of the earliest statewide EMS data systems, starting in the 1990s.

The 1990 Utstein style of EMS data reporting for cardiac arrest patients created a more detailed set of EMS data elements and allowed comparison between systems.<sup>2</sup> In 1994, the National Highway Traffic Safety Administration's Office of EMS (NHTSA EMS) developed a national consensus document that defined the first national prehospital EMS data set, with 81 thoroughly defined data elements. This data set formed the foundation for the National EMS Information System, NEMSIS, which was established in 2001. Version 3.5 of the EMS data dictionary is currently in development and encompasses over 500 data elements. The NEMSIS data registry includes data from over 30 million EMS activations submitted by over 10,000 agencies serving 49 states and territories.<sup>1</sup>

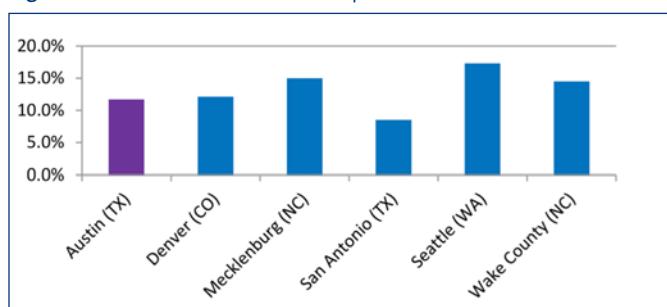
While this is an impressive national data set and a unique healthcare enterprise that can answer many research questions, for privacy and efficiency reasons the national data set does not include many elements that are important at state, regional, or individual service, provider, or patient levels. However, similar software is in use at these levels and allows robust local analysis. As is true with any large database where the information is entered without significant oversight, the NEMSIS dataset contains some inaccurate

data. However, improvements in data entry rules, physician quality assurance review of EMS charts, and increased understanding of the importance of accurate EMS data should gradually improve data quality. Thus, there is an EMS data pyramid, with a broad base representing individual and local data tapering to a smaller (but still robust) data set at the national level. Topics of particular interest, such as cardiac arrest, highway crash incidents, epidemics, and opiate overdose, merit focused databases.

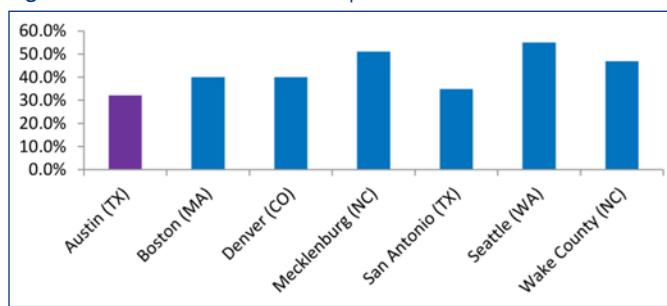
## CARDIAC ARREST DATA AND CARES

For cardiac arrest, independent projects to gather data and benchmark using the Utstein guidelines developed, culminating in the Cardiac Arrest Registry to Advance Survival (CARES) in 2004. CARES was formed through collaboration between the CDC and Emory University's Department of Emergency Medicine. The CARES registry began collecting data in the Atlanta area in 2005 with 600 patients, and has now expanded to statewide data collection in 23 states and 63 community efforts in an additional 18 states, as well as 8 countries outside the US. The registry now includes over 350,000 patients representing the efforts of over 1,400 EMS agencies and 1,800 hospitals.<sup>3</sup> A major use of the CARES registry is benchmarking, as seen in **Figure 1**, with individual agencies able to perform both internal benchmarking against prior performance as well as comparison with like

**Figure 1A.** Overall Survival Rate Comparison



**Figure 1B.** Utstein Survival Rate Comparison



Source: CARES data obtained from Medical Directors for various EMS providers, June 2013

CARES Survival Rate Comparison, 2012 data  
<https://mycares.net/sitepages/uploads/2015/CARES%20in%20Action%20Abridged.pdf> Accessed Aug. 2018.

## Figure 2. CARES Registry Sites



systems or the registry in general. The project also allows discussion of diversity and location information.

Since the NEMSIS database has evolved to include most of the 66 CARES registry elements, barriers to membership have decreased, but abstraction of hospital data still requires significant personnel effort. CARES membership fees present a significant hurdle to many states and agencies, currently including Rhode Island, as shown in Figure 2.<sup>4</sup> However, the involvement of focused and dedicated data abstraction personnel also means that the CARES dataset is likely more accurate than the NEMSIS data cube.

In Rhode Island, there is interest in CARES enrollment, currently complicated by lack of funding. However, other efforts are underway including inclusion of CARES elements in the RI EMS data set and efforts to search both traditional data and parse narrative data to develop a strong and accurate statewide EMS database for research and quality purposes.

## CASE EXAMPLES

Several hypothetical case examples illustrate the capabilities and utility of EMS data analysis.

## Case 1: Individual Patient Data

A 68-year-old male patient has diabetes and congestive heart failure. He lives alone, has poor vision due to diabetic retinopathy. He often has difficulty taking his medication properly but does not qualify for home nursing services. About twice a month, he calls 911 due to symptoms of his chronic diseases, and is often hospitalized. Noting this pattern of readmission, a case management meeting occurred, involving the local EMS agency and their data system. From an analysis of their individual EMS run data, the care team determines that many of his 911 calls have been related to medication errors. With the patient's permission, he is entered into a community paramedicine program where

members of the EMS agency visit him at home and assist him with medication dosage and compliance, reducing the need for 911 calls and re-hospitalization.

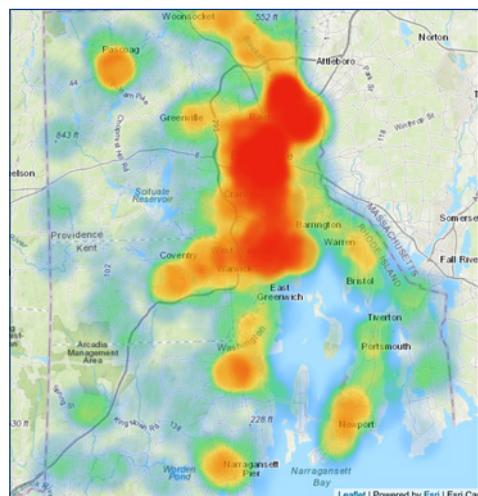
### Case 2: State System Data Improves Cardiac Arrest Care

A state EMS office receives several complaints about questionable resuscitation rates in some communities. In a number of cases during the prior year, patients suffering cardiac arrest in these communities had long waits for EMS care. A query of the prior year's EMS data identifies the set of patients with witnessed and unwitnessed cardiac arrest, and identifies those with bystander CPR, including those who received CPR instructions via 911/Dispatch. After analysis, there does not appear to be discrimination based on cultural or ethnic characteristics, place of residence, responding agency or provider. However, most of the patients in question had their emergency occur during peak call volume times of day, contributing to the prolonged response times. After discussion with several involved providers, the state office determines that low percentages of bystander CPR and dispatcher instruction in CPR via telephone represent a gap in the current system. Focused efforts in both areas begin, and resuscitation rates rise compared with prior year baselines.

### Case 3: National Data Reveals Health System Patterns

Syndromic surveillance of EMS data in real time by the National Collaborative for Bio-Preparedness, enabled by BioSpatial, is currently in place.<sup>5</sup> This capability, dependent on prompt uploading of individual EMS system data to state databases and a cooperative agreement between state EMS offices and BioSpatial, monitors a number of syndromes of national interest (cardiac arrest, opiate overdose, motor vehicle crashes, gastrointestinal symptoms, influenza-like illness, etc.). Data at the national level is scrubbed and averaged to avoid privacy concerns, but at the state and service level the system allows access to the original data (at the same level these entities already enjoy). **Figure 3** depicts a year of Rhode Island cardiac arrest data as a heat map – the

**Figure 3.** Rhode Island EMS Cardiac Arrest Volume Heat Map (Year prior to 2018 Aug.)  
Biospatial analysis of RI Department of Health data.



southernmost portion of the state not visible due to map zoom range.

Such EMS data analysis and syndromic surveillance can be used to uncover clusters of foodborne illness and aid in tracking the source, find concentrations of opiate overdose patients to enable community response, and identify the location of accident-prone intersections and segments of highway to facilitate traffic engineering improvements. Surveillance of cardiac arrest data enables identification of neighborhoods at risk due to lack of EMS coverage, AED availability, or low rates of bystander CPR.

### SUMMARY

Availability of robust electronic EMS data and tools to share, analyze, and report these data have profound implications for the healthcare system, ranging from ability to improve individual patient disease management to national level syndrome identification and response. Today's data systems and analysis tools, including the NEMSIS Data Cube, the CARES registry, and the National Collaborative for Bio-Preparedness BioSpatial graphic information system analysis and mapping capabilities, provide powerful real-time capabilities for understanding EMS data and improving care across our prehospital system.

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### Disclaimer

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# A History and Overview of Telecommunicator Cardiopulmonary Resuscitation (T-CPR)

HEATHER RYBASACK-SMITH, MD, MPH; JOSEPH LAURO, MD, FACEP

## ABSTRACT

Few events in pre-hospital medicine inspire as much attention and resources as out-of-hospital cardiac arrest (OHCA), yet the survival rate for such events has remained stagnant and unacceptably low. The first links in the chain of survival are early recognition and early CPR; yet EMS services do not arrive to the scene of a medical call for on average 7 minutes. Emergency dispatchers are generally the first trained individuals involved in medical emergencies; they can provide pre-arrival instructions, specifically telecommunicator CPR (T-CPR), and represent the potential to double the bystander CPR rate and increase return of spontaneous circulation. Yet, according to survey data, fewer than half of all public safety answering points (PSAPs) provide any T-CPR and even fewer provide hands-only CPR instruction.<sup>1</sup> This article will provide a brief overview, history and introduction to the evidence supporting the use of T-CPR to improve outcomes in OHCA.

