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Review

Prehospital transport and termination of resuscitation of cardiac arrest patients: A review of prehospital care protocols in the United States

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Abstract

Background: The objective was to describe emergency medical services (EMS) protocol variability in transport expectations for out-of-hospital cardiac arrest (OHCA) patients and the involvement of online medical control for on-scene termination of resuscitation in the United States. Whether other aspects of OHCA care were mentioned, including the definition of a "pediatric" patient, and use of end-tidal carbon dioxide monitoring, mechanical chest compression devices (MCCDs), and extracorporeal membrane oxygenation (ECMO), were also described.

Methods and Results: Review of EMS protocols publicly accessible from https://www.emsprotocols.org and through searches on the internet when protocols were unavailable on the website from June 2021 to January 2022. Frequencies and proportions were used to describe outcomes. Of 104 protocols reviewed, 51.9% state to initiate transport after return of spontaneous circulation (ROSC), 26.0% do not specify when to initiate transport, and 6.7% state to transport after ≥20 minutes of on-scene cardiopulmonary resuscitation for adults. For pediatric patients, 38.5% of protocols do not specify when to initiate transport, 32.7% state to transport after ROSC, and 10.6% state to transport as soon as possible. Most protocols (42.3%) did not specify the age that defines "pediatric" in cardiac arrest. More than half (51.9%) of the protocols require online medical control for termination of resuscitation. Most protocols mention the use of end-tidal carbon dioxide monitoring (81.7%), 50.0% mention the use of MCCDs, and 4.8% mention ECMO for cardiac arrest.

Conclusions: In the United States, EMS protocols for initiation of transport and termination of resuscitation for OHCA patients are highly variable.

Keywords: Cardiac arrest, Resuscitation, Emergency medical services, Protocols, Variability

Introduction

Out-of-hospital cardiac arrest (OHCA) affects over 356,000 people annually in the United States, with a dismal survival rate of approximately 11%.[1] In OHCA, prehospital emergency medical services (EMS) personnel are tasked with immediate assessment, resuscitation, and transport of the patient to the hospital when warranted. In the United States, EMS agency certification is granted by individual states. Each state has the authority to regulate EMS and determine the scope of practice and clinical protocols for its EMS personnel.[2–4] Universally adopted prehospital practice guidelines are rare; many states and communities modify national guidelines.[5] This leads to the common adage, "if you've seen one EMS system, you've seen one EMS system"[5] often quoted by experienced EMS leaders.

Cardiac arrest resuscitation science continues to evolve with novel treatment opportunities such as mechanical chest compression devices (MCCDs) and extracorporeal membrane oxygenation (ECMO), and these novelties are slowly being adopted by hospitals. However, in the out-of-hospital setting, where conditions are suboptimal and resources are limited,[6] cardiac arrest care may be less uniform than the in-hospital setting. There is wide variation in when OHCA patients are transported to the hospital, based on agency and region. The debate regarding whether to resuscitate OHCA patients on-scene until either ROSC is achieved or resuscitative efforts are terminated or to immediately initiate transport with ongoing resuscitation efforts to the hospital is not new.[7] Some

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EMS agencies have their EMS personnel transport almost all OHCA patients to the hospital, regardless of whether ROSC is achieved, while others rarely transport unless ROSC is achieved.[8] There is also considerable variation in when transport is initiated and when resuscitation is terminated.[8–9] Transporting patients in cardiac arrest to the hospital interferes with high-quality chest compressions, leads to interruptions in chest compressions, and places EMS personnel at risk for injury.[10–11] Therefore, some advocate for on-scene resuscitation rather than immediate transport.

