Pediatric Out-of-Hospital Cardiac Arrest in the State of Arizona

A Thesis submitted to the University of Arizona College of Medicine – Phoenix in partial fulfillment of the requirements for the Degree of Doctor of Medicine

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Dedication

To my family for their love and support, to my friends, especially my best friend and partner Christian, for keeping me sane and relaxed throughout med school, and to my wonderful girlfriend Gwynn for her incredible love and patience.
Acknowledgements

A very sincere thanks to my family and friends for their love and support during medical school, to Dr. Heidi Dalton and Dr. Pamela Garcia-Fillion for very helpful assistance and feedback, to Dr. Ben Bobrow for profound mentorship and use of SHARE database, and most importantly Dr. Sandra Buttram for three years of mentorship, advice, patience, suggestions, and guidance through the entirety of this project.
Abstract

Comprehensive databases which collect data on out of hospital cardiac arrests have been useful in identifying markers of outcome in adults, but this data is limited in children. The Arizona Department of Health Services’ Save Hearts in Arizona Registry and Education (SHARE) database contains data on pediatric cardiac arrests in the field and offers a unique opportunity to examine outcome measures and pre-hospital care.

We retrospectively analyzed 312 children (1-215 months) from the SHARE database between 2004-2010. Variables assessed included: bystander cardiopulmonary resuscitation (CPR) administration, transport times and impact of Pediatric Intensive Care Unit (PICU) availability on outcome to hospital discharge. Data were analyzed by t-test and Fisher’s exact test.

Of 312 children with out of hospital cardiac arrest, 11 (3.6%) survived to hospital discharge. The low survival rates in this review make statistical comparisons difficult, though potential trends were noted that, with additional numbers to increase power, may provide insight into factors affecting survival from pediatric OHCA that have not been assessed on a wide scale in this vulnerable population.
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Introduction

Pediatric out-of-hospital cardiac arrest (OHCA) is an uncommon medical emergency associated with significant morbidity due to neurologic sequelae and mortality. The limited study of pediatric out-of-hospital cardiac arrest (OHCA) that has been undertaken in the last 40 years has done little to improve outcomes. The CanAm Pediatric Cardiopulmonary Arrest Group estimates that 15,000 children suffer from cardiac arrest each year due to a variety of conditions including complex medical illness, trauma, and most commonly, respiratory insults such as drowning, choking, or respiratory failure. Various retrospective studies and metaanalyses estimate survival to hospital discharge from 8.4% to 12.1% for pediatric OHCA\(^1,2\). One recent retrospective study of pediatric OHCA patients who experienced return of spontaneous circulation (ROSC) demonstrated improved survival rate of 38%\(^3\). Hypoxic ischemic injury with resultant neurologic deficits is a frequent sequelae in patients that survive to hospital discharge and the likelihood that a patient will return to the quality of life experienced before the cardiac arrest is low\(^4,5\). Age also plays an important role in outcomes—the survival rates associated with pediatric OHCA are in part influenced by the inclusion of data from infants less than 1 year old, whose survival rates are even poorer\(^6\).

Properly performed cardiopulmonary resuscitation (CPR) can maintain a baseline level of perfusion and oxygenation which can decrease morbidity from hypoxic-ischemic neurologic injury\(^7\). As the average time from EMS dispatch to EMS arrival in Arizona is approximately six minutes, there is a significant period of time where in the absence of intervention the brain and other vital organs can experience hypoxic-ischemic injury\(^8\). Bystander CPR performed during this time can drastically improve survival of adult patients with ventricular fibrillation/ventricular tachycardia by extending the amount of time before the myocardium suffers from metabolic failure\(^9\).

In adults, there is well-established evidence supporting the performance of early bystander CPR as being crucial to increasing survival\(^10\). Bystander CPR in children has only recently been shown to improve OHCA outcomes\(^11\). A nationwide, prospective population-based observational study in Japan published in 2010 demonstrated statistically significant increases in survival for patients who received bystander-CPR\(^11\). Conventional CPR with rescue
breathing was found to be associated with improved survival in patients in arrest due to non-cardiac causes, while cardiac cases showed similar increases in survival with either conventional or compression only CPR\textsuperscript{12}. There is also evidence in adults that the individual resources, services offered, and degree of training of health care providers at a medical facility is associated with outcomes in trauma, cardiac arrest, and cerebrovascular disease\textsuperscript{13}. The effects of specialized pediatric care on OHCA outcomes have not been definitively assessed.

