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Safety Events in Pediatric Out-of-Hospital Cardiac Arrest

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Abstract

Objective—The objective of this study was to explore the types of patient safety events that take place during pediatric out-of-hospital cardiac arrest resuscitation.

Methods—Retrospective medical record review from a single large urban EMS system of EMS-treated pediatric (<18 years of age) out-of-hospital cardiac arrests (OHCA) occurring between 2008 and 2011. A chart review tool was developed for this project and each chart was reviewed by a multidisciplinary review panel. Safety events were identified in the following clinical domains: resuscitation; assessment, impression/diagnosis, and clinical decision making; airway/breathing; fluids and medications; procedures; equipment; environment; and system.

Results—From a total of 497 critical transports during the study period, we identified 35 OHCA cases (7%). A total of 87% of OHCA cases had a safety event identified. Epinephrine overdoses were identified in 31% of the OHCA cases, most of which were 10-fold overdoses. Other medication errors included failure to administer epinephrine when indicated and administration of atropine when not indicated. In 20% of OHCA cases, 3 or more intubation attempts took place or intubation attempts were ultimately not successful. Lack of end-tidal C02 use for tube confirmation was also common. The most common arrest algorithm errors were placing an advanced airway too early (before administration of epinephrine) and giving a medication not included in the algorithm, primarily atropine, both occurring in almost 1/3 of cases.

Conclusions—Safety events were common during pediatric OHCA resuscitation especially in the domains of medications, airway/breathing, and arrest algorithms.

Keywords

pediatrics; heart arrest; emergency medical services

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1. Introduction

Pediatric out-of-hospital cardiac arrest (OHCA) is a rare but devastating problem affecting about 15,000 children annually in the US. Overall survival is approximately 8%. Survival is lowest in infants and is highest in older children, and those with shockable rhythms. Over the last 10–15 years, survival from adult OHCA has improved as well as survival from pediatric in-hospital arrests. [1–5] The improvement in adult OHCA may be attributed to emphasis on CPR in the community and emphasis of CPR quality among professional rescuers. Despite improvements in adult OHCA survival and pediatric in-hospital arrest survival, survival from pediatric OHCA has not improved over the same period of time.[6] Survival from pediatric OHCA does vary significantly across different EMS systems while controlling for the factors known to be associated with survival from pediatric OHCA.[7] Variability in the quality and safety of care across EMS agencies may be one mechanism for the difference in survival across EMS systems. In addition, compared with adult arrests, pediatric arrests are potentially more challenging to manage due to variability in equipment sizes and drug dosing across the age spectrum of childhood. Pediatric arrests are also rare and are likely high stress events for providers. Cumulatively, these factors may put children with OHCA at higher risk for safety events and increase the likelihood of errors in management which may adversely affect survival.

In previous work, we identified OHCA as the highest risk clinical condition for patient safety events among critical pediatric transports. Previous studies have identified epinephrine overdoses as a common safety event, though there is limited comprehensive assessment of safety events during pediatric OHCA. The objective of this study is to characterize the nature of safety events in pediatric OHCA using a medical record review.

2. Methods

2.1 Study Design

The Children's Safety Initiative-EMS (CSI-EMS) is an NIH/NICHD (R01HD062478) funded program with the objective to identify the epidemiology and contributors to patient safety events in pediatric EMS. Overall, the CSI-EMS is a study with several components that have been described elsewhere.[8–14] This portion of the study consisted of a medical records review of lights and sirens ("Code 3") pediatric transports from an urban county in Oregon. The study was approved by the IRB of Oregon Health & Science University.

2.2 Study Setting

The study took place in an urban area with over 700,000 residents. The EMS system in this area provides "dual advanced life support" with both public fire services and private ambulance transport teams responding to all calls. The transporting agencies have two paramedics and the fire teams have 3–5 members with at least one paramedic on each fire response unit. Fire response units reach 90% of calls in less than seven minutes and transport units respond to 90% of calls in less than 8 minutes. Survival from cardiac arrest in adults in this area is relatively high compared with other sites and likely indicates a highly functional EMS system.[15] All paramedics in this system are trained in Pediatric Advanced Life Support

(PALS). In addition, this system uses a locally developed pediatric length-based resuscitation booklet that includes drugs and equipment used in cardiac arrest. All arrest patients transported to a hospital use lights and sirens priority in this system. Approximately 30% of pediatric arrests are terminated in the field and not transported to the hospital. Non-transported patients were not included in this analysis.

