Pediatric Resuscitation: Lessons Learned and Future Directions

LINDA L. BROWN, MD, MSCE; LAURA CHAPMAN, MD

ABSTRACT

The science of resuscitation has had significant and meaningful advances over the past fifty years, with resultant improvements in outcomes for both adult and pediatric populations. This article aims to describe some of the recent advances in pediatric resuscitation, including aspects of care affecting the management of cardiac arrest and sepsis, and to give a glimpse into technologies and methodologies that may be utilized to improve outcomes for children in the near future.

KEYWORDS: pediatric, resuscitation, sepsis, shock

INTRODUCTION

The history and epidemiology of pediatric resuscitation

In the early 1960s, the American Heart Association (AHA) initiated the first program in cardiopulmonary resuscitation. Over fifty years later, the science of resuscitation has grown significantly in scope and breadth and has led to improvements in outcomes across all age ranges. It is well documented that pediatric cardiac arrests differ from those in adults in incidence, etiology, management and the eventual outcomes from these infrequent but potentially devastating events. Unlike the primary cardiac causes that lead to the majority of arrests in adult populations, cardiac arrests in children are likely to be secondary to progressive respiratory failure or shock. The initial cardiac rhythm upon presentation to medical care is often asystole (78%) or pulseless electrical activity (12.8%), with the ventricular dysrhythmias found commonly in adults, documented in only 5-15% of pediatric cases.[1,2] Pediatric specific advanced life support (PALS) guidelines were initially developed in 1988 to address the unique characteristics of this population and have continued to undergo regular updates based on evolving evidence and expert consensus, with the most recent release in 2010.[1]

Survival estimates from pediatric cardiac arrests differ based upon the location where the arrest takes place. Children with an out-of-hospital arrest have generally poor outcomes with estimates of approximately 3-9% survival to hospital discharge, with the majority of survivors left with significant neurologic sequelae. These numbers have remained essentially unchanged over time while interventions continue to be aimed at improving bystander cardiopulmonary resuscitation (CPR) and the pre-hospital care these children receive. The outcomes from in-hospital pediatric cardiac arrests, however, have had more meaningful improvements. Survival rates in the 1980s for children after an in-hospital cardiac arrest were reported as 9%, while recent reports reveal survival rates of up to 27-35%.[3-6] The basis for these improvements is likely multifactorial, including earlier recognition and management of shock and impending respiratory failure that can lead to cardiac arrest, the institution of rapid

Figure 1. Simulation is currently being used in the Hasbro Children's Hospital ED to train multidisciplinary teams caring for simulated pediatric patients within the resuscitation room.

response teams, updates in PALS algorithms, improvements in the quality of cardiac compressions, and advances in the training of the healthcare providers responsible for the resuscitation of these critically ill pediatric patients.

Pediatric septic shock: New pathways in recognition and management

As previously stated, pediatric arrests are often secondary to respiratory failure or shock. Overwhelming infection, leading to septic shock, is one of the largest causes of morbidity and mortality in pediatrics. The overall mortality rate of septic shock in children is 13.5%.[7-9] Previously healthy children with sepsis have a mortality rate of 9-10%, while chronically-ill children have a 12-15% mortality.[7-9] Pediatric sepsis is a complex disease state; the core process that leads to end organ dysfunction is complicated, multifaceted, and not clearly understood.

The recognition of early sepsis has also proven to be difficult for myriad reasons. Children may be scared or upset during their examination, making the evaluation of mental status and accurate vital signs challenging. Normal vital signs also vary by age group, so memory aids or advanced electronic medical records (EMR) may be necessary to alert providers to subtle abnormalities. Hypotension is a late finding in pediatrics, and, unlike in adults, is not required for the diagnosis of sepsis or septic shock. In fact, children have impressive cardiovascular reserve and can compensate for severe illness, sometimes with normal heart rates and normal blood pressures, until they "fall off the cliff" and rapidly decompensate. There is also a lack of pediatric literature to support the routine use of biomarkers, such as lactate, to aid in the diagnosis and management of sepsis. Despite these difficulties in recognition, studies have clearly shown that rapid identification and timely treatment consisting of early goal-directed therapy, which includes fluid administration and antibiotics, leads to improved outcomes.[10-12]