A recent study by Grunau et al. published in 2020 found that transporting adult OHCA patients with ongoing resuscitation to the hospital was associated with a lower probability of survival to hospital discharge compared with continued on-scene resuscitation.[9] This study suggests that continuing resuscitation on-scene may be more beneficial.[9] Further, some EMS protocols require online medical control authorization to terminate resuscitation, some protocols do not, and some protocols *advise* contacting online medical control. Due to the aging population, the incidence of OHCA will only increase. Therefore, the development and implementation of evidence-based guidelines for the prehospital care of OHCA patients is of paramount importance.

The heterogeneity in cardiac arrest protocols for EMS personnel should be described first to develop evidence-based and standardized guidelines regarding prehospital transport of OHCA patients. The objective of this study was to describe the variability in prehospital protocols in the United States regarding when OHCA patients should be transported and whether online medical control is required for EMS personnel to terminate resuscitation. We also sought to describe whether EMS protocols for cardiac arrest define “pediatric” and whether they mention end-tidal carbon dioxide monitoring, MCCDs, and ECMO.

Methods

Study design and population

This was a cross-sectional review of a convenience sample of EMS protocols in the United States for the treatment of cardiac arrest. Following methodology from prior literature,[12–13] we accessed EMS protocols from the publicly accessible website https://www.emsprotocols.org.[14] This website includes links to EMS protocols from around the United States and Canada and is periodically updated based on the public availability of protocols. For this study, only protocols from the United States were reviewed. The review of protocols took place between June 2021 and January 2022. For protocols not available on the website https://www.emsprotocols.org, attempts at obtaining protocols were made through internet searches. The goal was to obtain and review at least one EMS protocol per state. Institutional Review Board approval was not required, as this study did not involve human subjects and all protocols were publicly available.

Data collection and analysis

A standardized electronic data collection form was created by the research team for this study, as there are no validated and/or published tools for reviewing prehospital cardiac arrest protocols. After reviewing the first five protocols, the data collection form was revised and finalized. After receiving initial training by the lead author (TL), EMS protocols that were accessible were abstracted by the research team, consisting of EMS personnel and/or medical school students. Any research team member having trouble completing the data collection for a certain protocol flagged the protocol to be reviewed by the entire research team that included two EMS physicians (PB and JB).

The data collection form included fields that asked when adult and pediatric cardiac arrest patients should be transported, whether online medical control consultation is needed for termination of resuscitation, whether the protocol mentions the use of end-tidal carbon dioxide monitoring, MCCDs, and ECMO, and the age that is used to define a “pediatric” patient in the context of cardiac arrest.

Due to the wide variety of responses across various protocols, categories of responses were created to represent the data. Descriptive statistics, including frequencies and proportions, are reported to summarize results.

Results

As shown in Table 1, a total of 104 EMS protocols were accessible and reviewed, spanning 43 states. Most protocols were from the states of California (18.3%), Colorado (4.8%), Illinois (4.8%), Oregon (4.8%), and Virginia (4.8%).

For adult patients, 51.9% of protocols state to initiate transport after ROSC is achieved, 26.0% of protocols did not specify when to initiate transport, 6.7% state to transport after 20 minutes of on-scene cardiopulmonary resuscitation (CPR), while the other remaining protocols provide other directives (Table 2). For pediatric cardiac arrest patients, the majority of protocols (38.5%) did not specify when to initiate transport, while 32.7% state to transport after achieving ROSC, and 10.6% state to transport as soon as possible.

The definition of “pediatric” varied across protocols (Table 3). Most protocols (42.3%) did not specify the age that defines “pediatric” in the context of cardiac arrest, 12.5% used <18 years, and 12.5% also used <8 years. Other age thresholds, ranging from <2 to <17 years, were also used by several protocols.

Other aspects of cardiac arrest management are presented in Table 4. More than half (51.9%) of the protocols require online medical control authorization for termination of resuscitation. The vast majority of protocols mention the use of end-tidal carbon dioxide monitoring (81.7%), and 50.0% mention the use of MCCDs. However, only 4.8% of protocols mention ECMO for cardiac arrest.