2.3 Inclusion Criteria

We included all lights and sirens EMS transports of OHCA from January 1st 2008 to December 31st 2011 for patients less than 18 years of age. In this system, transport priority is determined at the discretion of the treating EMS team for patients felt to have a life or limb threatening condition including cardiac arrest. Cardiac arrest is defined as any patient who receives either CPR or defibrillation by EMS.

2.4 Medical Record Review Details

We developed a chart review tool (Pediatric prehospital safety Event Detection System, or PEDS) using an iterative process to identify adverse safety events in the EMS setting. We modeled the tool after the landmark hospital-based patient safety tool developed by Brennan et al.[16,17] We adapted the tool to the EMS environment and pilot tested it on 30 charts with physician and paramedic reviewers who provided feedback. A user guide was created to address common questions, and was iteratively updated. All reviewers received two hours of in-person training on the tool and completed test cases and received specific feedback. Each EMS patient care report (PCR) was independently reviewed in tandem by a trained Emergency Physician and Paramedic. A third reviewer, one of two pediatric emergency physicians with expertise in EMS, completed a third review to arbitrate disagreements. Reviewers were blinded to study hypotheses and interim analysis. There were a total of 13 paramedic reviewers and 7 physician reviewers. Paramedic reviewers were from the local EMS community and not part of the agencies submitting charts for review. Physician reviewers all worked in the pediatric ED of a local children's hospital that provides online medical control for the region. All identifiers were removed from charts prior to review. Inter-rater reliability was established between the final arbitrating reviewers as to the presence or absence of a safety event in the domains described below. These reviewers had 87% agreement, corresponding to a Kappa of 0.62, indicating substantial agreement.

The review tool was designed to identify safety events in the following domains: resuscitation; assessment, impression/diagnosis, and clinical decision making; airway/breathing; fluids and medications; procedures; equipment; environment; and system. We created a classification system for safety events that was designed to be broadly inclusive by reducing the punitive connotation of safety event identification using the following nomenclature: **U**nintended consequence, **N**ear miss, **S**uboptimal action, **E**rror, and **M**anagement complication (UNSEM). They review tool was administered via SurveyMonkey™ and included a series of check boxes and Likert-type rating scales as well as open ended questions. The chart reviewers identified the dispatch code, paramedic primary impression, all procedures performed, whether a safety event took place, the nature of the safety event, the degree of potential harm from the event, and the preventability. The degree of harm was assessed by the reviewers using their clinical judgment on a 3-level

scale: 1) no harm likely or near miss, 2) mild or temporary harm including additional treatment, and 3) permanent or severe harm including death.

2.5 Analysis

We identified the subgroup of children who experienced a cardiac arrest treated by EMS. We then tabulated the safety events identified by the chart reviewers in each of the domains listed above. The study team reviewed the free text responses to identify the specific nature of the safety events in each domain (e.g. in the airway/breathing domain, too many intubation attempts). We grouped the types of safety events by major domains including medications, technical performance of procedures, and assessment and management, which included a subdomain related to following the specific indicated arrest algorithm according to American Heart Association guidelines.

Univariate logistic regression analysis was performed on each patient and call characteristic variable thought to be a predictor of OHCA. Categorical variables were coded into dummy variables. Unadjusted odds ratios, 95% confidence intervals (CIs), and p-values are reported in Table 1. Odds ratio estimates from variables with zero cell counts were approximated by adding 0.5 to all table cells.

3. Results

We identified a total of 497 (4.4%) pediatric lights and sirens transports that met our inclusion criteria from a total of 11,328 pediatric transports during the study period. We excluded five cases because we were unable to obtain the fire department chart for the case. We excluded two additional cases due to missing data leaving a total of 490 (99%) charts for analysis. Out of the 490 cases, there were 35 cardiac arrests (7%).