**KEYWORDS:** Cardiac Arrest, Emergency Medical Dispatch, Telecommunicator CPR, Emergency Medical Services

## INTRODUCTION

Although the actual incidence is not tracked in Rhode Island, extrapolations would suggest that every year an estimated 1,000 people suffer an out-of-hospital cardiac arrest (OHCA), when their heart stops beating normally.<sup>2</sup> Of these, approximately 40% are witnessed.<sup>3</sup> Although an estimated 25–50% of all OHCAAs are due to a treatable arrhythmia like ventricular fibrillation (VF), the rate of survival to hospital discharge after a witnessed OHCA is estimated to be 31.4%.<sup>3</sup> This number has remained stagnant for years, with the exception of isolated, high performance EMS systems. Factors that increase the survival rate for witnessed cardiac arrest include bystander CPR, early AED and early advanced cardiac care. Multiple studies have shown that bystander CPR doubles rates of survival in OHCA;<sup>4,5</sup> however, the rate of bystander CPR in Rhode Island is an abysmal 20% in recent data analysis<sup>6</sup> and across the country remains a stagnant 40%.<sup>5</sup> In other words, in Rhode Island, up to 80%

of cardiac arrest victims must wait for the arrival of EMS services before CPR is initiated.

Survival decreases by around 5% for each minute between cardiac arrest and the initiation of CPR and yet EMS response times in urban settings are on average 7.0 (SD 4.4) minutes, 7.7 (SD 5.4) minutes in suburbia and 14.5 (SD 9.5) minutes in rural settings.<sup>7</sup> Anoxic brain injury can occur after just a few moments following cardiac arrest. Bystander CPR, whereby CPR is performed by untrained bystanders prior to EMS arrival, can bridge this gap, buying valuable time for the initiation of Advanced Cardiac Life Support (ACLS) protocols. Unfortunately although the general public widely recognizes the importance of CPR, bystander CPR rates remain low nationally.<sup>5</sup>

One proven way to increase the rates of bystander CPR is through the use of telecommunicator CPR (T-CPR). Across the country, from Rochester to Seattle, communities have dramatically increased their cardiac arrest survival rate with programs that include evidence-based, quality-controlled, physician-led, dispatcher-assisted CPR. Arizona now has an overall survival rate of 35% for VF cardiac arrest.<sup>8</sup> In Rochester, victims of witnessed VF arrest have a 50% chance of survival.<sup>9</sup> In Seattle/King County, WA, the survival rate for witnessed VF arrest in one analysis was 62%.<sup>10</sup>

## WHAT IS T-CPR?

T-CPR is defined as the “provision of CPR instructions by emergency dispatchers and call-takers to 9-1-1 callers who potentially encounter cardiac arrest.”<sup>11</sup> T-CPR is real-time, over the phone CPR instruction given to bystanders by trained emergency dispatchers with a goal of having “hands on the chest” within 3 minutes of the 9-1-1 call.

T-CPR is part of a group of standardized, scripted pre-arrival instructions. These pre-arrival instructions are designed to provide immediate, life-saving interventions prior to the arrival of EMS, by bystanders under the instruction of trained medical dispatchers. Pre-arrival instructions, when provided by certified Emergency Medical Dispatchers (EMDs) have been proven safe, effective, and lifesaving.<sup>11</sup> Trained 9-1-1 operators coach people through immediate measures such as CPR as well as for other emergencies like bleeding control, choking, or assistance for drug overdose victims, meanwhile collecting key information for

emergency responders prior to their arrival. T-CPR has been included in the American Heart Association guidelines for resuscitation care since 2010, and has been graded as the highest level (Class I) recommendation in the most recent 2017 guidelines.<sup>12</sup> Pre-arrival instructions such as T-CPR enable emergency medical dispatchers to be the true first responders to medical emergencies, buying valuable time for patients suffering life-threatening illness or injury.

T-CPR employs a rapid triage assessment of the victim, using a “no, no, go” paradigm. This consists of a two-question screening: 1) Is the patient conscious? 2) Is the patient breathing normally? If the answer is no to both questions, the telecommunicator gives brief, easy to understand instructions to the caller. Generally this involves getting the patient to a flat, hard surface, placing hands on the chest and pushing hard and fast with coaching by the telecommunicator.

### HISTORY OF T-CPR

Modern CPR has evolved over the last half century alongside the evolution of organized EMS, medical dispatch and the specialty of Emergency Medicine. Though the first documented instances of chest compressions occurred as early as the 1800s, CPR as we know it today was created in the mid-20th century. In the early 1960s, the American Heart Association (AHA) formerly endorsed CPR and created the first program to teach what was then called “closed chest cardiac massage” to physicians in the hospital setting.<sup>13</sup> By the 1960s, EMS was becoming more organized, and CPR quickly became standard instruction for newly minted EMS providers. The provision of CPR training to laypeople soon followed. The very first documented instruction of laypeople in CPR took place in Cleveland in 1961,<sup>14</sup> and the 1970s marked the first large-scale rollout of CPR training to the lay public. In 1972, Leonard Cobb held the first public CPR training in Seattle, WA<sup>14</sup> and by the end of the 1970s ACLS was developed at the third national conference on CPR.<sup>13</sup> It was some years later that emergency medical dispatchers began offering instructions to callers.

The very first documented pre-arrival instructions were provided in 1975 by paramedic Bill Tune in Phoenix, AZ.<sup>15</sup> Paramedic Tune gave spontaneous, unscripted instructions to the mother of a child who was not breathing. The child survived and Phoenix began routinely offering non-standardized, non-scripted, pre-arrival instructions.<sup>15</sup> However, despite this (and likely other undocumented occurrences), T-CPR was not widely adopted until later, following the development of the EMD and standardized EMS dispatch protocols. Utah boasted the first formal training program for emergency dispatchers and also was the first state to require use of medically approved dispatch protocols in 1983. This was the same year the US Department of Transportation issued a sample curriculum and protocol for EMD training.<sup>15</sup> Throughout the 1980s multiple jurisdictions across the US

began using pre-arrival instructions for critical events like CPR, choking and childbirth and T-CPR began to be formally incorporated into dispatch center protocols.

### EVIDENCE TO SUPPORT USE OF T-CPR

Survival from OHCA requires complex systems of care and chain of survival that begins with early access to CPR and an Automatic Defibrillator (AED), continued with robust pre-hospital management of cardiac arrest and care at the hospital. Dispatcher-assisted bystander CPR has been shown to improve survival especially when integrated with other links in the chain like AED use, more CPR education and advanced systems of care.<sup>11,16</sup>

Studies have shown that bystander CPR increases rates of survival by over 200% in OHCA.<sup>4</sup> Though most Americans are familiar with CPR,<sup>17</sup> rates of bystander CPR remain very low.<sup>5</sup> T-CPR pre-arrival instructions have been shown to double the rates of bystander CPR,<sup>16</sup> are nearly as effective as CPR provided by a trained medical professional,<sup>11</sup> are expected by the general public<sup>17</sup> and have been shown to be feasible and effective.

Phoenix, AZ, provides an example of the positive survival effects of institution of effective T-CPR programs. Phoenix previously provided pre-arrival CPR instructions at regional dispatch centers but had not adopted formal, evidence-based guidelines for identification of OHCA, quality improvement or training. They instituted a T-CPR bundle of care based on AHA guidelines for T-CPR, including guideline-based protocols, training, data collection and feedback to two regional dispatch centers and analyzed before-and-after outcome data. Among the favorable outcomes seen in before-and-after analysis were: 9.3% increase in provision of T-CPR (95% CI, 4.9%–13.8%), all rhythm survival increase from 9% to 12% (aOR 1.47 [95% CI, 1.08–2.02]), survival after shockable rhythm 35% from 24.7% (aOR 1.70 [95% CI, 1.09–2.65]), and a favorable functional outcome of 8.3%, up from 5.6% (aOR 1.68 [95% CI, 1.13–2.48]).<sup>18</sup> Other cities have observed increases in bystander CPR, survival to discharge and good neurologic outcome after the initiation of T-CPR and T-CPR quality improvement/training protocols.<sup>19</sup>

Across the country, from Rochester to Seattle, communities have dramatically increased their cardiac arrest survival rate with programs that include dispatcher-assisted CPR, but T-CPR alone is not a panacea. There are, and likely will remain, many barriers to performance of bystander CPR including patient positioning and location and the ability of the bystander to physically perform effective compressions. Based on the experience of high-performance systems such as Seattle/Kings County and Rochester, T-CPR must be a part of a vibrant, robust EMD program with quality assurance and improvement, data collection and tracking and physician involvement. Public Safety Answering Points (PSAPs), the call centers responsible for answering calls to

an emergency telephone number for emergency services, must be provided the oversight, budget, staffing and training to accomplish the goals of evidence-based EMD, including T-CPR. Future directions of EMD may include CPR instructions provided via smart phone, use of drones to deliver AEDs and provide CPR instruction and feedback, and smartphone, social media-based deployment of CPR-trained Samaritans to public OHCA. These ideas have been explored and imagined in various settings and are the subject of active research efforts.

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# Comparison of EMS Provider In-Transit Performance and Exertion with Standard and Experimental Resuscitation Protocols during Simulated Out-of-Hospital Cardiac Arrest

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## ABSTRACT

**OBJECTIVE:** To assess the effect of a device-assisted out-of-hospital cardiac arrest (OHCA) resuscitation approach on provider performance during simulated transport.

**METHODS:** BLS and ALS providers were randomized into control and experimental teams. Subjects were fitted with wireless heart rate (HR) monitors. Control teams simulated with standard protocols and equipment; experimental teams with resuscitation-automating devices and goal-directed protocols. Chest compression quality, pulmonary ventilation, defibrillation, and medication administration tasks were monitored; subjects' HR's were continuously recorded.

**RESULTS:** Ten control and ten experimental teams completed the study (20 EMT-B's; 1 EMT-I, 8 EMT-C's, 11 EMT-P's) with similar resting HR's and age-predicted maximal HR's (mHR). All exhibited suboptimal in-transit resuscitation quality during initial simulations; HR did not differ significantly between the groups. Experimental teams exhibited improved chest compression and ventilation quality during transport along with lower subject HR.

**CONCLUSION:** OHCA resuscitation automation improved the in-simulation quality of critical in-transit tasks and reduced provider exertion.