Discussion

Although studies have documented variation in prehospital cardiac arrest care and clinical outcomes of cardiac arrest patients through evaluation of prehospital care reports, this is the first study to assess variation in prehospital EMS protocols regarding transport and termination of resuscitation of OHCA patients in the United States. In various industries, limiting operational variability and increasing standardization in decision-making have been associated with reduced errors and improved performance, most often seen in the commercial aviation industry.[15] In our current study, we found variability and inconsistency in the determination of transport decisions in out-of-hospital cardiac arrest, as well as the definition of a “pediatric” patient in the context of cardiac arrest. Our review focused on prehospital care protocols in the United States. While we did not review protocols from other nations, with differences in geography, culture, and practices, EMS protocols in other nations are

Table 1 – State / County / Region / Agency Protocols Included in Review (n = 104 Protocols / 43 States).

State	State / County / Region / Agency	n (%)
Alabama	Alabama Statewide	1 (0.96%)
Alaska	Anchorage Fire Department; Fairbanks North Star Borough; Matanuska-Susitna Borough	3 (2.88%)
Arizona	Central Arizona Regional; Southeast Arizona; Phoenix Fire Department	3 (2.88%)
California	Alameda County; Coastal Valley EMS; Yolo County; Ventura County; Solano County; Sierra - Sacramento Valley; Santa Cruz; Santa Barbara; San Mateo County; San Luis Obispo; San Joaquin; San Francisco; San Benito; Sacramento; North Coast; Nor-Cal EMS; Napa County; Contra Costa County; Mountain Valley EMS	19 (18.27%)
Colorado	Boulder County; Denver Metro; Mesa County; Thompson Valley EMS; Chaffee County	5 (4.81%)
Connecticut	Connecticut Statewide; North Central Connecticut EMS Council	2 (1.92%)
Delaware	Delaware Statewide	1 (0.96%)
Florida	Delray Beach Fire Rescue; Franklin County EMS; Okaloosa County	3 (2.88%)
Idaho	Treasure Valley EMS	1 (0.96%)
Illinois	East Central Illinois EMS; Good Samaritan; Regional EMS; Illinois Region 6; Illinois Region 8; Illinois Region X	5 (4.81%)
Indiana	IU Health LifeLine; Indianapolis Metro	2 (1.92%)
Iowa	MercyOne Ambulance; Scott County; West Des Moines	3 (2.88%)
Kansas	Douglas County EMS; Great Bend Fire/EMS	2 (1.92%)
Kentucky	Kentucky Statewide	1 (0.96%)
Maine	Maine Statewide	1 (0.96%)
Maryland	Maryland Statewide	1 (0.96%)
Massachusetts	Massachusetts Statewide	1 (0.96%)
Minnesota	Hennepin County	1 (0.96%)
Missouri	SSM EMS; Kansas City Missouri Fire Department; Cole County	3 (2.88%)
Montana	Montana Statewide	1 (0.96%)
Nebraska	Nebraska Model Statewide	1 (0.96%)
Nevada	Clark County	1 (0.96%)
New Hampshire	New Hampshire Statewide	1 (0.96%)
New Jersey	New Jersey Statewide	1 (0.96%)
New Mexico	New Mexico Statewide; Sandoval County	2 (1.92%)
New York	New York City REMAC; New York Statewide; Suffolk County EMS System	3 (2.88%)
North Carolina	Buncombe/Madison/Yancey EMS; North Carolina Statewide; Wake County; Orange County	4 (3.85%)
North Dakota	North Dakota Ambulance Services	1 (0.96%)
Ohio	Lucas County; Southwest Ohio; Summa Region 8	3 (2.88%)
Oklahoma	Oklahoma Statewide	1 (0.96%)
Oregon	East Cascade EMS; Jackson County; Josephine County; Lane County; Multnomah County	5 (4.81%)
Pennsylvania	Pennsylvania Statewide	1 (0.96%)
Rhode Island	Rhode Island Statewide	1 (0.96%)
South Carolina	South Carolina Statewide	1 (0.96%)
South Dakota	Rapid City Fire Department	1 (0.96%)
Texas	Austin-Travis County; BioTel; Houston Fire Department; Montgomery County Hospital District	4 (3.85%)
Utah	Davis County	1 (0.96%)
Vermont	Vermont Statewide	1 (0.96%)
Virginia	Blue Ridge; Central Shenandoah EMS; Old Dominion EMSA; Peninsulas EMS; Prince William County	5 (4.81%)
Washington	Chelan/Douglas County; Grays Harbor; San Juan County; Spokane County	4 (3.85%)
Washington DC	District of Columbia	1 (0.96%)
West Virginia	West Virginia Statewide	1 (0.96%)
Wisconsin	Dane County	1 (0.96%)

