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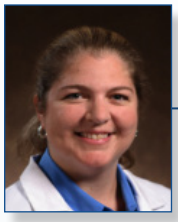

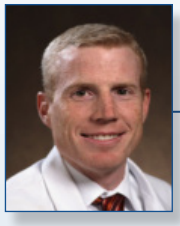

Pediatric Emergency Medicine: From small beginnings, a subspecialty emerges and evolves in RI, nationwide

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GUEST EDITOR


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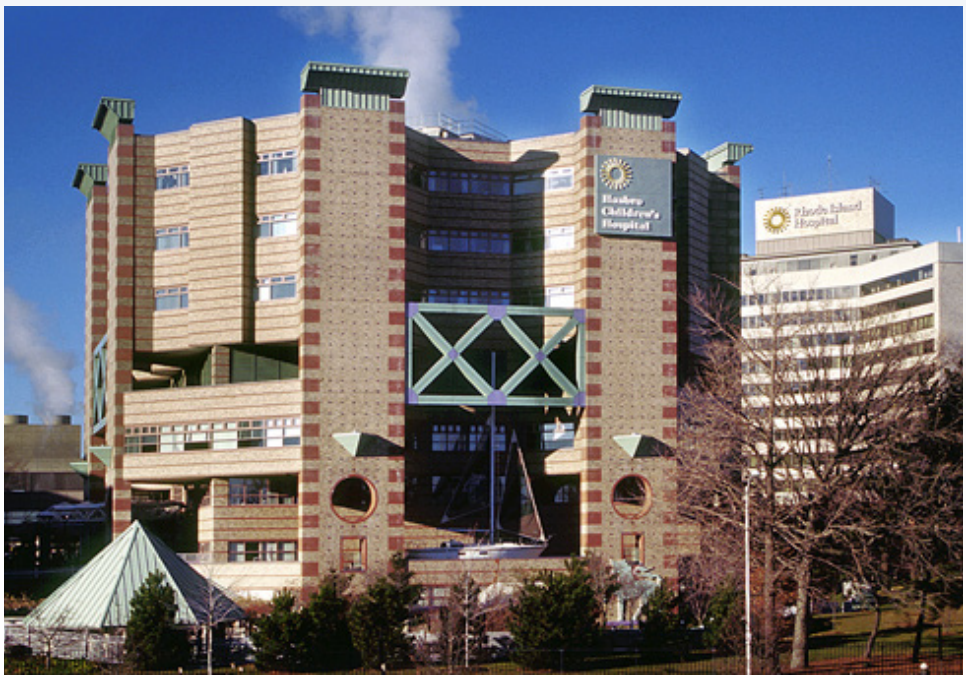
Pediatric Emergency Medicine (PEM) was introduced in Rhode Island in 1985, the year after the establishment of the federal EMS-C program designed to assist states in improving emergency medical care for children. Based at Rhode Island Hospital, PEM began as a fledgling subspecialty when **DR. WILLIAM LEWANDER** was recruited as Rhode Island's first PEM subspecialist by the divisions of Emergency Medicine and Pediatrics. Dual-trained in PEM and toxicology and a member of the first class of PEM fellows at Boston Children's Hospital, Dr. Lewander was charged with building a system of regional emergency care dedicated to the medical needs of children and their families. Early in his career, he worked tirelessly caring for patients and educating physicians, nurses and EMS providers about the evolving body of medical evidence which recognized that children were not "little adults" and were best served when receiving specialized emergency care befitting their unique physiologies and responses to injury and illness. Within a few years of arrival, additional PEM medical and nursing colleagues joined Dr. Lewander. Together, they collaborated with emergency medicine physicians and pediatric surgeons to develop a multifaceted emergency medical system focused on the unique medical, developmental and social needs of children and adolescents.

From a few rooms at RIH to Hasbro Children's Hospital

The first "pediatric emergency department" at RIH was only a few rooms embedded in the adult emergency department and in 1985 cared for approximately 9000 pediatric emergency patients. Critical pediatric patients were managed in resuscitations bays poorly equipped for the care of young children and staffed primarily by adult-trained caregivers. Over the course of a few years, however, practices evolved as the division grew and expanded its educational, research and injury prevention focus and established a fellowship in PEM. These efforts paralleled an increased demand, both locally and nationally, for pediatric emergency and urgent care that was bolstered by the 1993 Institute of Medicine Report, "Emergency Medical Service For Children," a document providing the first "comprehensive view of the need for and effectiveness of pediatric emergency care services in the U.S." As the region's pediatric emergency and trauma patient population increased, so did the need for dedicated space and staff to accommodate children's specialized needs, as well as serve as a resource and referral center for community emergency providers.