**KEYWORDS:** Medical Simulation, Cardiac Arrest, Mechanical CPR, Workload

## INTRODUCTION

The delivery of meaningful cardiopulmonary resuscitative care during patient transport is challenging.<sup>1-3</sup> While in motion, even basic tasks and actions can become complicated and difficult regardless of provider experience and skill.<sup>3</sup> In order to explore potential ways to assist Emergency Medical Service (EMS) providers in their delivery of high-quality care in challenging pre-hospital environments, investigators initiated the Standardized Treatment and Optimal Resuscitation through Mechanical Adjuncts (STORM) program.<sup>4,5</sup> Focusing on the aspects of cardiac resuscitation repeatedly observed to be suboptimal,<sup>6,7</sup> the program studied

the experimental, goal-directed integration of BLS and ACLS principles into an alternative algorithmic approach for standardized and streamlined patient care.

The overall STORM program employed a study design that incorporated on-scene and in-transit simulation of pre-hospital OHCA resuscitation; study metrics were chosen for objective assessment of resuscitation task performance quality and workload in mixed-response (BLS-ALS) teams. This manuscript presents the *in-transit* aspects of the program's simulation-based comparison of EMS teams employing standard and experimental OHCA resuscitation protocols and equipment.

## METHODS

### Study Design

The study used a randomized, non-blinded, controlled experimental design. The research program was conducted at a hospital-affiliated academic simulation center. Emergency Medical Technicians (EMT) licensed at the Basic (B), Intermediate (I), Cardiac (C) or Paramedic (P) levels were recruited through regional EMS events and networks. Interested and qualifying subjects were paired and scheduled as two-provider teams (one EMT-B and one EMT-I/C/P). The overall STORM program and the in-transit component were approved by the hospital institutional review board.

### Study Protocol and Metrics

Accepted formats for reporting of cardiopulmonary resuscitation quality (*e.g.*, guidelines set forth by Kramer-Johansen et al.<sup>8</sup>) were reviewed and modified for programmatic objectives. Core performance metrics were selected *a priori* for chest compression (hand position, depth, rate and release) and pulmonary ventilation (rate, volume). Proportions of transport time without any compressions and without adequate compressions were selected as composite performance metrics.

The STORM research protocol<sup>4,5</sup> specified unobtrusive measurement of subject exertion and effort during on-scene and in-transit resuscitation through measures of physiologic stress and self-reports of perceived workload on validated assessment tools (NASA-TLX and Borg RPE). Investigators configured Polar H7 (Polar Electro, Lake Success, NY) chest strap systems to monitor subjects' heart rates (HR) through

wirelessly-paired iPod Touch devices (Apple, Cupertino, CA) running DigiFit app software (DigiFit, Santa Barbara, CA). The iPods were configured to store and export summary reports of subjects' monitoring duration, average HR and time-vs.-HR plot for each simulation.

### Experimental Resuscitation Protocol and Equipment

Provider-assistive devices were reviewed for specific OHCA tasks, *i.e.*, chest compression,<sup>3,9</sup> defibrillation,<sup>10,11</sup> advanced airway management,<sup>12-14</sup> pulmonary ventilation,<sup>15</sup> vascular access, and medication administration.<sup>16</sup> The program built on these efforts and developed a systems-based, experimental re-engineering of OHCA response. Specifically, a step-wise algorithm to enable small teams to expeditiously perform multiple complex interventions was designed with a mnemonic aid and modular assortment of select equipment (see **Figure 1**). The experimental equipment setup consisted of the following devices: automated chest compressor (LUCAS 2, Jolife AB / Physio-Control, Lund, Sweden), supraglottic airway device (King LT, Kingsystems, Noblesville, Indiana; Aura-I ILMA without endotracheal tube, Ambu, Ballerup, Netherlands), battery-powered portable mechanical ventilator (EPV-200, Allied Healthcare Products, St. Louis, Missouri), powered intraosseous access device (EZ-IO, Vidacare, San Antonio, Texas), defibrillator with AED mode (Zoll R

series +, Zoll, Chelmsford, Massachusetts) and simulated ACLS medications (SimuAids, Saugerties, New York). Fully in compliance with American Heart Association life support guidelines, the protocol and equipment selection were simulation-tested on the SimMan 3G simulator (Laerdal, Wappingers Falls, NY) and recursively revised by investigators for utility, usability and safety.

### Study Sessions

Standardized preparatory instructions were emailed prior to study sessions. Subjects were consented, randomly assigned as a team to either the control or experimental group, oriented to the simulation environment, and surveyed on demographic and licensing information, resuscitation training and experience, current practice setting, and previous simulation exposure. Each subject was fitted with a HR monitor and tested for signal transmission and accuracy of DigiFit HR measurements. After passive exposure to a relaxing nature video presentation for one minute, each subject's stable resting HR was recorded over a minute and his/her age-predicted maximal HR (mHR) was calculated with the Tanaka formula.<sup>17</sup>

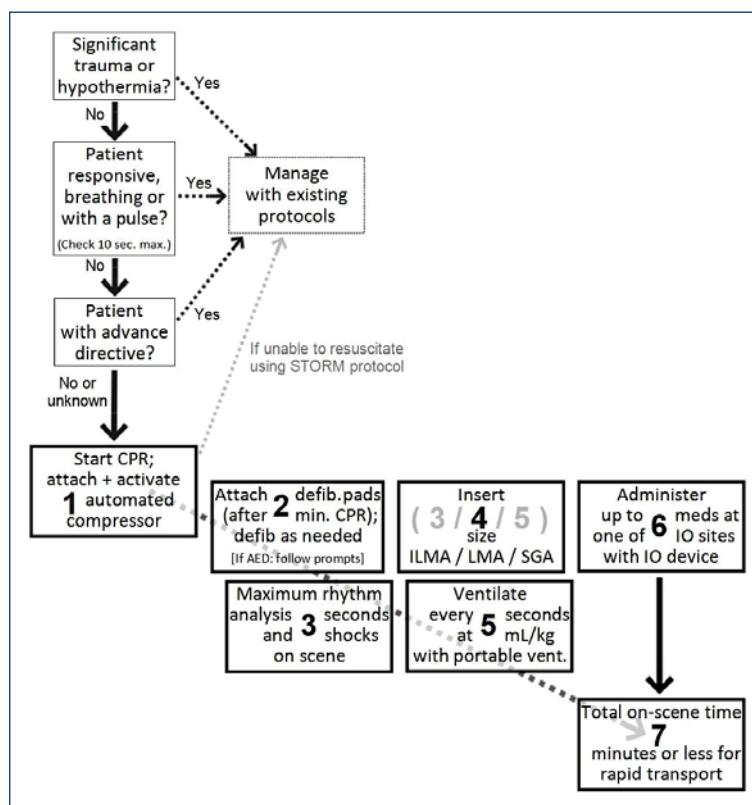
Subjects were brought into the study area at the start of their first simulations then instructed to resuscitate and transport a simulated OHCA patient. While being videotaped and monitored for performance and HR, study teams performed simulated OHCA resuscitation with transport of the manikin 250 feet through an office building on an ambulance stretcher.

Between the first and second simulations, control teams completed a 35-minute high-performance cardiopulmonary resuscitation review with hands-on manikin compression training and real-time objective feedback. The experimental group's intervention consisted of a 35-minute presentation on the program's alternative pre-hospital OHCA resuscitation approach; subjects completed didactic and hands-on training with the experimental protocol and associated equipment. Second simulations (with the same OHCA scenario as first simulations) were completed by control and experimental groups immediately after the just-in-time training interventions; performance metrics and HR data were collected in real time.

### Data Analysis

Subject demographics, clinical and training experience were compared between study groups for failure of randomization with Fisher exact and Mann-Whitney *U* tests. Teams' resuscitation performance data were extracted from audiovisual records using StudioCode (SBG, Camarillo, CA). These data were synchronized with the manikin log dataset and analyzed with Excel (Microsoft, Redmond, WA); medians and

**Figure 1.** Experimental pre-hospital sudden cardiac arrest resuscitation protocol with assistive devices.



interquartile ranges (IQRs) were calculated. Performance changes ( $\Delta$ ) within each study team from first simulation to second simulation were determined along with the differences between control and experimental groups' changes [ $\Delta(\Delta)$ ]; Mann-Whitney  $U$  tests were completed with an alpha of 0.05 for significance on the within-group  $\Delta$  and between-group  $\Delta(\Delta)$  values. Subjects' DigiFit-exported HR plot image files were processed with DigitizeIt (Bormisoft, Brunswick, Germany) optical plot recognition (OPR) software to extract their HR data. Each subject's average HR during simulated patient transport was then used to determine his / her in-transit level of exertion; the subject's resting HR and age-predicted mHR were used to define his / her expected range of exertion. Within-subject changes in HR from baseline, e.g.,  $\Delta\text{HR}_1$  = simulation 1 HR - resting HR, and in percentage of mHR attained [ $\Delta\%$ mHR] were calculated for each simulation, where each subject acted as his/her own control; these data were used to derive between-group differences in  $\Delta\text{HR}$  and  $\Delta\%$ mHR for analysis with Mann-Whitney  $U$  tests.

## RESULTS

Twenty EMT-B's, one EMT-I, eight EMT-C's and eleven EMT-P's were recruited into 20 BLS-ALS teams over the two-year study period; seven recruited subjects who failed to present for study sessions were excluded. Control and experimental groups were similar in age and sex, clinical training, and simulation exposure. Levels of clinical experience were different for control and experimental ALS providers (supraglottic airway use,  $p<0.01$ ; mechanical ventilator use,  $p=0.05$ ; and intraosseous needle insertion,  $p<0.01$ ), see Table 1 for details.

Total simulation time and the duration of transit (as a percentage of simulation time) at baseline were similar (median and interquartile range [IQR] 1–3) at 1,174 (860–1,197) seconds and 8.9% (7.1%–9.9%) for control groups, and 1,060 (993–1,217; NS) seconds and 9.1% (6.6%–11.4%; NS) for experimental groups. Total resuscitation time was shorter in second simulations ( $p\leq0.01$  for both groups) without changes in duration of transit time (NS for both groups).