expected to be similarly varied. Therefore, a larger study assessing EMS protocols at the international level is expected to yield results that further highlight the variation in EMS protocols for cardiac arrest.

According to a consensus statement by the International Liaison Committee on Resuscitation (ILCOR), it is suggested that EMS providers resuscitate patients on-scene rather than transport patients with ongoing resuscitation, unless there is a justification.[16] In a position statement from the National Association of EMS Physicians (NAEMSP), it is stated that EMS providers may consider terminating resuscitation if these three conditions are met: 1) the cardiac arrest was not witnessed by an EMS provider, 2) there was no shockable rhythm identified by an automated external defibrillator or electronic monitor, and 3) there was no ROSC prior to transport.[17] The NAEMSP also states that further research is needed to determine the appropriate duration of resuscitation before deciding that ROSC will not be achieved prior to EMS transport and the benefit of medical control oversight in termination of resuscitation protocols.[17] The American of Academy of Pediatrics policy statement on withholding or terminating resuscitation for children state that EMS providers should consider terminating resuscitation after 30 minutes of resus-

Table 2 – Guidelines for Initiation of Transport of Adult and Pediatric Cardiac Arrest Patients in EMS Protocols.

When should a cardiac arrest patient be transported?	Adult Patients (n = 104 protocols) n (%)	Pediatric Patients (n = 104 protocols) n (%)
After 5 minutes of CPR	0 (0.00%)	1 (0.96%)
After 10 minutes of CPR	5 (4.81%)	3 (2.88%)
After 15 minutes of CPR	1 (0.96%)	9 (8.65%)
After 20 minutes of CPR	7 (6.73%)	3 (2.88%)
After 30 minutes of CPR	2 (1.92%)	1 (0.96%)
After consulting with OLMC	1 (0.96%)	0 (0.00%)
After ROSC	54 (51.92%)	34 (32.69%)
Reservable causes identified	6 (5.77%)	2 (1.92%)
As soon as possible	1 (0.96%)	11 (10.58%)
Not specified	27 (25.96%)	40 (38.46%)

CPR: cardiopulmonary resuscitation; OLMC: online medical control; ROSC: return of spontaneous circulation.

Table 3 – Definitions of "Pediatric" in Cardiac Arrest according to EMS Protocols (n = 104 protocols).

Definition of "Pediatric" in Cardiac Arrest	n (%)
<8 years	13 (12.50%)
<12 years	4 (3.85%)
<13 years	3 (2.88%)
<14 years	6 (5.77%)
<15 years	8 (7.69%)
<16 years	6 (5.77%)
<17 years	1 (0.96%)
<18 years	13 (12.50%)
Other	6 (5.77%)
Not specified	44 (42.31%)

Table 4 – Other Aspects of Cardic Arrest Resuscitation Mentioned by EMS Protocols (n = 104 protocols).