When Hasbro Children's Hospital opened in 1994, its Emergency Department had an annual census of approximately 34,000 patients, 13 treatment rooms, 2 resuscitation bays, 12 PEM faculty and fellows and a core of pediatric emergency nurses. Over the next 10 years, the census, faculty, staff and number of patient rooms nearly doubled and



PEM expanded its clinical, educational, research and injury prevention missions within the academic Department of Emergency Medicine of The Alpert Medical School of Brown University and the clinical departments of Emergency Medicine and Pediatrics at Hasbro.

This issue of the *Rhode Island Medical Journal* is dedicated to aspects of pediatric emergency medicine that distinguish the subspecialty and highlight care that is provided in pediatric emergency departments. The topics were selected with the insight that the majority of children in the United States, including those in Rhode Island, receive emergency and urgent care, not in dedicated pediatric medical centers, but in general emergency departments and urgent care facilities. With that in mind, the authors focused their articles on enhancing awareness of pediatric conditions and managements pertinent to all clinicians who provide acute care to children.

Section overview

"Pediatric Resuscitation: Lessons Learned and Future Directions" by **LINDA L. BROWN, MD, MSCE**, and **LAURA CHAPMAN, MD**, reviews the goals of pediatric resuscitation and the importance of preparedness and training to improve outcomes for relatively infrequent and high-stress pediatric events. In addition, it includes a review of the emerging practice of early recognition and goal-directed therapy for pediatric sepsis.

"Going With The Flow" by **THERESE L. CANARES, MD**; **CRAIG TUCKER, RRT-NPS** and **ARIS GARRO, MD, MPH**, focuses on the management of pediatric respiratory illnesses, conditions that are particularly burdensome to the very young and which commonly bring children to emergency departments for treatment and which are the most common reasons for pediatric admissions.

"Not Just Not Little Adults, A Pediatric Trauma Primer" by **FRANK L. OVERLY, MD**; **HALE WILLS, MD, MS**, and **JONATHAN H. VALENTE, MD**, highlights the importance of dedicated pediatric trauma care, the unique pediatric physiology and response to trauma as well as the benefits of a skilled approach to assessment and management.

"Fear and Loathing in the ED: Managing Procedural Pain and Anxiety in the PED" by **CHRIS MERRITT, MD, MPH**, examines the importance of a developmentally appropriate and multidisciplinary approach to the management of pediatric pain and anxiety.

"Multicenter Pediatric Emergency Medicine Research and Rhode Island" by **THOMAS H. CHUN, MD, MPH**, focuses on the frontiers of PEM research and the important role of multicenter collaboration in enhancing knowledge of pediatric emergency conditions and care. In 25 years, the subspecialty of PEM has made great strides in enhancing care, setting national standards and improving systems of emergency care for children, particularly in well-populated regions. The subspecialty continues to strive on a local and national level to set standards and improve the emergency care for children and adolescents in every medical setting.

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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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Disclosures

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Going with the Flow: Respiratory Care in the Pediatric Emergency Department

THERESE L. CANARES, MD; CRAIG TUCKER, RRT-NPS; ARIS GARRO, MD, MPH

ABSTRACT

Providers in pediatric emergency departments (ED) frequently encounter a variety of life-threatening respiratory illnesses. This article reviews current updates on the management and unique adjuncts for 3 common respiratory illnesses. Discussed first is bronchiolitis and the impact of high flow nasal cannula on reducing the need for intubation. Next, the current therapy for croup and the adjunctive use of Heliox and finally, the ED approach to asthma and treatment with breath actuated nebulizers.

KEYWORDS: pediatrics, respiratory care, bronchiolitis, asthma, croup

BRONCHIOLITIS

Bronchiolitis is a lower respiratory tract illness that produces acute inflammation, edema, and necrosis of epithelial cells lining small airways, leading to increased mucous production and bronchospasm.[1] In winter, bronchiolitis is the number one reason infants are admitted to hospitals and a significant portion of infants is cared for in Hasbro Children's Hospital Emergency Department (HCH ED).

The HCH ED follows the American Academy of Pediatrics (AAP) bronchiolitis management recommendations, which emphasize the importance of clinical assessment and supportive care.[1] Noninvasive interventions are the first line approach to bronchiolitis. Infants are suctioned (by bulb or suction catheter) and repositioned to improve airway patency. The impact of bronchiolitis on infant feeding and hydration can be significant. Infants unable to tolerate milk products or with mild dehydration may attempt oral hydration with Pedialyte. Patients admitted may receive nasogastric tube feeding if there is moderate dehydration or mild respiratory distress during feeds. This provides enteral nutrition and hydration while minimizing trauma. Intravenous hydration is reserved for infants with moderate to severe respiratory distress or dehydration.