Control and experimental groups performed chest compressions at baseline without significant differences in hand position, depth, rate and chest release; proportions of in-transit resuscitation time without adequate compressions were similarly high for both groups (NS). Pulmonary ventilation was generally inadequate by all teams (NS); defibrillations and medications were infrequently administered during transport (data not shown). Control teams did not exhibit changes in compression or ventilation metrics across simulations. During second simulations, teams using the experimental protocol and equipment performed deeper compressions (+19mm [15–26mm,  $p<0.01$ ]) with better release and a trend toward faster compressions; their change in in-transit resuscitation proportion without adequate compressions did not attain significance ( $p=0.11$ ). Experimental teams improved their minute

ventilation volumes during second simulations (+2,893mL/min [2,120–3,670mL/min,  $p<0.01$ ]). The within-group changes across simulations for compression depth, chest release and ventilation rate were significantly different between control and experimental groups, see Table 2 for details.

Both resting HR and age-predicted mHR did not differ significantly across study groups or by provider level. During first simulation transports, the median change in average HR, i.e.,  $\Delta\text{HR}$  from resting HR, was +80.7bpm (72.9–92.1bpm) and +66.7bpm (53.0–83.1bpm) for control BLS and ALS subjects, respectively. Experimental BLS and ALS subjects displayed similar increases in average HR during first simulation transports, and there was no significant difference in the percentage of age-predicted mHR attained by control and experimental teams (comparison data not shown).

Control teams'  $\Delta\text{HR}$  during second simulation transports were not different from their first simulation  $\Delta\text{HR}$ . The experimental teams' second-simulation  $\Delta\text{HR}$  of -23.6bpm (-29.4– -11.3bpm) for ALS providers was significantly lower than their first-simulation  $\Delta\text{HR}$  ( $p=0.04$ ). Changes across simulations in percentage of mHR attained, i.e.,  $\Delta\%$ mHR, were different for control and experimental teams: BLS providers' median  $\Delta\%$ mHR: -5.1% (-10.9%– -0.3%),  $p<0.01$ , relative to controls' +3.0% (2.4%–7.3%); ALS providers: -12.3% (-16.0%– -6.1%),  $p=0.02$ , relative to controls' +0.2% (-5.3%–2.6%), see Table 3.

## DISCUSSION

Findings from the STORM program's completed research components suggest that an experimental, device-assisted protocol may improve the quality of select *on-scene* resuscitative tasks while reducing provider workload without similar improvements from a control, high-performance CPR training intervention.<sup>4,5</sup> In-transit study subjects' sub-optimal baseline resuscitation performances during patient transport were consistent with the poor resuscitative quality observed in previous live<sup>1</sup> and simulation<sup>2</sup> investigations. Although limited to 250 feet of stretcher-assisted movement over even terrain in approximately 1.5 minutes, study teams using standard protocols and equipment consistently failed to meet AHA-specified chest compression rates and depths as well as pulmonary ventilation rates and volumes.

Despite this poor clinical performance, subjects' HR's generally doubled from resting rates during the transportation phase of study simulations and registered at approximately 80% of their age-predicted maximal heart rates. In healthy individuals, this level of exertion and physiologic activation could be concerning with respect to their ability to function effectively as EMS providers – equivalent levels may be hazardous in pre-hospital workers with cardiopulmonary comorbidities.

A structured and hands-on intervention for high-performance CPR failed to meaningfully improve compressive

**Table 1.** Comparison of subjects' demographic, clinical experience and previous training characteristics by study group and provider level.

Subject Characteristic (units)	Control Group (median and inter-quartile ranges unless specified otherwise)		Experimental Group (median and inter-quartile ranges unless specified otherwise)		p <sup>v</sup>	
	BLS provider	ALS provider	BLS provider	ALS provider	BLS provider	ALS provider
<b>Demographic Information</b>						
Age (years)	25.5 (23.3–27.8)	32.5 (28.0–44.5)	25.0 (24.0–26.0)	31.0 (26.5–33.8)	0.91	0.47
Gender (female, %)	10%	10%	20%	0%	1 <sup>o</sup>	1 <sup>o</sup>
Primary current clinical role (n)	EMT-B: 10	EMT-I: 0 EMT-C: 2 EMT-P: 8 (RN: 1)	EMT-B: 10	EMT-I: 1 EMT-C: 6 EMT-P: 3 (RN: 2)	1 <sup>o</sup>	1 <sup>o</sup>
Pre-hospital clinical employment (years)	2.0 (1.3–2.8)	5.0 (5.0–9.0)	3.0 (1.6–4.8)	7.0 (6.0–12.5)	0.26	0.43
Pre-hospital patient load (patients per week)	35.0 (15.0–42.3)	5.0 (4.3–10.0)	15.0 (7.6–23.8)	22.5 (8.5–25.0)	0.10	0.10
<b>Clinical Experience</b>						
Out-of-hospital cardiac arrest resuscitation in primary provider role (n)	0.0 (0.0–4.0)	35.0 (10.5–50.0)	1.5 (1.0–16.5)	20.0 (11.3–43.8)	0.20	0.97
External CPR chest compression (patients)	0.0 (0.0–1.8)	35.0 (2.8–50.0)	1.5 (1.0–12.3)	22.5 (11.0–43.8)	0.14	0.97
Automated chest compression device application (patients)	0.0 (0.0–0.8)	9.0 (2.0–10.0)	0.5 (0.0–2.0)	1.5 (0.0–6.8)	0.43	0.13
Semi-automated / manual defibrillation (patients)	0.0 (0.0–0.0)	16.0 (1.0–45.0)	0.0 (0.0–1.5)	7.5 (3.5–23.8)	0.62	0.82
Bag-valve-mask ventilation (patients)	0.5 (0.0–1.8)	40.0 (7.5–50.0)	3.0 (1.0–16.5)	27.5 (11.0–63.8)	0.09	0.85
Endotracheal intubation (patients)	0.0 (0.0–0.0)	16.5 (0.3–40.0)	0.0 (0.0–0.0)	5.5 (3.0–41.3)	0.73	0.85
Supraglottic airway device use (patients)	0.0 (0.0–0.0)	5.0 (3.0–7.8)	0.0 (0.0–0.0)	0.0 (0.0–1.8)	0.73	<0.01
Mechanical ventilator use (patients)	0.0 (0.0–0.0)	4.5 (1.3–14.3)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	1	0.05
Intravenous catheter insertions (patients)	0.0 (0.0–0.0)	40.0 (2.8–387.5)	0.0 (0.0–0.0)	75.0 (16.3–150.0)	1	0.67
Intraosseous needle insertions (patients)	0.0 (0.0–0.0)	17.5 (6.0–38.8)	0.0 (0.0–0.0)	0.5 (0.0–4.3)	0.73	<0.01
<b>Previous Training (In-servicing)</b>						
Automated chest compression device (%)	20%	80%	50%	50%	0.27 <sup>o</sup>	0.35 <sup>o</sup>
Semi-automated/manual defibrillation (%)	90%	100%	70%	90%	0.47 <sup>o</sup>	1 <sup>o</sup>
Endotracheal intubation (%)	70%	100%	30%	100%	0.14 <sup>o</sup>	1 <sup>o</sup>
Supraglottic airway device (%)	40%	100%	80%	100%	0.14 <sup>o</sup>	1 <sup>o</sup>
Mechanical ventilator use (%)	0%	90%	10%	40%	0.73 <sup>o</sup>	0.06 <sup>o</sup>
Intravenous catheter insertion (%)	50%	100%	20%	100%	0.27 <sup>o</sup>	1 <sup>o</sup>
Intraosseous needle insertion (%)	40%	100%	20%	80%	0.47 <sup>o</sup>	0.47 <sup>o</sup>
<b>Simulation Experience (%)</b>						
	None: 40% Limited: 30% Moderate: 30% Significant: 0%	None: 10% Limited: 0% Moderate: 30% Significant: 60%	None: 30% Limited: 20% Moderate: 30% Significant: 10%	None: 0% Limited: 20% Moderate: 50% Significant: 20%	1 <sup>o</sup>	0.15 <sup>o</sup>

Table excerpted from Choi B, Asselin N, Pettit CC, Dannecker M, Machan JT, Merck DL et al. "Simulation-based Randomized Comparative Assessment of Out-of-Hospital Cardiac Arrest Resuscitation Bundle Completion by Emergency Medical Service Teams Using Standard Life Support or an Experimental Automation-assisted Approach."

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<sup>v</sup>Mann-Whitney U test unless specified otherwise   <sup>o</sup>Fisher exact test (2x2, 2x3 or 2x4)

**Table 2.** Comparison of in-transit simulated resuscitation task performance and quality by study group during first and second simulations.