Table 1 includes descriptive statistics for the subgroup of the lights and sirens cohort with cardiac arrest and the subgroup without cardiac arrest. It also presents the results of univariate regression of patient age and gender, scene location, and type of first responder versus OHCA. No association was observed for gender or the type of first responder. Statistically significant associations were observed for age and location: the odds of OHCA was 13.1 (95% CI 3.37–51.3) and 16.9 (95% CI 5.44–52.2) in patients 0–28 days old and patients 29 days to 11 months old respectively, relative to patients 12–17 years old; the odds of OHCA was 0.05 (95% CI 0.01–0.40) in calls from the street/highway and 0.18 (95% CI 0.05–0.59) in calls from a hospital/clinic, relative to calls from home.

Out of the 35 OHCA cases, 87% had at least one safety event identified by reviewers. Table 2 displays adverse safety events related to medications. Epinephrine overdoses were identified in 31% of the cases, most of which were 10-fold overdoses. Other medication related errors included failure to administer epinephrine when indicated and administration of atropine when not indicated. Table 3 includes errors related to technical performance of procedures and is divided into airway and vascular access sections since these were the two broad areas where errors were observed in this domain. The most common error in the airway domain was performing 3 or more intubation attempts which was noted in 20% of cases. Lack of end-tidal C02 use for tube confirmation was also relatively common. Table 4

demonstrates errors in assessment and management. The most common assessment error was failure to check glucose which was noted in 43% of cases. The most common arrest algorithm errors were placing an advanced airway too early (before administration of epinephrine) and giving a medication not included in the algorithm, primarily atropine, both occurring in almost 1/3 of cases.

4. Discussion

The goal of this analysis was to describe safety events occurring during pediatric OHCA resuscitation using a medical record review. We found that these safety events are common, occurring in 87% of pediatric OHCA cases and seemed to cluster within the domains of airway management and medications. We found 20% of cases had multiple intubation attempts (3+) and 31% of administered epinephrine involved an overdose, most of which were 10-fold overdoses. We also found that infants less than 1 year of age and arrests that were found at home were at highest risk for safety events.

Epinephrine overdoses have previously been identified as a common problem in pediatric resuscitation. One previous study conducted in Michigan found that 55% of intravenous/intraosseous doses of epinephrine varied at least 20% from the recommended dose though the number of 10-fold overdoses was unclear.[18] A study conducted in Southern California found that the rate of incorrect epinephrine dosing was 66%, though this decreased to 33% following the introduction of a length-based precalculated dosing protocol.[19] High dose epinephrine, 10 times the currently recommended dose, has been associated with worse survival in pediatric OHCA.[20] Though the existing literature demonstrates that use of length-based resuscitation guides results in lower rates of epinephrine overdoses, our study suggests that medication dosing errors remain a prevalent problem despite the use of a pediatric resuscitation guide. Potential explanations are that epinephrine is available in two concentrations with confusing nomenclature, is packaged in adult-sized jet packs that contain large volumes (10mL) of medication relative to the required pediatric dose (often <1 mL), and pediatric doses can be very small making it difficult to prepare and administer accurate doses; finally, there is a high potential for decimal place errors in dose to volume conversions. Technological innovation that reduces the likelihood of drug overdose may be necessary to improve safety in this area.

Airway management during pediatric OHCA is controversial, our study identified several types of errors in this domain. A controlled trial conducted more than 20 years ago included many cardiac arrest victims and found no difference in survival among patients who were treated with bag-valve-mask ventilation compared to endotracheal intubation.[21] However, this study received some criticism since some felt intubation training was suboptimal and the study was conducted among a heterogeneous population including all patients eligible for advanced airway management regardless of disease process. Despite the findings of no benefit, a recent study demonstrated that intubation is a commonly used technique to manage the airway in pediatric OHCA.[22] Our study highlights that intubation during pediatric OHCA is frequently associated with problems including multiple or failed attempts, failure to appropriately confirm tube placement, incorrect tube depth, and tube displacement, all of which have the potential to negatively impact outcomes. In children, it is

difficult to intubate without pausing chest compressions, which makes our finding that 20% of patients required 3 or more attempts particularly concerning. A recent video review of cardiac arrests treated in a pediatric ED found an average pause in compressions of 25 seconds for each intubation attempt.[23] Alternatives to endotracheal intubation in pediatric OHCA include bag-valve-mask ventilation or use of supraglottic devices, though the effect of supraglottic devices on pediatric OHCA outcomes has not been assessed.