As per AAP guidelines, bronchodilators may be given as a trial with observation for positive clinical response but are not routinely repeated unless there is clinical benefit. Similarly, corticosteroids are not routinely used in the management of bronchiolitis given the insufficient evidence to improve length of stay or clinical score.[1] A novel therapy for bronchiolitis is nebulized 3% hypertonic saline. The saline concentrate causes osmotic movement of water from the pulmonary interstitium into the airways, thereby decreasing interstitial edema and viscosity of intraluminal mucous. The preliminary evidence shows mixed results with some reports of decreased length of stay and others showing no clinical effect. There are no studies that demonstrate impact of emergency department visits. All studies on hypertonic saline report no harm or adverse effects.[2-4]

Despite interventions, some infants with bronchiolitis have persistent respiratory distress that requires additional support such as high flow nasal cannula (HFNC). HFNC provides heated, humidified airflow via a wide-diameter cannula. The shorter, wider nasal prongs provide increased flow at lower resistance than traditional nasal cannulas, and humidification prevents desiccation of the nasal mucosa that can occur with high flow rates. It serves as an alternative form of respiratory support than nasal continuous positive airway pressure in infants.[5]

HFNC has revolutionized the management of infants with moderate to severe bronchiolitis, often removing the need for intubation. HFNC has been studied in infants with bronchiolitis in the emergency department (ED), pediatric intensive care unit (PICU), and pediatric ward settings.[6-8] The primary indication to initiate HFNC is moderate to severe respiratory distress in infants, based on tachypnea, hypoxia, and accessory muscle use. HFNC significantly increases median SpO_2 by 1-2%, decreases end tidal CO_2 by 6-8 mmHg, and decreases respiratory rate by 13-20 breaths per minute, as compared to standard nasal cannula.[8] This adjunct therapy improves heart rate and respiratory rate within 60-90 minutes, and therefore HFNC in bronchiolitis may decrease the need for intubation.[5] After institutional guidelines for HFNC use were implemented for infants in one ED there was 83% reduction in the number of intubations.[7]

There are preliminary data that children with bronchiolitis benefit from use of Heliox. Heliox is a gaseous mixture of helium and oxygen and is frequently combined in 80%/20% or 70%/30% ratios. Helium's property of lower density leads to laminar flow of inspired gas across a narrowed airway, and therefore improves oxygen delivery particularly in upper airway obstructive processes.[9] Carbon dioxide diffuses through helium 4-5 times faster than through air, thus Heliox improves gas exchange at the alveolar level.[9] In infants with bronchiolitis, Heliox decreases work of breathing[9] and

improves respiratory scores particularly in the first hour of use.[10-12] Despite these improvements, Heliox use has not been shown to affect the rate of intubation or PICU length of stay.[11]

At the HCH ED, respiratory therapists supply HFNC with an oxygen blender using an institutional protocol of flow based on age (**Figure 1**). At this institution, HFNC is initiated for children ages < 6 months at 2-8 L/min, ages 6-18 months at 4-12 L/min, and ages > 18 months at 8-15 L/min. Rate of flow and fraction of inspired oxygen (FiO_2) is titrated to effect of improved work of breathing and maintaining SpO_2 > 92%. The majority of patients requiring HFNC are admitted to the PICU, except in high-patient volume months during the winter. Anecdotal data from the HCH PICU show a 50% decline in rates of intubation on patients started on HFNC since it became routinely used in 2009, as compared to 2012 (55 versus 27 patients, respectively).

CROUP

Croup, also known as laryngotracheobronchitis, is characterized by inflammation and edema of the subglottic area causing hoarseness, barking cough, and in some cases inspiratory stridor. Croup is often preceded by symptoms of an upper respiratory tract infection, frequently caused by viral pathogens, parainflueza or influenza.[13,14] Patients with croup frequent EDs due to the acuity of onset of stridor and respiratory distress, particularly during the night.

The first line of treatment for croup is glucocorticoids. Glucocorticoids have demonstrated improvement in croup scores at 6 and 12 hours, decreased return visits or readmissions, and decreased ED and hospital length of stay.[14] Glucocorticoids reduce the subglottic swelling and inflammation, thereby improving respiratory effort. Children with inspiratory stridor and respiratory distress due to croup are treated with nebulized racemic epinephrine which causes upper airway vasoconstriction and therefore decreasing edema. It improves croup scores by 30 minutes post-treatment, although no significant improvement is seen at 2 or 6 hours post treatment.[15] The HCH ED utilizes dexamethasone routinely in patients with croup, and nebulized racemic epinephrine in those with distress, followed by a 2-4 hour observation period for recurrent stridor or respiratory distress.