The importance of rescue breathing during resuscitation is emphasized in pediatric OHCA due to respiratory failure being the most common arrest etiology. Intubation in the field can secure an airway and ensure proper oxygenation but is often a difficult and time-consuming process that can keep a provider from performing other interventions\textsuperscript{14}. In non-respiratory pediatric OHCA cases, the maintenance of coronary artery perfusion pressure is the key predictor of survival\textsuperscript{15}. Comparing EMS interventions received by patients intubated with those who were not could lead to protocols de-emphasizing this traditionally important element of resuscitation and the ability for EMS to continue providing other pharmacologic interventions, defibrillation, or chest compressions.

The Arizona Department of Health Services in collaboration with the University of Arizona Sarver Heart Center created the Save Hearts in Arizona Registry and Education (SHARE) in 2004 with the goal of improving pre-hospital care and outcomes for OHCA in the state of Arizona. SHARE operates a statewide registry that collects Utstein- style data for every OHCA event responded to by state and municipal emergency medical services (EMS)\textsuperscript{16}. The goal of our project was to analyze pediatric OHCA events collected in the SHARE database to investigate how several factors- bystander CPR, post-arrest hospital care, and intubation by EMS providers- have influenced pediatric OHCA outcomes in the state of Arizona.
Methods

Study Design

We conducted a retrospective cohort study of children (0-18 years) in Arizona who had an OHCA and had records of their event submitted to the SHARE database between December 2004 and July 2010. Inclusion criteria were based on signs of cardiorespiratory arrest as assessed by municipal or private EMS upon arrival to the scene. Patients in cardiorespiratory arrest secondary to accidental trauma, drowning and choking were included. This study was conducted in accordance with the Arizona Department of Health Services quality improvement initiatives and were therefore exempt from IRB review.

Data Collection and Analysis

Utstein-style data elements (for full list, see Appendix 1) for each event were collected from EMS and hospital records, de-identified, and entered into the SHARE database. All relevant data elements used in this analysis are defined in the attached data dictionary (Appendix 2). The variables from the extensive database which were assessed included: bystander CPR administration, EMS interventions (resuscitation medications, intubation, defibrillation and fluid bolus), transport times and Pediatric Intensive Care Unit (PICU) availability. The primary outcome measurement was survival to hospital discharge. Descriptive statistics are reported as medians and interquartile range (IQR) or number (percent) as appropriate. Fisher’s exact test was used to compare survival among groups. RxC contingency tables were used to stratify intubated or non-intubated patients with either the number of other interventions they received or transport times and χ square analysis was performed.
Results

Three hundred and twelve patients with pediatric OHCA from December 2004 to July 2010 were recorded in the SHARE database. The median age was 12 months (IQR 3, 73). Further characteristics of the study sample are listed in Table 1. Table 2 contains the etiologies of the arrests. Only eleven (3.6%) patients survived to hospital discharge. Outcomes were not available for twelve cases (3.8%).

Of the eleven survivors, three were at neurologic baseline at discharge, two had poor neurologic outcomes, and neurologic status was unknown for the remaining six patients. Patients receiving bystander CPR (n=150) had survival of 4.6% vs. 2.7% survival with no bystander CPR (p=0.54). Figure 1 compares the surviving and deceased groups and breaks down each by % incidence of bystander CPR. EMS providers transported pediatric OHCA patients to forty-one medical centers throughout the state of Arizona. Of these, 9/41 (22%) had a designated PICU. Patients (n=105) taken to sites with an identified PICU had survival of 6.6% compared to 2.3% for patients (n=171) at centers without a PICU (p=0.11) (Figure 2).

One hundred sixty nine patients were intubated either in transport or upon arrival to the emergency department (ED). Eighty-eight patients arrived to the ED without a secure airway and did not obtain ROSC. Fifty-five patients either did not survive to transport (N=11) or did not have their airway status recorded (N=44). The average transport time of an intubated patient was 22 ± 5 minutes compared to 19 ± 6 minutes for patients that arrived in the ED not intubated. Intubated survivors had an average transport time of 23 ±9 minutes (n=8) while one non-intubated survivor had a transport time of 53 minutes. Transport time varied by need for pre-hospital intubation and number of interventions (resuscitation medications, defibrillation and fluid bolus) performed by EMS prior to hospital arrival but were not significant. Figures 3 and 4 demonstrate the stratification of non-survivors between intubation status, number of interventions, and transport time.
Table 1: Characteristics of study sample