Resuscitation Quality Metric (units; [recommended performance], if specified <sup>1</sup> )	Control Group (Standard out-of-hospital cardiac arrest resuscitation protocol and equipment; median and inter-quartile ranges)				Experimental Group (Experimental out-of-hospital cardiac arrest resuscitation protocol and equipment; median and inter-quartile ranges)				Between-simulation Δ by group (Δ[Δ]) p <sup>ψ</sup>
	Simulation 1 (n=9)	Simulation 2 (n=10)	Δ	p <sup>ψ</sup>	Simulation 1 (n=10)	Simulation 2 (n=10)	Δ	p <sup>ψ</sup>	
<b>Simulation</b>									
Total simulation duration (sec)	1,174 (860–1,197)	689 (562–801)	-339 (-448–-186)	0.01	1060 (993–1,217)	770 (734–871)	-309 (-402–-178)	<0.01	0.85
<b>Transportation</b>									
Duration of transit (sec)	86 (83–107)	98 (84–102)	+4 (-3–13)	0.87	101 (67–142)	100 (88–103)	-7 (-40–35)	0.80	0.90
Duration of transit (% of total simulation duration)	8.9% (7.1%–9.9%)	12.4% (10.9%–17.9%)	+5.1% (4.3%–6.7%)	0.04	9.1% (6.6%–11.4%)	12.5% (11.4%–13.3%)	+3.9% (0.8%–6.7%)	0.05	0.35
Transportation speed (mph for 250ft transport)	2.0 (1.6–2.1)	1.7 (1.7–2.0)	-0.1 (-0.3–0.0)	0.84	1.7 (1.2–2.6)	1.7 (1.7–1.9)	+0.1 (-0.9–0.4)	0.82	0.97
<b>In-transit Chest Compression</b>									
Proportion of compressions with proper hand position	1.00 (1.00–1.00)	1.00 (1.00–1.00)	0.00 (0.0–0.0)	1	1.00 (1.00–1.00)	1.00 (1.00–1.00)	0.00 (0.0–0.0)	1	1
Compression depth (mm; [>50 mm])	25 (24–31)	30 (28–35)	+4 (0–11)	0.39	25 (23–31)	47 (44–50)	+19 (15–26)	<0.01	<0.01
Compressions delivered per minute (cpm; [>100 cpm])	81 (80–90)	81 (69–102)	0 (-10–28)	0.87	68 (26–100)	101 (98–102)	+34 (-3–74)	0.09	0.13
Chest release to <1cm from starting position (%; [100%])	99% (91%–99%)	95% (86%–99%)	-1% (-7%–0%)	0.37	99% (54%–100%)	100% (100%–100%)	+1% (0%–46%)	0.05	0.03
In-transit resuscitation proportion without any compressions	0.00 (0.00–0.19)	0.00 (0.00–0.00)	0.00 (-0.19–0.00)	0.49	0.11 (0.00–0.46)	0.00 (0.00–0.00)	-0.11 (-0.46–0.00)	0.02	0.13
In-transit resuscitation proportion without adequate compressions	1.00 (1.00–1.00)	1.00 (1.00–1.00)	0.00 (0.00–0.00)	0.71	1.00 (1.00–1.00)	0.96 (0.25–1.00)	-0.04 (-0.75–0.00)	0.11	0.11
<b>In-transit Pulmonary Ventilation</b>									
Minute ventilation volume (mL/min)	347 (0–1,459)	173 (0–702)	0 (-904–0)	0.71	117 (0–1,052)	3,670 (3,000–3,900)	+2,893 (2,120–3,670)	<0.01	<0.01
• Ventilation rate (bpm)	1.3 (0.0–3.9)	0.4 (0.0–2.8)	-0.0 (-1.6–0.0)	0.60	0.5 (0.0–2.7)	12.2 (11.9–12.5)	+11.3 (9.5–12.1)	<0.01	<0.01
• Ventilation volume (mL)	275 (0–400)	75 (0–434)	0 (0–100)	0.90	125 (0–390)	300 (250–325)	+75 (-52–269)	0.38	0.74

<sup>ψ</sup>Mann-Whitney U test <sup>1</sup>American Heart Association Basic Life Support and Advanced Life Support guidelines

Key: bpm = breaths per minute; cpm = compressions per minute; CPR = cardiopulmonary resuscitation; ft = feet; min = minute; mL = milliliters; sec = second

and ventilatory task performance during patient transport; repeating the simulation scenario only reduced on-scene time. In contrast, the experimental approach resulted in deeper compressions and increased pulmonary ventilation during the transport phase of care. Additionally, experimental BLS and ALS providers' heart rates did not increase as much as those of control subjects. Taken together, these findings indicate that device-assisted automation of select OHCA resuscitation tasks can improve in-transit performance on common CPR metrics while requiring less exertion of provider teams. This finding is of particular interest as the optimal duration of pre-hospital OCHA scene resuscitation prior to transport is unclear.

In light of the time-critical and error-intolerant nature of

successful cardiocerebral resuscitation, the ever-increasing complexity of healthcare, and the steadily expanding scientific insight into human performance, efforts to augment provider capabilities are likely to be beneficial. The experimental OHCA resuscitation approach demonstrated its viability and potential as a mechanism to advance patient care delivery during challenging, transitive periods. On-going investigations are attempting to overcome the significant challenges<sup>18</sup> associated with translating these benefits to real-world settings. Further study of the experimental approach for its implications on healthcare work conditions and occupational hazards<sup>19,20</sup> is planned; future application testing may address rural, remote, and/or specialized environments.

**Table 3.** Comparison of in-transit provider heart rates by study group during first and second simulations.

	Control Group (Standard out-of-hospital cardiac arrest resuscitation protocol and equipment; median and inter-quartile ranges)				Experimental Group (Experimental out-of-hospital cardiac arrest resuscitation protocol and equipment; median and inter-quartile ranges)				Between group p <sup>ψ</sup>				
<b>Basic Life Support provider (EMT-B; n=10)</b>													
Workload Metric (units)													
Resting heart rate (bpm)	73 (67–76)				77 (67–85)				0.45				
Predicted maximal heart rate (mHR; bpm) <sup>ω</sup>	190 (189–192)				191 (190–191)				0.91				
Resting heart rate as percentage of mHR (%)	38.2% (35.4%–42.2%)				40.5% (35.1–44.7)				0.62				
	Simulation 1	Simulation 2	Δ	p <sup>ψ</sup>	Simulation 1	Simulation 2	Δ	p <sup>ψ</sup>					
In-simulation change in average heart rate during transport (ΔHR from resting heart rate; bpm)	+80.7 (72.9–92.1)	+82.8 (77.8–94.0)	+5.8 (4.6–13.8)	0.49	+64.6 (55.9–83.8)	+57.0 (41.2–63.5)	-9.7 (-20.8–0.6)	0.24	<0.01 <sup>λ</sup>				
In-simulation average heart rate during transport as percentage of mHR (%)	79.8% (77.7%–86.6%)	83.1% (80.7%–87.2%)	+3.0% (2.4%–7.3%)	0.31	77.2% (66.2%–85.6%)	70.2% (56.9%–77.8%)	-5.1% (-10.9%–0.3%)	0.31	<0.01 <sup>λ</sup>				
<b>Advanced Life Support provider (EMT-I/C/P n=10)</b>													
Workload Metric (units)													
Resting heart rate (bpm)	70 (62–81)				75 (70–79)				0.67				
Predicted maximal heart rate (mHR; bpm) <sup>ω</sup>	185 (177–188)				186 (184–189)				0.47				
Resting heart rate as percentage of mHR (%)	36.8% (35.5%–44.0%)				39.6% (36.9–43.2)				0.76				
	Simulation 1	Simulation 2	Δ	p <sup>ψ</sup>	Simulation 1	Simulation 2	Δ	p <sup>ψ</sup>					
In-simulation change in average heart rate during transport (ΔHR from resting heart rate; bpm)	+66.7 (53.0–83.1)	+67.8 (52.5–76.1)	+0.3 (-9.7–4.3)	0.94	+73.2 (52.9–76.1)	+43.4 (38.2–68.3)	-23.6 (-29.4–11.3)	0.04	0.02 <sup>λ</sup>				
In-simulation average heart rate during transport as percentage of mHR (%)	77.3% (73.9%–80.1%)	72.3% (70.1%–82.1%)	+0.2% (-5.3%–2.6%)	0.71	76.1% (70.6%–85.4%)	67.0% (62.8%–74.1%)	-12.3% (-16.0%–6.1%)	0.02	0.02 <sup>λ</sup>				

<sup>ψ</sup>Mann-Whitney U test   <sup>ω</sup>Predicted maximum heart rate = 208 – (0.7 × age) using Tanaka formula [14]<sup>λ</sup>Between-simulation ΔHR or Δ% mHR by group (Δ[Δ]) Key: bpm = beats per minute; HR = heart rate

## LIMITATIONS

The research program budget and difficulties with subject recruitment limited the sample size, which resulted in a failure of randomization for ALS providers' levels of clinical experience. Healthy, young subjects were studied as impromptu two-provider teams without shared work backgrounds. The accuracy of HR data extraction by OPR is unknown. The simulation method and HR monitoring setup may have acted as confounders when studying subject performance and exertion; the ability of study findings to be translated to live settings is unknown. Provider performance and exertion were not evaluated inside EMS vehicles.

## CONCLUSION

An experimental SCA resuscitation approach with task-automating devices improved the in-simulation quality of select in-transit task performance and reduced EMS provider exertion.

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# Pilot Study of the Effect of a Protocol of 30 Minutes of Scene Care in Out-of-Hospital Cardiac Arrest in Rhode Island

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## ABSTRACT

**BACKGROUND:** Improved outcomes in out-of-hospital cardiac arrest (OHCA) have been demonstrated with increased focus on high-quality CPR. In 2017, the RI Department of Health mandated 30 minutes of on-scene CPR for atraumatic cardiac arrest victims. The effects of this intervention are unknown.

**METHODS:** An EMR query was performed to identify OHCA cases presenting to a Lifespan hospital during the months of March 2016 (pre-intervention) and March 2017 (post-intervention) with an estimated severity index of 1 or cardiac arrest.

**PRIMARY RESULTS:** 63 cases of OHCA were identified. ROSC at ED presentation increased in the post-intervention period, though it was not statistically significant (12% vs 22%, CI = -0.01,0.25 vs. 0.09,0.35). Endotracheal intubation and ACLS medication use increased as well.

**CONCLUSIONS:** This pilot study of a protocol emphasizing on-scene CPR in urban Rhode Island resulted in changes in pre-hospital OHCA management and there was a trend toward increased ROSC in the post-intervention period.

**KEYWORDS:** Cardiac Arrest, Emergency Medical Services, ROSC

## INTRODUCTION

Over the past 10 years, studies focusing on the provision of pit-crew style "high-quality CPR" have suggested that there are significant benefits from "high-quality CPR," compared with traditional CPR among patients with out-of-hospital cardiac arrest (OHCA). These benefits include increased survival to admission and hospital discharge, as well as improved neurologic function at discharge.<sup>1,2</sup> Focus on the provision of "high-quality CPR" is predicated on the idea that initial on-scene resuscitation eliminates potential degradation in CPR quality due to patient moving, transport, packaging, and other factors. These studies have mostly been conducted in high-functioning emergency medical service (EMS) systems with aggressive medical control and leadership, central organization and a high proportion of

**Table 1.** Comparison of Rhode Island EMS scope of practice in OHCA.

Intervention	EMT Basic	AEMT - Cardiac	Paramedic
Airway	Bag Valve Mask	Bag Valve Mask	Bag Valve Mask
	Supraglottic Airway	Supraglottic Airway	Supraglottic Airway
		Endotracheal Intubation	Endotracheal Intubation
Vascular Access	None	Intraosseous	Intraosseous
		Intravenous	Intravenous
Medications	No ACLS	Basic ACLS:	Basic ACLS plus:
		Epinephrine	Magnesium
		Lidocaine	Vasopressors
		Amiodarone	Procainamide, etc
Electrical Therapy	Automated External Defibrillation	Manual Defibrillation	Manual Defibrillation

paramedic-level EMS personnel. Rhode Island EMS providers are predominantly "EMT-Cardiac" level, which is a designation unique to Rhode Island and typically permits all BLS-level interventions, as well as ACLS medications and airway techniques, see **Table 1** for EMS scope of practice in OHCA. Additionally, prior studies have been confounded by increased rates of cardiac catheterization, new advanced airway equipment, hospital triage, and other changes.