Children with refractory croup may benefit from Heliox. Heliox improves respiratory scores in children with croup, and has similar efficacy to racemic epinephrine, without the adrenergic side effects.[9,13,16,17] The major impediment to Heliox use is hypoxia because of the limited FiO2 that can be achieved due to a high concentration of helium versus oxygen. In addition, the tanks and blenders are cumbersome, and require knowledge of the equipment, thus limiting use to respiratory therapists. Heliox is therefore best used as an adjunct in croup for children with medical conditions that may be exacerbated by racemic epinephrine use, or those with persistent stridor despite multiple doses of racemic epinephrine.

Heliox is supplied by the respiratory therapy department at Hasbro Children's Hospital, and is typically used with HFNC prongs in infants or non-rebreather facemask in children (**Figure 2**). The helium:oxygen ratio is titrated to maintain normoxia and flow rate of nasal cannula is adjusted to improve respiratory distress.

Figure 1. The equipment setup for heated, humidified, high flow nasal cannula. Below: A comparison of the wider diameter of HFNC prongs to the standard infant/small child nasal cannula prongs.

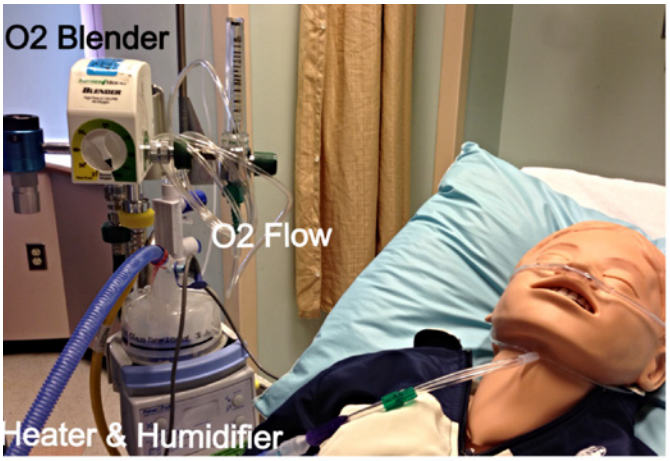
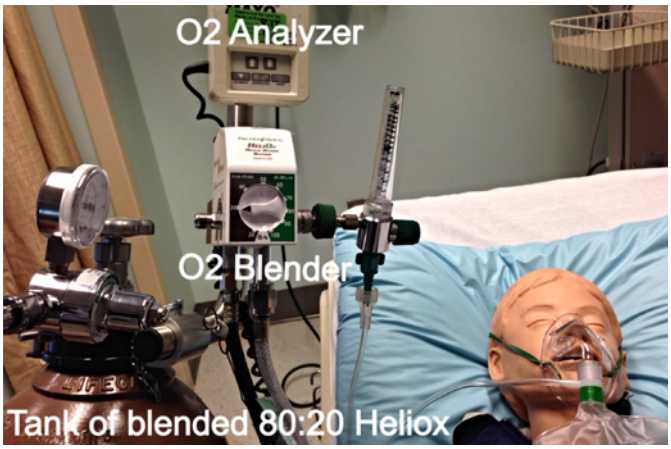


Figure 2. Depicted is the setup and equipment for Heliox, applied with a non-rebreather mask.



ASTHMA

Asthma is a chronic condition of airway inflammation and hyperreactivity, and is a frequent reason for ED visits. Beyond treating acute asthma exacerbations, the HCH ED serves as an alternative setting to initiate education and improve primary care linkage for children with poorly controlled asthma.

HCH ED providers treat asthma as recommended by the National Heart, Lung, Blood Institute (NHLBI) guidelines. Nebulized albuterol and ipratropium (Duoneb) are used for initial management of moderate-to-severe asthma exacerbations, and are administered with breath-actuated nebulizers (BANs).