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Median (IQR*)</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (months)</td>
<td>12 (3, 73)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>183 (58.7)</td>
<td></td>
</tr>
<tr>
<td>Mortality</td>
<td>289 (96.3)</td>
<td></td>
</tr>
<tr>
<td>Location of Death Pronouncement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-hospital</td>
<td>24 (8)</td>
<td></td>
</tr>
<tr>
<td>Emergency Department</td>
<td>220 (73.4)</td>
<td></td>
</tr>
<tr>
<td>Inpatient Ward</td>
<td>33 (11)</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>12 (3.8)</td>
<td></td>
</tr>
</tbody>
</table>

*IQR = interquartile range*
### Table 2: Etiologies of cardiac arrest

<table>
<thead>
<tr>
<th>Etiology</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
<td>106 (33.9)</td>
</tr>
<tr>
<td>Complex medical problems</td>
<td>37 (11.9)</td>
</tr>
<tr>
<td>Accidental trauma</td>
<td>31 (9.9)</td>
</tr>
<tr>
<td>Respiratory failure (other)</td>
<td>30 (9.6)</td>
</tr>
<tr>
<td>Complications of birth/prematurity</td>
<td>25 (8)</td>
</tr>
<tr>
<td>Drowning</td>
<td>22 (7.1)</td>
</tr>
<tr>
<td>Suspected SIDS</td>
<td>13 (4.2)</td>
</tr>
<tr>
<td>Congenital Cardiac disease</td>
<td>13 (4.2)</td>
</tr>
<tr>
<td>Overdose</td>
<td>13 (4.2)</td>
</tr>
<tr>
<td>Suspected non-accidental trauma</td>
<td>9 (2.9)</td>
</tr>
<tr>
<td>Suicide</td>
<td>6 (1.9)</td>
</tr>
<tr>
<td>Other</td>
<td>4 (1.3)</td>
</tr>
<tr>
<td>Seizure</td>
<td>3 (1)</td>
</tr>
</tbody>
</table>
Figure 1 compares the surviving and deceased groups and breaks down each by % incidence of bystander CPR.
Figure 2: Pediatric OHCA Outcomes With and Without PICU Care

Figure 2 compares the outcomes of patients taken to pediatric centers with PICUs against patients taken to hospitals without PICUs.
Figure 3: Transport time of Intubated Non-Survivors Stratified by Interventions

Figure 3 shows patients who were intubated but did not ultimately survive (n=169) stratified by the number of interventions they received by EMS personnel while in transport. Red boxes indicate number of patients, blue bars average transport time, and vertical error bars reflect standard deviation in transport time. The data did not show a statistically significant relationship between the number of interventions EMS and the transport time. (p=0.38)
Figure 4: Transport time of Non-Intubated Non-Survivors Stratified by Interventions

Transport Times of Non-Intubated Non-Survivors (n=88) by Number of Interventions

Figure 4 shows patients who were not intubated and did not ultimately survive (n=88) stratified by the number of interventions they received by EMS personnel while in transport. Red boxes indicate number of patients, blue bars average transport time, and vertical error bars reflect standard deviation in transport time. The data showed a trend of increasing transport times with increasing interventions but was not statistically significant (p=0.1).
Discussion

The first and most striking conclusion to be drawn from analysis of pediatric OHCA events in the SHARE database is the profound mortality. This cohort had a lower survival rate than the aggregate rates reported in the pediatric OHCA literature, as well as a lower survival rate than the 13.3% for adult OHCA victims in Arizona. This fact could be attributable in part to a number of factors. First, the median age of 12 months is lower than many population based papers in the literature. Forty eight percent of the cohort was less than 12 months old, and the literature has shown that the survival from OHCA in infants is 3-4%. Second, recently, Arizona has focused education and public awareness emphasizing chest compression only CPR. A portion of the known etiologies of arrest were respiratory failure, and it is not unexpected that the significant improvements witnessed in adult cardiac arrest are not seen in this population, especially if some of the arrests with an unknown etiology which made up a large portion of the cases involved a respiratory component. Lastly, additional epidemiologic and geographic features could partially influence lower survival rates. Though the SHARE database extract did not include information on patient ethnicity, Arizona is a diverse state with large Hispanic, Native American, and refugee populations. Communication and cultural barriers could contribute to increased difficulty coordinating EMS response.