Seeking to improve outcomes from OHCA, in March of 2017, the Rhode Island Department of Health instituted new protocols requiring EMS providers to stay on the scene of an atraumatic cardiac arrest for 30 minutes, or until return of spontaneous circulation (ROSC) was achieved.<sup>3</sup> Traditionally, EMS providers have been taught to transport OHCA patients to hospitals quickly, so mandating them to remain on scene for up to 30 minutes is controversial. According to the American Heart Association (AHA), approximately 355,000 people each year suffer an OHCA event (110 events per 100,000 population). Studies vary, but the overall survival rate for OHCA is anywhere from 6-12%<sup>4,5</sup> nationally. Extrapolating these statistics to Rhode Island's population of 1 million, an estimated 1,100 Rhode Islanders are having OHCA each year, or 3 people every day.

Based on prior research demonstrating improved outcomes after the implementation of protocols centered on high-quality CPR, we hypothesized that an increased rate of ROSC at presentation to the ER would be seen after similar protocols were established in Rhode Island. We expected high compliance with mandatory 30-minute on-scene CPR, as well as increased use of medications and advanced airway techniques.

## STUDY DESIGN AND METHODS

This study was conducted at Lifespan affiliate hospitals in Rhode Island: Rhode Island Hospital (a tertiary-level, academic hospital), The Miriam Hospital, and Newport Hospital. New CPR protocols were instituted in March of 2017. To evaluate these protocols, OHCA patients were identified via electronic medical record query. Period 1 was chosen as March 2016, approximately 1 year prior to the institution of new CPR protocols. Period 2 was chosen as March 2017, the first month after institution of new CPR protocols. The same month pre- and post-intervention was chosen to help limit the seasonal variability of ER presentations. The study protocol was approved by the institutional review board.

Inclusion criteria for brief chart review included: estimated severity index<sup>6</sup> of 1, or chief complaints of "ventricular fibrillation", "VF", "cardiac arrest", "CPR", and "code blue." Exclusion criteria included age <18, pregnant patients, prisoners, and transfers. Patients who had OHCA while en route to the hospital were also excluded, as were post-arrest transfers from other facilities. The initial EMR query identified 214 patients. These charts were reviewed by one of the authors (JT). Based on the EMS report, and ED physician and nursing notes, those records deemed to be due to non-cardiac causes were then excluded, such as stroke, trauma, primary respiratory arrest, and overdose. When unclear, the patients were assumed to be cardiac in etiology. Post-mortem reports, inpatient notes, discharge summaries and other inpatient data were not reviewed. After exclusion of non-OHCA patients, the total number of patients in period 1 was 25 and period 2 was 38.

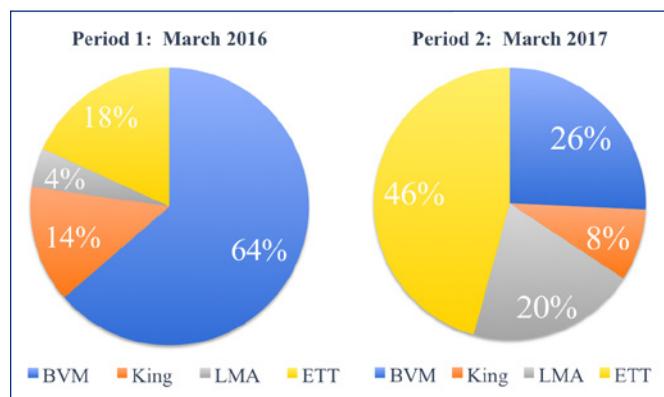
These OHCA charts (n=63) were then reviewed further and data was abstracted, including EMS run sheet narratives and timestamps, EMS provider level (EMT-B, "cardiac" or paramedic), EMS agency distance from hospital (median EMS station distance to hospital), patient demographics and comorbidities, use of automated CPR devices, airway management methods, duration of CPR, patient cardiopulmonary status at presentation to the ER, return of spontaneous circulation (ROSC), patient disposition (to ICU, catheterization lab, morgue, etc.), and ER length of stay. The primary outcome for the study was ROSC at presentation to the ER, i.e., if the patient had a pulse upon arrival to the ER after receiving treatment by EMS providers. Whether the patient received less than 30 minutes by EMS, or greater than or

equal to 30 minutes of CPR was coded in a binary fashion. Data were analyzed by the new CPR protocol periods (period 1 = pre, period 2 = post). Data are reported descriptively as counts or percentages with the appropriate 95% confidence intervals (CI) calculated.

## RESULTS

63 total patients had a complete chart review performed (Figure 1). Average age was 64 years, and 58% of the patients were male. 15 patients received bystander CPR. CPR devices were commonplace, having been used in nearly half of resuscitations with data available. Initial shockable rhythms occurred in 18 of 58 cases with complete data. EMS was dispatched to a patient's home in 68% of cases. 81% of patient EMR charts had EMS charts scanned-in and available for review.

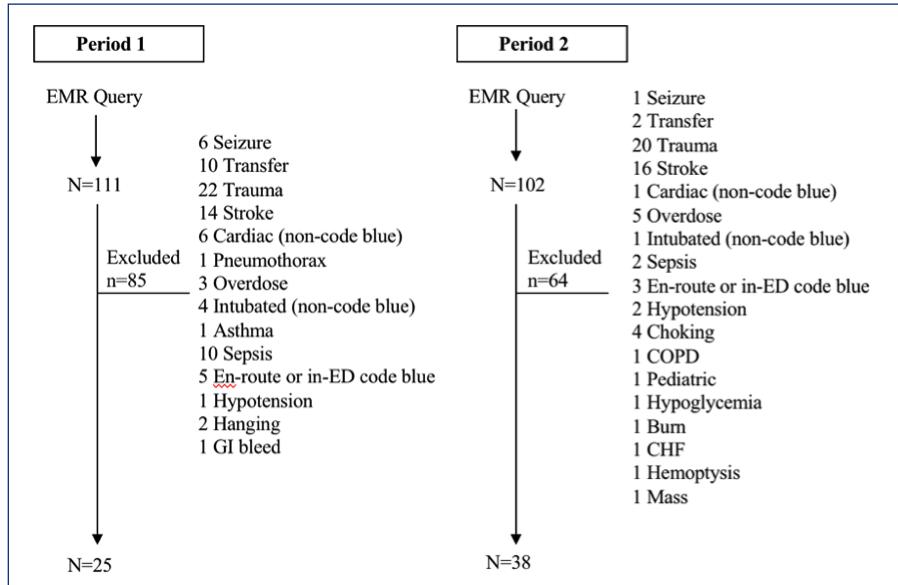
**Figure 1.** Comparison of prehospital airway use between the two study periods. Bag Valve Mask (BVM), King LT (King), Laryngeal Mask Airway (LMA), Endotracheal Tube (ETT).



11 of these patients had ROSC at presentation to the ER. 3 of these patients were in period 1, while 8 of them were in period 2, though this difference in ROSC was not statistically significant (12% vs 22%, CI = -0.01,0.25 vs. 0.09,0.35). In period 1, none of the patients received 30 minutes of CPR, while in period 2, 19 of 37 patients received 30 minutes of CPR.

Airway use changed dramatically between the time periods (Figure 2). The majority of EMS airway management consisted of bag-valve mask (BVM) use in period 1 (14 of 22) while endotracheal tubes were significantly more common in period 2 (16 of 36). EMS attempted intubation in 10 cases in period 1, and were successful in 4 cases (40% success rate; 95%CI: 21, 59), while in period 2, intubation was attempted in 23 cases and successful in 16 (70% success rate; 95%CI: 55, 85). Medication use was also altered, the median milligrams (mg) of epinephrine in period 1 was 2mg, while it increased to 5mg in period 2; with some patients receiving as much as 12mg of epinephrine.

Figure 2. Inclusions and exclusions for both study periods.



All patients who had ROSC at presentation to the ER (n=11) survived to admission to the hospital. Most commonly, patients were admitted to the MICU (n=6), followed by the CCU (n=4). Notably, there was an additional cohort of patients who did not have ROSC at presentation to the ER, but did survive to admission (n=8); 5 of these 8 patients were in period 1, and 2 of the 3 patients who had no ROSC at presentation to the ED but did survive to admission had ROSC for EMS but had lost a pulse upon presentation to the ER.

## DISCUSSION

This is the first study on the new CPR protocols in Rhode Island. More broadly, prior studies on “high-quality” CPR have studied CPR bundled with other interventions, such as increased triage to PCI centers, have simultaneously implemented rigorous CPR training for first responders and EMS providers, and have been confounded by additional interventions, such as the implementation of new airway equipment. However, these studies have reported improved outcomes including better neurologic outcome at discharge and higher rates of ROSC.<sup>1,2,7-13</sup> These studies have also been in high-functioning EMS systems with rigorous medical control and a high proportion of paramedic-level EMS providers. It is important to note that our study is limited by lack of control for patient arrest characteristics, age and comorbidities, provider level, and other factors.

This observational, retrospective pilot study reported outcomes from 63 patients suffering from OHCA treated by 16 different departments with predominantly EMT-Cardiac level providers. While the number of patient cases of OHCA was relatively limited in this study, and its retrospective nature gives rise to several limitations, we did observe trends

in management. Over the study period, there was an increase in the number of patients receiving 30 minutes of CPR in compliance with the new RI Department of Health protocols, an increase in the use of advanced airways and increase in the amount of medications patients received.