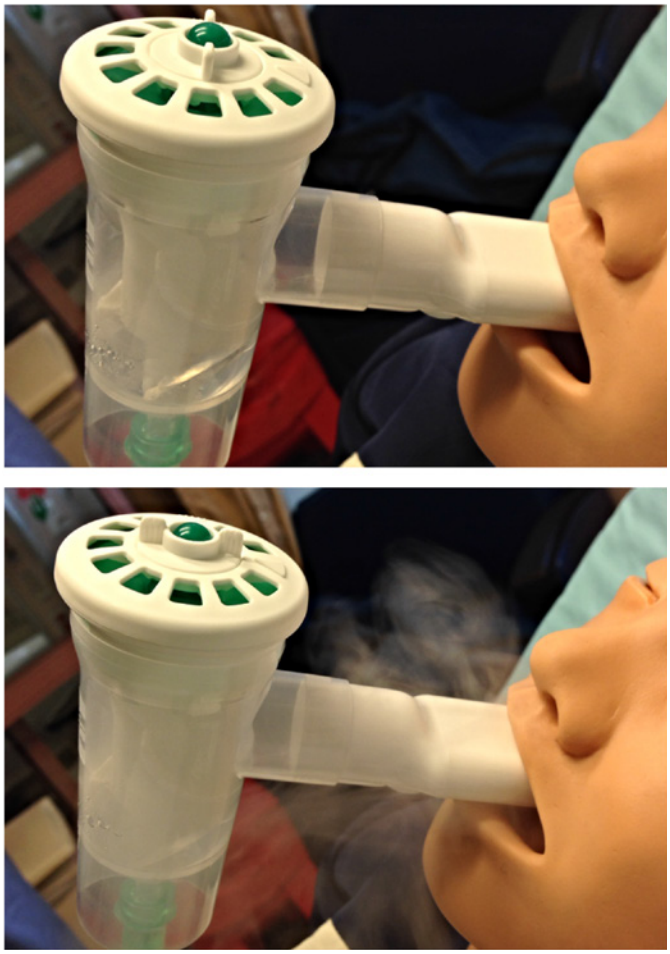
BANs have been introduced in the last 10-15 years for efficient nebulized medication delivery for patients with asthma. When used in the appropriate clinical scenarios BANs are cost effective. BAN devices deliver aerosol particles at the onset of inhalation, thus limiting the loss of aerosol during exhalation.[18,19] Only 4% of medicine is lost to the environment versus > 30% with the conventional nebulizer.[20] Randomized pediatric trials of conventional nebulizer versus BAN during asthma exacerbations demonstrated superior results of BAN on asthma scores, respiratory rates, spirometry, oxygen saturation, length of stay, and admission rates.[18,21] BANs can be used with a mouthpiece for older children, or tight-fitting facemask for the younger child and are routinely utilized for children of all ages with asthma in the HCH ED (**Figure 3**). Due to more effective medication delivery children are reassessed after each nebulized treatment to determine need for further treatments.

For infants who are unable to generate enough force to deliver the aerosol, the nebulizer may be converted to continuous administration with a twist of the top of the device (Figure 3). Use of the BAN for continuous delivery, however, is not as cost effective as more traditional nebulizer delivery systems that provide continuous delivery. In older children with mild symptoms, multi-dose inhaler (MDI) with a spacer is administered. Observation of MDI use by ED staff provides an opportunity for education about administration techniques.

Management of acute asthma includes systemic corticosteroids to reduce airway inflammation in patients who do not completely respond to a single albuterol treatment. Oral prednisone or dexamethasone is utilized in patients who can tolerate oral medication, and IV methylprednisolone is reserved for severely ill or vomiting patients. Due to its 36-72 hour half-life, dexamethasone is often administered in 2 doses: day 1, and day 2 or 3. Children who do not respond to first-line therapies are typically given continuous albuterol and adjunctive treatments such as IV fluids, IV magnesium sulfate and those with significant distress may benefit from additional respiratory interventions such as Bipap or Heliox.

Heliox may improve medication delivery to obstructed airways in children with asthma by improving laminar flow, but the limited data available has not demonstrated consistent benefits.[9,23,24] One study showed improvement in asthma scores in the ED,[22] but other studies showed no difference in asthma scores or length of stay.

Figure 3. Depiction of Breath Actuated Nebulizer. Note that during exhalation the green ball in the center is raised (above), and during inhalation it becomes depressed, releasing nebulized medication (below). The white tabs on the top can be turned to change the mode from breath actuated to continuous nebulization.



Prior to discharge from the ED, steps are taken to maximize outpatient asthma management. HCH ED providers regularly communicate with the primary care provider, educate families on an asthma action plan, and if indicated, initiate inhaled corticosteroids or refer to the "Draw A Breath" program which is an innovative asthma education program that provides families with the knowledge and skills to manage asthma and serves over 800 families in Rhode Island.

CONCLUSION

Respiratory illnesses are common pediatric conditions that often require emergency treatment. Unique modalities are available in a tertiary pediatric emergency department for the care of children with 3 common respiratory illnesses:

bronchiolitis, croup and asthma. In addition to traditional guideline-based therapies, the HCH ED has incorporated several treatment adjuncts including HFNC, Heliox, and BANs. HFNC or Heliox use are currently limited to the hospital environment, however, BANs are a simple and cost-effective device that can be integrated into the primary care, urgent care, or community ED setting.

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'Not Just Little Adults' – A Pediatric Trauma Primer

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ABSTRACT

This article describes pediatric trauma care and specifically how a pediatric trauma center, like Hasbro Children's Hospital, provides specialized care to this patient population. The authors review unique aspects of pediatric trauma patients broken down into anatomy and physiology, including Airway and Respiratory, Cardiovascular Response to Hemorrhage, Spine Injuries, Traumatic Brain Injuries, Thoracic Injuries and Blunt Abdominal Trauma. They review certain current recommendations for evaluation and management of these pediatric patients. The authors also briefly review the topic of Child Abuse/Non-accidental Trauma in pediatric patients. Although Pediatric Trauma is a very broad topic, the goal of this article is to act as a primer and describe certain characteristics and management recommendations unique to the pediatric trauma patient.