The aim of our project was to assess the impact of bystander CPR on patient survival. Kitamura et al. showed increases in survival in pediatric OHCA patients among their respective populations. The American Heart Association now emphasizes bystander CPR as one of the key elements to increase survival. Bystander CPR was administered to half of the children in this study, a rate that is comparable to those reported in the literature. Though survival rates in patients who received bystander CPR before EMS arrival were nearly double compared to those who did not, the overall low survival precluded this from reaching statistical significance. However, we do expect that with additional cases improved outcomes would be seen.

Similarly, in the few survivors, there was a more than three-fold increase in survival seen in patients taken to locations with PICUs. PICUs were selected as a surrogate marker for pediatric-specific care due to the high concentration of pediatric trained specialists, advanced pediatric life support resources including extracorporeal membrane oxygenation (ECMO).
technology, and association with dedicated children’s hospitals that also include pediatric specific emergency departments. Two thirds of patients were taken to medical centers without PICUs.

The rural nature of many Arizona communities results in children receiving treatment at medical centers focused solely on adult care. Also, a majority of the centers without exclusive pediatric services had less than ten cases of pediatric OHCA over the five-year span. These centers have such a low volume of pediatric OHCA patients that it is unrealistic to expect the same level of expertise and care possessed by a pediatric specific facility.

EMS personnel responding to pediatric out of hospital cardiac arrest have a monumental task in immediately starting crucial interventions which include airway management, chest compressions, IV access, medications, and defibrillation, all while transporting the patient as quickly as possible to a center for definitive medical care. While airway management is crucial to treating cardiac arrest due to respiratory etiology, intubation can be a time consuming process, especially in the field on children with difficult airways. We attempted to evaluate whether this time and concentration intensive task prevents EMS providers from focusing on other interventions including CPR, using transport time and additional interventions as surrogate measures.

We found that among surviving patients, there was no statistically significant relationship between intubation status, the number of interventions they received, and their subsequent transport times. We did see a trend in greater transport time with increasing number of interventions for intubated patients who did not survive, but this seems to suggest simply that additional interventions take time to perform and neither addresses our initial question of whether intubation itself distracts from these or whether there is any impact on survival.

Limitations of this study primarily include the low number of survivors that precludes any findings with statistical significance, missing and incomplete outcome data, and the potential for bias in a retrospective analysis of a voluntarily reported database.
Future Directions

Preliminary data for 2011 and 2012 was obtained from the SHARE database after the initial analysis which described an additional 139 incidents in 2011 and 97 in 2012, both annual totals significantly higher than in prior years. Survival increased to thirty-five patients among a total verified outcome set of five hundred and five (6.8%), which is more consistent with numbers reported in the literature.

From a public health standpoint, it would be interesting to further investigate whether there truly is a relationship between survival and care at pediatric specific facilities. With such low volume and lack of pediatric practitioners at rural, general medical centers, the trade-off in increased survival might be worth additional time spent in transport to reach a center where trained pediatric specialists are able to a higher level of care, similar to the triage of pediatric trauma patients. For patients in rural areas where transport to major centers are simply not feasible, utilization of telemedicine might allow for the expertise and experience of pediatric practitioners to be useful in the care of patients from a distance.

Though a majority of arrests ultimately had an unknown etiology, education and outreach for potentially preventable causes like sudden infant death syndrome (SIDS), non-accidental trauma, and especially drowning could conceivably decrease the incidence of pediatric OHCA, and emphasis on bystander CPR and the importance of rescue breathing for pediatric patients might improve
Conclusion

Pediatric OHCA is an underappreciated public health problem that has affected hundreds of children in Arizona over the last ten years. The SHARE database provides a powerful tool for investigating factors that may impact survival of pediatric OHCA but unfortunately the low survival rates in this review made statistical comparisons difficult. The impact of bystander CPR, transport time, and treatment at centers with PICUs on survival remains intriguing but requires larger sample sizes with a greater number of survivors to potentially answer these questions. This may be accomplished through gathering additional data in subsequent years but an increase in collaboration with other centers to pool data sets might also increase power. Ultimately, further investigation into the relationship of the aforementioned variables and outcomes may aid in prioritizing pre-hospital care and optimal destinations for children following cardiac arrest.
References