With respect to airway management, supra-glottic devices and endotracheal tubes were more common in period 2 than period 1. This likely owes to the fact that EMS providers feel that bag valve mask ventilation of patients for 30 minutes is inferior to advanced airway devices and may be difficult with vomiting or the effort required for a good face-mask seal for the entire 30 minutes. Prior literature has suggested that patients with advanced airways, conversely, have worse outcomes. For

example, in one retrospective cardiac arrest database, among 10,691 OHCA patients, survival was highest among patients treated with BVM compared with other devices (OR 1.31).<sup>7</sup> While this may indicate that patients who were more likely to have a good outcome did not require placement of an advanced airway, such as those who woke up immediately after defibrillation and therefore did not require additional airway management, it is also possible that increased focus on patient airways may have taken focus and time away from CPR. Studies have shown that pre-hospital providers sometimes pause compressions for intubation; one study found a median pause of 109 seconds.<sup>8</sup> Research has found pauses in CPR to be deleterious – one recent study of 319 defibrillator OHCA cases, showed that increasing peri-shock pause was associated with decreased survival.<sup>9</sup> Though more patient intubations were attempted during period 2 than period 1, we cannot comment on success rates of intubation given the small n, though success rates of pre-hospital intubation have been cited as anywhere between 60 and 93%.<sup>10</sup>

During pre-hospital codes, patients received a variety of medications, including epinephrine, naloxone, sodium bicarbonate, and glucose. One patient received as much as 12mg of epinephrine, which is of questionable utility. Prior studies have shown that epinephrine use during cardiac arrest is associated with increased rates of ROSC, though may ultimately worsen outcomes.<sup>9-12</sup> In these studies, patients receiving over 5mg of epinephrine had the lowest odds of survival (OR 0.23), relative to patients who did not receive epinephrine. This retrospective study is also subject to similar confounding – that is, that patients receiving more epinephrine had been pulseless for a longer period of time, which is certainly associated with a worse prognosis.

## LIMITATIONS

The study was limited by the fact that EMS agencies in Rhode Island began using the new CPR protocols at different time periods. This study was retrospective and may not account for confounders such as EMS training, new equipment and apparatus, although there was no system-wide institution of new protocols and procedures, as there has been in past studies. EMS chart availability was not uniform, which may also bias results. EMS providers are supposed to submit their reports for scan into the EMR, which does not reliably occur. Finally, researchers may have mis-categorized patients as victims of OHCA (or excluded them as non-OHCA patients) who were suffering from respiratory arrest, overdose or another process. While the treatment for OHCA and pulseless arrest is CPR, a primary process other than cardiogenic OHCA, such as overdose, might call for higher prioritization of other treatments, such as administration of naloxone or a secure airway. Patients suffering from respiratory arrest-induced OHCA could have worse outcomes when treated with "high-quality CPR" than patients with VF-induced OHCA, though this has not been studied.

## CONCLUSIONS

Overall, we found that EMS agencies are complying with 30-minute CPR protocols. More patients had ROSC at presentation to the ER and survived to admission in period 2, post-intervention, than did in period 1, though this difference was not statistically significant. Future directions for the project include abstraction of more data, including expanding periods 1 and 2 to include >1 year of data, as well as case-matching patients to more definitively determine the effects of CPR duration on patient outcomes at presentation, as well as neurologic function at discharge.

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## Disclaimer

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# Case Report: Intact Survival Following Prolonged Out-of-Hospital Cardiac Arrest Care

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**KEYWORDS:** Cardiac Arrest, Emergency Medical Services, Systems of Care

## CASE REPORT

A 57-year-old woman with a past medical history of diabetes, was found lying in bed and apneic by her partner, who activated 911. No bystander CPR was performed. An ambulance with two EMS providers, and a fire engine with three EMS providers, arrived on scene within 4 minutes of initial dispatch. The patient was found pulseless and apneic. Continuous manual compressions were performed by a single responder until a mechanical compression device was attached to the patient. The patient's airway was initially secured with an oropharyngeal airway (OPA) and ventilations administered via a bag-valve mask. The first electrocardiogram detected pulseless electrical activity. The OPA was removed in favor of successful placement of a laryngeal mask airway (LMA). Bag-valve ventilations were continued with high-flow oxygen.

After an unsuccessful IV attempt, an intraosseous (IO) device was used to establish access in the right humeral head and 1 milligram of epinephrine 1:10,000 was administered via IO push. A full cycle of CPR was performed and a second rhythm check detected ventricular fibrillation. A shock was delivered at 120 joules, bi-phasic, and an additional milligram of epinephrine was administered via IO push. The third rhythm check showed ventricular fibrillation and an additional shock was delivered at 150 joules, bi-phasic. Epinephrine and CPR were continued per ACLS protocols.

After 30 minutes of unsuccessful on-scene resuscitation EMS crews moved the patient via bag stretcher while the mechanical compression device continued chest compressions. EMS crews transferred care to emergency department personnel with CPR in progress 42 minutes after initial patient contact.

Upon arrival to the ED, the patient was without spontaneous respirations, and remained pulseless. Her pupils were fixed and dilated. The patient was intubated via direct laryngoscopy. The patient was noted to have a wide complex tachycardia without pulses. Defibrillation was attempted but unsuccessful. CPR was continued while the patient received lidocaine 100 mg, calcium gluconate 1g, insulin 10 units IV, and D50 IV. Amiodarone was subsequently administered, along with magnesium sulfate 1g IV. Return of spontaneous circulation (ROSC) was achieved but subsequently lost approximately 63 minutes after initial

EMS-patient contact. CPR was continued and the patient was next started on dopamine followed by norepinephrine. ROSC was re-achieved.

The patient's initial EKG showed a wide complex junctional rhythm with a rate of 75. Subsequent EKGs demonstrated a sinus tachycardia with a narrowed QRS complex and a RBBB. A bedside echocardiogram demonstrated no significant wall motion abnormality, no RV dilation, no pericardial effusion, and no evidence of pulmonary hypertension. A chest x-ray confirmed endotracheal tube placement and demonstrated pulmonary edema. Initial laboratory studies revealed an elevated creatinine (1.78 mg/dl) and glucose (485 mg/dl), and an anion gap of 19. The patient's wbc was 14,000, with 7% bandemia.

Additional history from the family revealed a prior hospital presentation for hypercalcemia, a recent thyroidectomy, and concern for parathyroid complications. The family also reported that the patient had been experiencing 2-3 days of severe diarrhea. Due to the severity of illness and recent surgical history, the patient was transferred to a tertiary care center via a critical care transport team.

During transport and at the tertiary care center, the patient became more alert, requiring sedation and analgesia, while the patient's blood pressure was tenuous and she received push-dose administration of epinephrine and titration of vasopressors. A CT scan of the chest and abdomen was negative for pulmonary embolism, but did demonstrate several rib fractures and a Thoracic vertebral fracture. Laboratory studies revealed mild hypokalemia and hypercalcemia. The patient was transferred to the Intensive Care Unit. A subsequent MRI did not show any cord signal abnormality.

## DISCUSSION

High quality CPR encompasses five key components: Minimizing interruptions in chest compressions, providing compressions of adequate rate and depth, avoiding leaning on the chest between compressions and avoiding excessive ventilation. A recent study<sup>1</sup> comparing on scene to transport chest compressions revealed that compressions during transport are significantly worse than on scene compressions. In an effort to enhance prehospital resuscitative efforts and improve survival from out-of-hospital cardiac arrest (OHCA) the RI Department of Health, Center for EMS, in conjunction with the RI Ambulance Service Advisory Board, updated the cardiac arrest protocol reflecting these priorities.

In March 2017 the RI Department of Health released new protocols<sup>2</sup> requiring EMS providers to remain on scene for

30 minutes for both witnessed and unwitnessed OHCA. This was prompted by the evidence supporting worsened outcomes with interruptions in compressions<sup>3</sup> which are associated with a decrease in coronary and cerebral perfusion pressures requiring up to a minute of continuous compressions to achieve sufficient perfusion pressures. By remaining on scene, EMS providers are able to focus on resuscitative efforts such as early epinephrine administration, airway management and most importantly, minimally interrupted CPR as opposed to focusing on packaging and transporting the patient to the hospital. The duration of scene time was determined through a literature search, showing cases of successful OHCA management with ROSC after long field resuscitation.<sup>4</sup>

As part of ongoing quality improvement efforts, data were collected (some presented in this journal) to better understand the impact of the RI EMS Protocol changes.<sup>5</sup> Prior to these protocol changes, standard practice was to "scoop and run" with OHCA patients. This generated some resistance to remaining on scene for an extended time, largely based upon the potential for increased resource utilization and need for mutual aid in busy systems. Public perception surrounding OHCA care was likely a major factor in this as well.

During the implementation phase excessive attention remained on the actual time on scene; however, as EMS providers became more comfortable with the protocol, the focus shifted to strategies to minimize interruptions in compressions and deliver high quality CPR. This "pit crew" approach to OHCA,<sup>6</sup> adopted in numerous EMS systems nationally, where providers treat patients aggressively at the site of collapse, has been associated with improved patient outcomes and increased rates of ROSC.<sup>6-8</sup>

Public and provider education, engagement of major stakeholders and engaged medical direction are key factors in implementation of protocols such as the "30-minute CPR protocol." As we move forward and collect prospective data we anticipate that a specific time requirement on scene may be enhanced by a protocol to resuscitate most OHCA on scene until ROSC or futility is achieved.

## CASE CONCLUSION

In the MICU the patient was weaned from vasopressors and was eventually extubated on hospital day 5, and placed in a brace for her spinal fracture. She required extensive Physical and Occupational Therapy, and was discharged on hospital day 25 to a skilled nursing facility. At the time of discharge, she was noted to have some mild cognitive deficits versus delirium of hospitalization. She was evaluated by cardiology and felt not to be a candidate for Automated Implantable Cardioverter Defibrillator placement, as there was little evidence her cardiac arrest was cardiogenic in nature. Based upon her most recent visits, we infer her Pittsburgh Cerebral Performance Category<sup>9</sup> (CPC) to be 2 – *Moderate disability but independent in activities of daily living*.

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## Disclaimer

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the Department of Emergency Medicine, Alpert Medical School of Brown University or the Newport Fire Department.