	Yes n (%)	No n (%)
Online medical control required for termination of resuscitation	54 (51.92%)	50 (48.08%)
Mentions use of end-tidal carbon dioxide monitoring for cardiac arrest	85 (81.73%)	19 (18.27%)
Mentions use of mechanical chest compression device	52 (50.00%)	52 (50.00%)
Mentions extracorporeal membrane oxygenation	5 (4.81%)	99 (95.19%)

citation.[18] Despite these recommendations from consensus and position statements, we observed substantial variability in EMS protocol recommendations regarding the initiation of transport for cardiac arrest patients.

Even when presented with clear guidelines, actual practice in the field may vary, the observational study by Scliopou et al. found that paramedics administered epinephrine for cardiac arrest according to the American Heart Association's Advanced Cardiovascular Life Support guidelines only in 14% of OHCA patients.[19] Despite the possibility of practice variability, the first step to improving the care delivered would be to develop and follow best practice guidelines. The absence of a standard of care is likely due to the individual obstacles and unique resources of each EMS system. As the science of cardiac arrest resuscitation progresses, it is reasonable to see further categorization in initial management or treatment, expanding from the simplistic one-size-fits-all algorithmic approach to a patient-centered, tailored care plan. Unfortunately, based on our review of current EMS protocols for cardiac arrest, they do not demonstrate differences based on patient subsets in this manner.

Cardiac arrest is perhaps the most relevant clinical opportunity to create an EMS system of rescue care, similar to other acute conditions such as major trauma, stroke, and myocardial infarction. Due to its recognized position amongst EMS leaders and stakeholders, cardiac arrest registries exist to collate shared data for scientific advancement. Despite registries and internationally recognized treatment guidelines such as the American Heart Association's algorithmic-based care for cardiac arrest, there are no published standards for universally accepted transport guidelines. In the absence of a standard of care, studies from multicenter registries represent the highest level of evidence in the literature.

The Resuscitation Outcomes Consortium (ROC) was a prospective, multicenter, observational registry that collected uniform data on all EMS-assessed adult OHCA across 11 sites in North America between December 2005 and May 2007.[8] Resuscitation by EMS was attempted for 13,518 patients (58%), with 7,945 of these patients (59%) transported, and a total of 1,124 transported patients survived to hospital discharge.[8] The treatment endpoint in this study did not specify or prognosticate the patient having a neurologically intact survival.[8] It was found that survival to hospital discharge was 28% for patients transported after ROSC, compared with 4% of patients surviving in the subgroup for whom transport was initiated without documented ROSC.[8] In our review of 104 EMS protocols, 51.9% of protocols state to initiate transport after ROSC is achieved in the adult patient population. With nearly half of the protocols reviewed leaving transport decisions up to EMS personnel's discretion or encouraging transport without ROSC, there is an opportunity for improvement in patient care and EMS personnel safety during transport. There are a few circumstances when a patient should be transported prior to ROSC, such as scene safety concerns, refractory rhythms, or rescue procedure considerations. However, these circumstances may be identified, protocolized, and best practice evidence-based guidelines should be made standard for EMS providers.

Based on our review, most protocols (38.5%) did not specify when to initiate transport for pediatric cardiac arrest patients, and 10.6% stated to transport as soon as possible. Unfortunately, this is the accepted practice in many areas of the country, minimizing any on-scene time and attempting to perform advanced life support interventions en route to the hospital. This is consistent with the known causative factors for pediatric cardiac arrest being unique compared to adults. This treatment plan could be because primary cardiac disease is rare compared with airway or respiratory causes of cardiac arrest in pediatric patients, or due to non-clinical concerns such as the social impact of resuscitating a child in cardiac arrest in a public setting. When it comes to critically ill children, the high acuity and low occurrence event creates an impetus to want to rush to the hospital. The study by Banerjee et al. reported that in Polk County, Florida, EMS crews operating in a county-wide EMS agency provided limited on-scene treatment for pediatric OHCA and focused on rapid transport of these patients prior to 2014, resulting in a 0% survival rate.[20] After implementing protocols and training that facilitated on-scene management of pediatric OHCA, survival increased to 23% and was sustained over the next two years.[20] An observational study by Tijssen et al. found that a scene time of 10 to 35 minutes was associated with the highest probability of survival, especially among adolescents.[21] These studies show that survival can be increased by the protocolization of transport determination in this patient cohort. We also found substantial variability in the definition of a pediatric patient across EMS protocols. There is an inherent limit when estimating age in young patients, however there should be a consensus on the definition of a pediatric patient.