17 Bobrow B et al. Chest Compression-Only CPR by lay rescuers and survival from out-of-hospital cardiac arrest. JAMA 2010;304(13)1447-1454


20 U.S. Census Bureau: State and County QuickFacts. Data derived from Population Estimates, American Community Survey, Census of Population and Housing, State and County Housing Unit Estimates, County Business Patterns, Nonemployer Statistics, Economic Census, Survey of Business Owners, Building Permits

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Appendix 1: List of Variables and Data Points De-Identified SHARE Database Extract Contained for Each Recorded Pediatric OHCA Incident

Destination hospital, internal case number, incident date, gender, date of birth, age in years, age in months, whether there was use of SHARE practice algorithm, whether there was administration of early epinephrine 0-5 minutes after arrest, time EMS were dispatched, time EMS arrived on scene, time EMS began transporting to hospital, time EMS arrived at hospital, time EMS performed first defibrillation, number of EMS defibrillations, whether persisted in asystole after first shock, weight in kg in patients less than 10 years, presumed etiology of OHCA, whether there was arrest after arrival of EMS, whether there was administration of bystander CPR prior to arrest, type of bystander CPR administered, whether there were agonal respirations initially following arrest, skin temperature, initial end tidal CO2, lowest end tidal CO2, initial oxygen saturation, highest oxygen saturation, initial monitored rhythm, rhythm on ED arrival, number of intubation attempts, whether intubated upon arrival to ED, route of EMS administration of medication, whether atropine had been given, whether atropine had been given twice, whether lidocaine had been given, whether sodium bicarbonate had been given, whether fluid bolus had been given, whether EMS pacing had been attempted, response of patient to resuscitative efforts, initial outcome, final outcome, discharge condition, child protective services involved, and free comments.
Appendix 2: Data Dictionary of Selected Terms

**Destination hospital**: Medical center to which pediatric OHCA was transported for definitive care.

**Use of SHARE practice algorithm**: Describes whether pre-hospital personnel followed documentation of the arrest with SHARE’s Utstein style documentation tool.

**Time EMS were dispatched**: Denotes time at which dispatch center forwarded incident description and location information to EMS.

**Time EMS arrived on scene**: Denotes time at which physical EMS presence arrived at location provided by dispatch services.

**Time EMS began transporting to the hospital**: Denotes time at which patient began to be moved from scene of arrest en route for destination hospital.

**Time EMS arrived at hospital**: Denotes time at which EMS vehicle arrived at designated patient unloading zone at destination hospital.

**Persistence of asystole after first shock**: Denotes whether patient’s monitored rhythm was asystole following first assessment post-shock.

**Presumed etiology of OHCA**: Subjective, preliminary determination on etiology of arrest based on contextual information provided by parents, EMS providers, medical personnel, or other parties combined with initial medical assessment, evaluation, and diagnosis at treatment center.

**Arrest after arrival of EMS**: Denotes whether EMS call was in response to other medical or emergent issue, at which point the patient arrests after EMS response to original issue.

**Administration of bystander CPR prior to arrest**: Denotes whether bystander CPR was administered prior to documented cessation of normal physiologic perfusion.

**Type of bystander CPR administered**: Denotes whether CPR with rescue breathing or chest compression only CPR was performed by bystander.

**Agonal respiration initially following arrest**: Whether patient was subjectively documented and assessed as exhibiting gasping respirations following cessation of perfusion.

**Skin temperature**: Surface temperature taken during resuscitation efforts.

**Initial end tidal CO2**: End tidal CO2 level documented when capnography is first established.
**Initial oxygenation saturation:** Percutaneous hemoglobin oxygen saturation level determined when oximetry is first established.

**Initial monitored rhythm:** Cardiac rhythm noted when electrocardiography is first established.

**Rhythm on ED arrival:** Initial cardiac rhythm noted with emergency department electrocardiography.

**Route of EMS administration of medication:** Access routes used to deliver medication by EMS personnel including intravenous, intraosseous, endotracheal, and percutaneous routes.

**Response of the patient to resuscitative efforts:** Subjective determination by EMS and hospital personnel assessing the status of the patient after interventions, chiefly focused on whether return of spontaneous circulation was obtained.

**Initial outcome:** Subjective assessment of condition upon treatment in the emergency room.

**Final outcome:** Subjective assessment of condition at time of hospital discharge.