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# Pediatric Out-of-Hospital Cardiac Arrest in Rhode Island: Concepts and Controversies

TANYA SUTCLIFFE, MD; NICHOLAS ASSELIN, DO, MS; LINDA BROWN, MD, MSCE

## ABSTRACT

Pediatric out-of-hospital cardiac arrest (POHCA) is an infrequently encountered event by emergency medical providers, both across Rhode Island and nationally. The etiologies of these events differ from those in adult cardiac arrests and overall outcomes remain poor. The skills required by emergency medical providers to care for these patients are performed and practiced infrequently. Pediatric patients are also at further risk of serious adverse events secondary to challenges with airway management and variation in equipment sizing and weight-based medication dosing. Recent changes to Rhode Island Emergency Medical Services protocols, particularly the requirement for all non-traumatic cardiac arrests to be managed on scene for a minimum of 30 minutes, have led to discussion and controversy. As we aim to improve the quality of care delivered during these resuscitations through education, research and collaborative protocol development, it is important to recognize and remain focused on the unique aspects of these pediatric patients.

**KEYWORDS:** Pediatrics, Cardiac Arrest, Emergency Medical Services

## INTRODUCTION

Pediatric out-of-hospital cardiac arrests make up less than 10% of Emergency Medical Service (EMS) resuscitations in the field and are often associated with poor outcomes.<sup>1</sup> Adult literature for out-of-hospital cardiac arrests (OHCA) has demonstrated improvement in outcomes following longer durations of cardiopulmonary resuscitation (CPR) prior to transport.<sup>2</sup> This approach stems from an understanding that, in adults, high-quality and minimally-interrupted CPR and early defibrillation are the key to improved survival. As a result, some EMS systems have altered protocols to encourage aggressive on-scene resuscitation in cases of adult OHCA. This approach has been recently been applied to the pediatric population and, in the updated 2017 Rhode Island EMS protocols, 30 minutes of on-scene CPR for POHCA was endorsed. This change has resulted in further discussion and some controversy, given the heterogeneity of pediatric patients and the differences in the pathophysiology of pediatric and

adult cardiac arrests. In this article, we aim to examine the relevant literature and discuss the potential controversies that exist in the prehospital management of POHCA.

The American Heart Association (AHA) recently released new statistics reporting an annual incidence of EMS-assessed POHCA of approximately 7,000 cases compared to nearly 340,000 in adults.<sup>3</sup> With these relatively low numbers, despite medical advances and efforts to increase training in pediatric resuscitation, POHCA events have continued poor neurologically-intact survival rates. This is in stark contrast to increases in survival outcomes from pediatric in-hospital cardiac arrests, where data from the Get With the Guidelines-Resuscitation registry reported a nearly threefold improvement from 2000–2009 with no worsening in neurologic outcomes.<sup>4</sup>

While there is a steadily growing body of literature regarding POHCA, it remains limited when compared to adult studies. Most published studies are retrospective and observational in nature, while some include the extrapolation of more robust adult data to the pediatric population.<sup>5</sup> The primarily cardiac etiology and larger numbers of adult arrests makes these events easier to study and therefore protocolize, whereas the etiology of pediatric arrests varies based on age, pathophysiology, and mechanism, resulting in more complicated and variable management for medical providers.

Rhode Island is unique given its small geographic size, with a population of only 1,059,639 according to 2016–2017 estimates. Children under 18 years of age make up 19.7% of the population. There are currently 87 licensed EMS agencies in RI with 4,779 licensed practitioners and in 2017 there were 183,902 documented EMS calls reported. Due to its geography, most areas of Rhode Island have short transport times to the closest emergency department. However, there is only a single Level 1 Pediatric Trauma Center, which can be distant from more rural areas. This information must be considered when determining optimal EMS protocols.

## POHCA ETIOLOGY

One of the factors complicating improvement in POHCA care may be the variable etiology of these arrests. The most common causes of POHCA's are trauma, sudden infant death syndrome (SIDS), respiratory disease and submersion.<sup>6–8</sup> The majority of cardiac rhythms found in the field are asystole

and PEA, with shockable rhythms making up less than 10% of pediatric arrests. This is significant and likely affects neurologically-intact survival rates, as evidence demonstrates that the presence of a shockable rhythm, such as ventricular fibrillation or ventricular tachycardia, on initial evaluation is associated with improved outcomes in children and adults.<sup>6-9</sup>

The majority of pediatric out-of-hospital cardiac arrests occur in children under the age of five years, with patients less than one year of age making up nearly half of these events.<sup>10</sup> SIDS is a common cause in this age group and etiology can often not be determined. However, many experts suspect there is a respiratory component given the decline in infant deaths following the Back-to-Sleep movement.<sup>11</sup> Pediatric arrests in the less than one-month age group in particular have further considerations due to the higher risk of sepsis, undiagnosed congenital heart defects, inborn errors of metabolism and increased vulnerability to respiratory illnesses.<sup>3,11</sup> As such, particularly in the infant age group, it may be difficult to immediately elucidate the cause of cardiac arrests in the field, and therefore the approach to these arrests may be more difficult to protocolize.

### PEDIATRIC RESUSCITATION CHALLENGES IN THE FIELD

Other challenges unique to pediatrics can occur during resuscitations in the field. While the new EMS protocols exclude trauma in their 30-minute on-scene CPR recommendations, external findings of non-accidental trauma can be subtle or non-existent, such as in cases of abusive head trauma. This leaves a significant population at risk and could lead to delays in identification and initiation of appropriate care.

Along with more subtle clinical findings, procedures in pediatric patients are also complex. Technical variables including equipment sizing and medication dosing, which vary based on patient age and size, often make a difficult situation even more stressful to medical providers and create the potential for adverse safety events.<sup>12</sup> Given the variation in pediatric anatomy, definitive airway management is also often more difficult than in the adult patient. The evidence around the effect of an advanced airway on survival after OHCA is mixed; however, with several studies supporting the use of bag and mask ventilation over endotracheal intubation in the prehospital setting and others refuting this claim.<sup>10,13-15</sup> With any method of airway management, however, prehospital providers have limited training and hands-on experience in pediatric patients. Published data regarding the ability of prehospital providers to manage the pediatric airway reveal that the majority has little or no experience with these critical procedures.<sup>10,16</sup> There is further evidence that pediatric continuing education is limited for many providers, and that rarely utilized pediatric skills, especially those learned outside of the clinical environment,

deteriorate quickly.<sup>17-18</sup> This lack of exposure to POHCA, minimal ongoing experience with important management guidelines and procedures, and limited pediatric continuing education can lead to critical delays and errors in care.

### PEDIATRIC RESUSCITATION EFFORTS/PEDIATRIC ARREST AND 30-MINUTE CPR IN THE FIELD

In the spring of 2017, Rhode Island updated the state EMS protocols, including updates to the pediatric cardiac arrest protocol. This updated protocol states, "Regardless of proximity to a receiving facility, absent concern for provider safety or a traumatic etiology for cardiac arrest, resuscitative efforts should continue for a minimum of 30 minutes prior to moving the patient to the ambulance or transporting the patient." This change is supported by adult literature that demonstrates improved outcomes for patients 18 years and older receiving 30 minutes of CPR for out-of-hospital cardiac arrests.<sup>2</sup> These improved outcomes are largely felt to be due to the detrimental impact of patient transport on high-quality CPR, along with the primarily cardiac etiology of adult arrests. The pediatric literature is less clear.

As previously stated, outcomes for POHCA in general are poor;<sup>1</sup> Tijssen et al, however, found that pediatric out-of-hospital cardiac arrests had improved outcomes with prehospital CPR times ranging from 10–35 minutes.<sup>19</sup> Banerjee et al found improved neurologic outcomes in early on-scene management of POHCA in a single county after initiation of targeted pediatric training and physiologic-driven procedures with on-scene resuscitation time average approximately 17 minutes.<sup>20</sup> Young et al, however, found no good neurologic outcomes in survivors who received greater than 31 minutes of CPR. A recent large retrospective study in Japan that examined POHCA and CPR duration found favorable 30-day survival with good neurologic outcome occurred in <1% of patients who received prehospital CPR of 42 minutes duration or longer. It is notable that this study only looked at ROSC obtained in the field, excluding the analysis of over 80% of POHCA in which ROSC was not obtained. In addition, epinephrine was administered less than 50% of the time in those POHCA in which ROSC was obtained, which does not follow standard protocols in the US.<sup>6</sup> As such, it is possible that the extrapolation of an adult protocol to the pediatric population may result in unintended harm by potentially delaying access to more definitive care by focusing only on the aspect of prolonged scene time and not on pediatric specific resuscitation training and high-quality CPR.

Discussion of length of on-scene resuscitation for pediatric cardiac arrest creates a paradox, where one group of POHCA patients, such as older children and adolescents who have anatomical and physiologic similarities to adult patients, may benefit from prolonged on-scene resuscitation, while another, younger children and infants, may not. It is without question that the delivery of high-quality CPR is the primary

factor in improving survival from cardiac arrest and education and training around this is critical. Other interventions that have been reported to increase survival from out of hospital cardiac arrest, and should be considered for use across Rhode Island include, dispatcher-assisted CPR, "pit-crew" approaches to teamwork, and real-time CPR feedback. In particular, RI lacks a system of formalized telecommunicator CPR, a resource which many states use to provide instructions to families over the phone, initiating resuscitation earlier, which can lead to improved outcomes. The challenge is in crafting resuscitation protocols that identify those who will benefit from protocols encouraging aggressive on-scene resuscitation, and those who would not. In Rhode Island, while it may take significant time, the development of a robust registry of POHCA cases may give valuable guidance to policymakers as well as pediatric emergency medicine and EMS physicians.

## CONCLUSION

Pediatric out-of-hospital cardiac arrests require prehospital providers to give careful thought to the etiology of the event while simultaneously delivering high quality resuscitative care. Acknowledging this complex process may prove relevant in the discussion around the utility of longer on-scene resuscitative efforts. The relative rarity of these events also highlights the importance of education for prehospital providers on specific skills and knowledge for pediatric patients.

Given the complexities of pediatric out-of-hospital cardiac arrests, and the scarcity of literature currently available on this topic, careful deliberation regarding the protocolizing of pediatric prehospital care must be given. Only through the recognition of the unique qualities of pediatric patients, the continued collaboration between prehospital and pediatric experts, the encouragement of ongoing pediatric specific training, and the call for increased prehospital pediatric-specific research, will we improve the outcomes for all children.

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