KEYWORDS: pediatric trauma care, pediatric trauma center, non-accidental pediatric trauma

INTRODUCTION

Trauma is the leading cause of death and disability in children and adolescents, accounting for 1/3 of all Emergency Department (ED) visits in patients less than 15 years of age.[1] There are significant differences between adult and pediatric trauma patients including anatomic variations in size, body proportions and ossification of the skeleton, physiologic responses to injury, patterns of injury, and psychological, emotional and social needs. This paper reviews some of the unique characteristics of pediatric trauma patients and how specialized care at Pediatric Trauma Centers (PTC) benefits this population.

Pediatric trauma patients who receive care at PTCs have been shown to have improved outcomes.[2] PTCs have specialized infrastructure, medical staff, ancillary support personnel and medical equipment to specifically assess and treat injured children. The Pediatric Trauma Team at Hasbro Children's Hospital (HCH) is jointly led by board-certified pediatric emergency medicine physicians and pediatric surgeons. In 2012, injured patients represented almost 13,000 of the 50,000 patients treated in the HCH ED.

Injured pediatric patients arriving at the HCH ED are immediately triaged by skilled RNs who evaluate mechanism of injury, physiologic parameters, perform gross assessment of injuries and activate the trauma system. There is a tiered response based on the mechanism of injury and physiologic condition of the injured patient. All patients are evaluated by a pediatric emergency physician who works in concert with the pediatric surgical team. When pediatric trauma patients are hemodynamically unstable or have sustained injuries that put them at immediate risk of mortality without rapid treatment, the highest trauma response is activated. This tier of the pediatric trauma system includes the following resources: the presence of the pediatric trauma attending surgeon, pediatric anesthesia, and respiratory therapy, notification of the operating room, blood bank, laboratory, Pediatric ICU, chaplain and social work services.

All pediatric trauma patients are systematically assessed according to the Advanced Trauma and Life Support (ATLS) protocols[3] beginning with a primary assessment focusing on the "ABCs" – Airway, Breathing, and Circulation. Each component is assessed and secured by the physicians before moving to the next with the goal of immediately addressing and correcting physiologic derangements, such as hypoxia or hypotension that could result in secondary insult or death if not recognized and treated quickly. Once stabilized, a secondary assessment is performed with a complete head-to-toe physical exam and may include laboratory and radiologic evaluations. Examinations are repeated throughout the initial resuscitation period to assess response to treatment or evidence of physiologic deterioration. When the correct disposition is determined, the patient is then transferred from the ED to the operating room, inpatient bed, or discharged home.[3] For those patients admitted to the hospital, tertiary assessments are carried out to identify any other injuries that were not apparent during the initial evaluation.

UNIQUE ASPECTS OF PEDIATRIC TRAUMA PATIENTS

Airway and Respiratory Reserves

Hypoxia and inadequate ventilation are the most common causes of pediatric cardiopulmonary arrest following trauma, therefore, efficient and effective airway management is a critical aspect for pediatric trauma.[4] The unique features of infant and pediatric airway anatomy and respiratory physiology make airway management one of the most challenging

components of pediatric trauma care. Infants and small children have relatively large heads that may result in flexion of the neck and airway causing airway obstruction in the unconscious patient. Children also have small oral cavities, relatively large tongues, and a more anteriorly and superiorly positioned larynxes compared to adults, limiting visualization of the airway during interventions. Clinicians at PTCs are specially trained in pediatric airway management using appropriately sized equipment based on the patient's age and size. Advanced techniques such as video-assisted laryngoscopy are sometimes utilized to establish a secure airway while minimizing manipulation of the patient's head and neck. Once intubated, due to relatively short tracheas, pediatric patients are at increased risk of endotracheal tube displacement, either into the right mainstem bronchus or accidental extubation if the tube is under tension. Appropriately securing the tube, adequate, safe sedation and close monitoring when transferring pediatric patients can help prevent complications.[5]

Cardiovascular Response to Hemorrhage

Children are better able to maintain relatively normal blood pressure despite significant blood loss, compared to adults. Studies have shown that pediatric patients can maintain a perfusing pressure with up to 35-40% blood loss prior to becoming hypotensive.[3] Furthermore, infants and small children must increase their heart rates to increase stroke volume and improve cardiac output. Therefore, any interventions or medications that decrease heart rate may cause a rapid and detrimental loss of perfusion.