An emerging facet of prehospital cardiac arrest management is extracorporeal membrane oxygenation (ECMO)-facilitated resuscitation.[22] As emerging technologies and advanced resuscitation techniques arise, and systems of care develop, such changes need to be protocolized for EMS personnel, and EMS systems need to be developed to integrate EMS into the larger system of care. In our review of protocols, we found that only 5 protocols (4.8%) mentioned ECMO. Another technology in the field of OHCA that is rising in popularity are mechanical chest compression devices (MCCDs). Although most studies have found that the use of MCCDs is not associated with improve rates of ROSC and survival,[23–25] there may be utility of MCCDs in the prehospital setting where personnel are limited, CPR may be prolonged, and transport times may also be prolonged. The most reasonable explanation for studies finding that MCCDs are not associated with improves ROSC and survival rates is that EMS personnel are underestimating the time needed to apply the device, resulting in a prolonged pause in CPR. The study by Rolston et al. found that chest compressions were interrupted for a median of 50 seconds due to application of the MCCD in the emergency department.[26] When using a MCCD, it is imperative that the device is placed in the proper position with minimal interruption in chest compressions.[27–28] We found that half of the protocols did not mention MCCDs at all. When best-practice guidelines are not written in protocols, EMS personnel may be left to seek knowledge on their own from various sources. By standardizing a best practice approach of when and how these devices should be placed, there is opportunity to minimize interruptions in CPR, and improve the care delivered to the patient.

There are several limitations of this study to acknowledge. First, we only reviewed a convenience sample of EMS protocols that were publicly posted and accessible on the internet. Protocols that were not readily accessible were not included in our review. However, we attempted to review at least one protocol from each state, and we were able to cover 43 states. Although we were able to find 104 protocols, 19 of them were from the state of California. Therefore, California may be over-represented and our results may present a biased summary of prehospital care protocols in the United States. However, this also reflects the reality of EMS in the United States; many communities have their own protocols. Second, although protocols may not specify, individual agencies may have specific guidelines or policies that would impact decision-making in OHCA that we were unable to identify. Third, we did not assess practice variability between EMS personnel within a specific agency and whether EMS personnel practice differently in the real world. Fourth, we did not study the treatment plan based on population density, access to care, available provider skill level or training, or other EMS system functions specific to cardiac arrest management.

Conclusions

EMS protocols for initiation of transport and termination of resuscitation for cardiac arrest patients are highly variable throughout the United States. Our findings suggest substantial variability in the determination of transport decisions in out-of-hospital cardiac arrest, as well as the definition of a pediatric patient. Further studies are needed to assess the utility of having discrepant regional and EMS system specific cardiac arrest protocols throughout contiguous geographic area.

CRediT authorship contribution statement

Timmy Li: Investigation, Conceptualization, Visualization, Supervision, Validation, Project administration, Methodology, Writing – original draft, Writing – review & editing. **Daniel Koloden:** Investigation, Writing – original draft, Writing – review & editing. **Jonathan**

Berkowitz: Conceptualization, Supervision, Methodology, Writing – review & editing. **Dee Luo:** Investigation, Writing – review & editing. **Howard Luan:** Investigation, Writing – review & editing. **Charles Gilley:** Investigation, Writing – review & editing. **Gregory Kurgansky:** Investigation, Writing – review & editing. **Paul Barbara:** Conceptualization, Supervision, Methodology, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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