The Surviving Sepsis Campaign was launched in 2002 with the goal of decreasing mortality by using evidence-based guidelines to implement recognition and management bundles. In adults, participation in the Surviving Sepsis database has led to a 5.4% absolute survival benefit.[13] The American College of Critical Care Medicine in combination with the AHA PALS program has created formal resuscitation guidelines for septic shock.[10] In brief, these guidelines recommend administration of 60 ml/kg of intravenous fluids and antibiotics within 60 minutes of sepsis recognition and initiation of vasoactive drugs, if indicated, at 60 minutes.

It has been shown that for every hour delay in return to normal vital signs and capillary refill in the community hospital emergency department has been associated with a twofold increase in odds of death.[14] Even in large children's hospitals there are impediments to initiating treatment and in delivering timely interventions. Some of these barriers include delayed recognition of sepsis, difficulty with IV access, slow administration of intravenous fluids, difficulties in obtaining medications from pharmacy, and delays in transportation from the community setting to a tertiary care pediatric hospital.[15-17]

This past year, Hasbro Children's Hospital joined a pediatric sepsis collaborative that included children's hospitals across the country. Over the next 5 years, with the support of the American Academy of Pediatrics, this collaboration will implement standard triage criteria and screening tools for sepsis in the pediatric emergency department as well as create intervention bundles for timely intravenous fluid administration and antibiotics. The collaborative goal is to decrease mortality by 20 percent across all participating sites. Additionally, aggressive treatment goals have been set to administer initial intravenous fluids within 15 minutes of recognition of sepsis and antibiotics within 1 hour. Smaller studies at individual institutions have shown this standardized approach to the treatment of pediatric sepsis improves time to fluid and antibiotic administration and has decreased the hospital length of stay, but few studies have been powered to show significant reduction in mortality.[16-17]

The future in pediatric sepsis likely will take two paths. Quality improvement projects will be implemented to distill the current knowledge we have and use it more efficiently and thus effectively. Early diagnosis and risk stratification may also be achieved in the future with the use of biomarkers of disease or with non-culture identification of pathogens using PCR, microarrays or mass spectroscopy. At this time, the studies for biomarkers in pediatrics have been small and the data conflicting, though larger scale projects are on the horizon.

Recent innovations in pediatric resuscitation

One of the factors that may be responsible for the improvements in survival and overall outcomes from in-hospital cardiac arrests may be the increasing utilization of rapid response teams (RRT). These teams have been instituted across many children's hospitals and are comprised of a group of healthcare providers, including nurses, respiratory therapists, and physicians, with significant experience in the assessment and management of critically ill pediatric patients. In several published studies, the early evaluation and management of the deteriorating pediatric patient by such teams has led to significant improvements in the incidence of cardiac and respiratory arrests, with decreases in these events by as much as 72% and decreased mortality by as much as 35%.[18-19] At Hasbro Children's Hospital in Providence, RI, the pediatric FAST team (Focused Assessment and Stabilization Team) was instituted in 2007, with ongoing updates, including the utilization of a PEWS score (pediatric early warning score) in 2009.[20] As of October 2013, data regarding intubations and cardiopulmonary arrests that have occurred outside of the emergency department or pediatric intensive care unit reveal no events in over two years, reinforcing the value of these teams.