SPECIFIC INJURIES

Spine Injuries

Spine injuries are relatively uncommon in the pediatric trauma patient, with approximately 1000 spinal cord injuries occurring each year in the United States.[6] About one-half of patients with vertebral fractures have no neurologic findings. Conversely, some patients have spinal cord injuries without radiographic abnormality (SCIWORA), where the normal laxity of the soft tissues of the child's spinal column leads to damage of the spinal cord without fracture or ligamentous injury. Spinal immobilization is therefore recommended when there is concern for cervical spine injuries based on mechanism of injury or if the patient cannot be adequately assessed due to agitation or altered mental status. Immobilization can be done with a pediatric C-collar and a rigid backboard.

Physical exam and plain radiography are the standards of care in pediatric spine evaluation. Plain radiographs have a higher relative sensitivity for diagnosing cervical spine fractures in pediatric patients compared with adults because children do not have the degenerative orthopedic changes seen in adults.[7] A concerted effort should be made to reduce radiation exposure with pediatric patients, especially to sensitive tissues like the developing thyroid gland. If there is a concerning finding on plain films or high clinical suspicion for fracture, a selective CT is more sensitive than plain films and is recommended. In contrast to adults who are more likely to suffer lower c-spine injuries, most spinal injuries in young children involve the upper c-spine due to their relatively larger heads that create a fulcrum-like effect on the upper c-spine region.[8] If there is concern for ligamentous injury or SCIWORA, patients should be placed in an extended wear rigid collar and best evaluated in concert with a pediatric spine specialist and may require MRI.

Traumatic Brain Injury

Traumatic brain injury is the leading cause of death in pediatric trauma patients. While the best management is prevention, once the injury has occurred, it is critical to prevent secondary insult to the brain from hypoxemia and hypotension.[9]

Early establishment of a secure airway and close monitoring and management of the hemodynamic status of patients are paramount. Rapid sequence intubation (RSI) should be employed using medications selected for their adjunctive neurologic properties. Lidocaine premedication can minimize increased ICP. Etomidate also has neuroprotective properties through its effects on intracranial pressure, cerebral blood flow, and cerebral metabolic rate of oxygen consumption.[10] In addition, etomidate maintains blood pressure. Either polarizing or non-polarizing paralytics are acceptable; however, agents that are rapidly cleared are ideal as they have minimal impact on ongoing assessment of the neurologic exam. Hyperventilation is no longer recommended as a PaCO2 <35 mmHg may result in cerebral ischemia. The use of continuous end tidal CO2 monitoring is recommended, with a target between 35-38 mmHg. Head of bed elevation 30 degrees may also decrease ICP; however this has not been well studied in children. When there is evidence of elevated ICP, Mannitol and 3% hypertonic saline boluses may transiently decrease ICP.[11,12] Goals should be limited to initial stabilization and expedited transfer to a PTC. Delays in transfer for imaging beyond a chest x-ray should be avoided. If neuroimaging has been obtained, it is important to share the findings with the PTC prior to transfer and to ensure a copy of the images accompanies the patient.[3]

Luckily, up to 98% of head trauma is not severe. A recent large, multicenter study established guidelines with an online calculator, "The Pediatric Head Injury/Trauma Algorithm" to identify those patients who had a low risk of a clinically important traumatic brain injury.[13,14,15] These guidelines can help clinicians safely avoid unnecessary head CTs and radiation exposure in many pediatric patients.

Thoracic Injuries

Thoracic injuries are the second leading traumatic cause of death in children.[16] The ribs and sternum are not fully ossified until late in adolescence so the chest wall provides less

protection to underlying vital structures, thus a significant amount of energy is transferred to the lungs, heart and great vessels. The most common life threatening thoracic injuries are tension pneumothorax, cardiac tamponade, airway obstruction, open pneumothorax and massive hemothorax and all can be rapidly addressed in the ED.

Blunt Abdominal Trauma

Blunt abdominal trauma is the third most common cause of pediatric trauma deaths, but is the most common unrecognized fatal injury. Many serious abdominal injuries have non-specific or subtle external signs, so a systematic approach is important to avoid a missed diagnosis.[17,18] Splenic and hepatic injuries are the most common followed by renal, small bowel and pancreatic injuries. Children have very compliant chest and abdominal walls, and a relatively larger volume of viscera with less fat within a smaller AP diameter. As a result, the liver and spleen are less protected by the rib cage, placing them at increased risk of injury during blunt trauma. Common mechanisms include high-speed motor vehicle collisions, falls from greater than 20 feet, and direct blows to the abdomen (i.e., bicycle handlebar injury). Concerning exam findings include abdominal wall abrasions or bruising, seat-belt marks, tenderness or rigidity, distension, referred shoulder pain from diaphragmatic irritation, and emesis.[19] Abdominal wall bruising is a significant finding as one study of restrained children in MVCs found that those with a "seatbelt sign" were 232 times more likely to have intra-abdominal injuries than those without.[20]

The evaluation and management of pediatric blunt trauma has changed significantly in recent years. In addition to considering screening x-rays of the c-spine, chest and pelvis, screening laboratory studies may include CBC, type and cross, and urinalysis. LFTs, amylase and lipase are used selectively for patients who cannot give a reliable abdominal examination or if there is a concern for child abuse. Indications for CT scanning include >50 RBCs/HPF on urinalysis, LFTs >3 times normal, elevated pancreatic enzymes in the absence of facial trauma.[21,22,23] CT scanning should only be done in a hemodynamically stable patient.