This study has several important limitations. First, we used a medical record review methodology and therefore we are limited to identifying problems that were documented in the chart. This likely biases our results by underestimating safety events since we would expect errors and other safety problems to be under-recorded in the medical record. In addition, we did not have a way to assess the quality of chest compressions or ventilation which are likely an important determinant of outcomes and a potential source of safety events in pediatric OHCA. Finally, because hospital records and patient outcomes were not available, the specific impact of the safety events identified in this study is uncertain, and certain safety events may have been missed that may have been identified after hospital arrival.

5. Conclusions

In this medical record review of EMS resuscitation of pediatric OHCA, we found that errors and patient safety events were common. Pediatric airway management, medications, and assessment and treatment according to AHA guidelines all pose threats to patient safety and present opportunities for future efforts to mitigate risk and reduce errors.

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Table 1

Patient and Call Characteristics of All Lights and Sirens Transports as Univariate Predictors of OHCA in the EMS-CSI Chart Review (n = 490)

Characteristics	Non-OHCA N = 455 (n, %)	OHCA N = 35 (n, %)	Odds Ratio	95% CI	P-value
Age					
0–28 days	17 (4)	6 (17)	13.1	3.37–51.3	<0.001
29 days – 11 months	42 (9)	19 (54)	16.9	5.44–52.2	<0.001
12 months – 5 years	165 (36)	4 (11)	0.90	0.22–3.68	0.89
6–11 years	82 (18)	2 (6)	0.91	0.16–5.07	0.91
12 – 17 years (ref.)	149 (33)	4 (11)	1.00	--	--
Female[a]	176 (39)	19 (54)	1.87	0.94–3.73	0.08
Scene location					
Home (ref.)	189 (42)	30 (86)	1.00	--	--
School	24 (5)	1 (3)	0.26	0.034–2.01	0.20
Street/highway	116 (25)	1 (3)	0.05	0.01–0.40	<0.01
Hospital/clinic	107 (24)	3 (9)	0.18	0.05–0.59	<0.01
Recreation/sport[b]	14 (3)	0 (0.0)	0.21	0.13–3.69	0.29
Other[b]	5 (1)	0 (0.0)	.57	0.03–10.5	0.71
First responder					
Ambulance (ref.)	173 (38)	10 (29)	1.00	--	--
Fire	166 (36)	15 (43)	1.56	0.68–3.58	0.29
Police[b]	14 (3)	0 (0.0)	0.57	0.03–10.2	0.71
Unknown	102 (22)	10 (29)	1.70	0.68–4.21	0.26

[a]The gender of the patient was not recorded for two charts.

[b]Odd ratios, confidence intervals, and p-values calculated from 2×2 tables of each category against the reference category. In situations where a zero cell appeared, 0.5 was added to all cells.

Table 2

Safety Events Related to Medications in OHCA Patients (N = 35)

Medication Error	Cases (n, %)
Incorrect dosing	
Epinephrine:	
• 2X–10X overdose	3 (9)
• 10X+ overdose	7 (20)
• 1:1000 concentration	1 (3)
Indicated and not given	
Epinephrine	6 (17)
Not indicated and given	
Atropine	8 (23)
Bicarbonate	1 (3)
Vasopressin	1 (3)

Table 3

Safety Events Related to Technical Performance of Procedures in OHCA Patients (N = 35)

Type of Problem	Cases (n, %)
Airway	
Too many attempts (3+) or failed	7 (20)
Failed despite multiple attempts	4 (11)
Incorrect equipment size	
Tube size	1 (3)
Other	2 (6)
Tube displacement	3 (9)
Tube too deep	3 (9)
Failure to confirm tube placement	5 (14)
Vascular Access (IV or IO)	
Access attempted and not obtained	3 (9)
Delay in access	4 (11)

Table 4

Safety Events Related to Assessment and Management of OHCA Patients (N = 35)

Type of Problem	Cases (n, %)
Assessment	
Failure to monitor pulse oxygenation	1 (3)
Delay in determining cardiac rhythm	2 (6)
Failure to check glucose	15 (43)
Arrest Algorithm	
Airway before epinephrine	10 (29)
Medication given but not indicated	
Atropine	8 (23)
Bicarbonate	1 (3)
Vasopressin	1 (3)
Neonatal Resuscitation Program algorithm not used but indicated (wrong algorithm)	4 (11)