Although the importance of early recognition and

management of the pediatric patient with impending respiratory failure or shock cannot be understated, for optimal patient outcomes improvements must also be made in the care of the patient once cardiac arrest occurs. The most recent update to the PALS guidelines in 2010 highlighted the importance of quality chest compressions (pushing hard, pushing fast, allowing for full recoil and minimizing interruptions). Immediate and effective bystander CPR has been shown to have a significant impact on the return of spontaneous circulation with preserved neurologic outcomes. Unfortunately, it has been estimated that only one third to one half of infants and children receive bystander CPR.[3] The C-A-B sequence for basic life support was introduced in 2010 and was aimed at increasing bystander CPR across all ages, with a theoretical delay of only 18 seconds if compressions start the sequence instead of ventilations. This delay is even shorter if two providers are available for the resuscitation. [4] Evolving technological advances are also assisting providers in performing quality compressions, with several real-time CPR feedback devices currently undergoing rigorous evaluation.[21]

Publications on the training of healthcare providers in BLS and PALS have been increasing, with the focus on the best methods to educate and promote retention of these crucial, yet infrequently utilized, skills and behaviors. Medical simulation has developed over the past twenty years as a means to educate healthcare practitioners and to allow practice of critical procedures and resuscitations by multidisciplinary teams. It is uniquely suited to train individuals and teams in the assessment and management of low frequency/high acuity events in a safe setting.[22,23] With the use of high-fidelity simulators, the clinical staff experiences real-time feedback of their decisions and interventions in the form of changes in the mannikin's "responsiveness," vital signs, prognosis and outcome. Published studies have shown that the use of simulation to teach and update PALS results in improved cognitive performance.[24] Furthermore, research regarding the use of "boosters," where providers receive a brief refresher and practice at the bedside, has been shown to improve the quality of BLS skills in simulated arrest scenarios.[25]

In situ simulation, in which portable mannikins are transported into actual clinical environments, has also been recently been used to directly evaluate clinical settings and systems, to optimize patient care and minimize potential adverse events.[23] Simulation is currently being used in the Hasbro Children's Hospital ED, through an ongoing relationship with the Lifespan Medical Simulation Center, to train multidisciplinary teams caring for simulated pediatric patients within the resuscitation room (**Figure 1**). The focus of these sessions includes the practice of infrequently used skills and behaviors as well as the ongoing assessment of the clinical systems that are involved in caring for these patients in a safe, timely and effective manner.

Pediatric Resuscitation: Where are we headed?

One of the interventions that has been shown to improve outcomes in adults after cardiac arrest is therapeutic hypothermia. During cardiac arrest there are significant derangements in perfusion resulting in ischemic, metabolic and inflammatory changes that continue even after return of spontaneous circulation. Although there have been randomized controlled trials of therapeutic hypothermia showing improved survival with good neurologic outcomes in adults and neonates, due to differences in pediatric physiology and the varying etiologies of cardiac arrests across the spectrum of ages, the findings from these studies cannot be directly translated to pediatric cardiac arrests. There are currently several major multi-center trials underway, involving two large federally funded pediatric clinical research networks (Pediatric Emergency Care Applied Research Network and the NICHD Collaborative Pediatric Critical Care Research Network), to evaluate the effect of therapeutic hypothermia in children after in-hospital and out-of-hospital cardiac arrests. After significant planning, the trial initiated in 2009, with a goal to enroll 900 patients over 6 years at approximately 37 clinical centers throughout the US and Canada.[26]

CONCLUSIONS

Important advances continue to be made in pediatric resuscitation, including the utilization of rapid response teams, changes in algorithms for the management of sepsis and cardiac arrest, ongoing research into new training methodologies for healthcare providers and new frontiers in post-resuscitation care. These developments have led to improved outcomes for children, and given the pediatric community a glimpse into the significant advances that are possible in the future.

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Authors

Linda L. Brown, MD, MSCE, is Assistant Professor of Pediatrics and Emergency Medicine, The Alpert Medical School of Brown University, and an Attending Physician at Hasbro Children's Hospital Emergency Department, Providence, RI.

Laura Chapman, MD, is Assistant Professor of Pediatrics and Emergency Medicine, The Alpert Medical School of Brown University, and an Attending Physician at Hasbro Children's Hospital Emergency Department, Providence, RI.

Disclosures

None

Correspondence

Linda Brown, MD MSCE
Hasbro Children's Hospital
593 Eddy Street
Providence, RI 02903
401-444-6237
lbrown8@lifespan.org