Non-operative management (NOM) has been shown to be successful in >90% of solid organ injuries (liver, kidney, and spleen). It is preferable to preserve the spleen to allow for maturation of the immune system and to avoid the potential morbidity and mortality related to infection and sepsis. NOM for severe hepatic injuries may be complicated by bile leak or hemobilia, which can usually be managed with interventional radiology or endoscopic techniques. NOM should only be attempted under the direction of a surgeon in a facility with intensive care monitoring and the ability to take patients emergently to the operating room if they become unstable. Indications for operative management of solid organ injuries include: hemodynamic instability, persistent requirement for blood transfusions or evidence of bowel injury. Patients who remain hemodynamically unstable or are only transiently stable after resuscitation with crystalloid and blood should undergo exploratory laparotomy.

The FAST ultrasound exam (Focused Assessment with Sonography for Trauma) has been popularized for adult trauma patients. However, FAST has a low sensitivity (66%) in the hemodynamically stable pediatric trauma patient. A negative FAST does not exclude intra-abdominal injury, especially to retroperitoneal or hollow organs. A positive scan may suggest the need for CT, but it should not be used as the sole indication for laparotomy in children.[4]

Child Abuse/Non-accidental trauma

Victims of non-accidental trauma (NAT) present for medical care with a spectrum of trauma and non-trauma complaints. Over the past year, Hasbro Children's Hospital has cared for 236 children who are confirmed or suspected victims of child abuse injury and 4 deaths as a result of NAT. When evaluating and caring for pediatric patients, it is important to consider that young children are at increased risk of significant morbidity and mortality from child abuse, especially non-ambulatory infants and children. Risk factors for abuse include delayed medical care, injuries not consistent with the history or the patient's developmental stage, and unexplained bruising or oral trauma, especially in non-ambulatory patients. The HCH has a team of pediatric child abuse specialists at the Lawrence A. Aubin Sr. Child Protection Center. If NAT is suspected, medical documentation, radiographs and laboratory tests are critical components of forensic evaluations. Other children in a family may also be at risk, so involving law enforcement and child protective agencies (such as RI DCYF) to investigate the safety of the home is another important component in the management of these patients.

CONCLUSION

Pediatric injuries and trauma are common. As reviewed in this article, there are many differences between adult and pediatric trauma patients including anatomical, physiological, psychological, emotional and social. Understanding these differences and having a systematic approach to these patients is critical to providing excellent care, preventing secondary insult and avoiding oversight of potentially significant injuries. It is also important to understand how the specialized care at Pediatric Trauma Centers (PTC) can benefit this population of injured patients and when expedited stabilization and transfer to a PTC is the most appropriate disposition.

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Fear and Loathing in the ER: Managing Procedural Pain and Anxiety in the Pediatric Emergency Department

CHRIS MERRITT, MD, MPH

ABSTRACT

The pediatric emergency department can be frightening for children. Visits are unplanned, and frequently accompanied by significant emotional and physical distress. While treatment of pain and anxiety in children have been historically inadequate, the barriers to their treatment have largely been overcome through increased awareness, child- and family-focused care, standardized assessment, institutional safety protocols, and newer pharmacologic agents. The pediatric emergency physician is now a primary advocate for treatment of children's pain and anxiety and for the safe and appropriate use of procedural sedation. This article focuses on the treatment spectrum available for providing safe and effective procedural sedation, analgesia and anxiolytic therapy.

KEYWORDS: Procedural sedation, analgesia

INTRODUCTION

The pediatric emergency department (PED) can be frightening for children. Unplanned visits, family anxiety, illness and injury lead to significant emotional and physical distress. Historically, treatment of pain and anxiety in children has been poorly delivered.[1] Infants and children were once thought to experience pain differently from adults, or not at all. Physicians may be hesitant to prescribe stigmatized medications, such as narcotics, to children. A long-discredited belief that analgesia may mask important diagnostic findings is still widely held. During different stages of development, anxiety and pain can be difficult to assess in infants and children and are often underestimated.[2]

Thankfully, myths and stigma surrounding the treatment of pain and fear have been largely minimized. Using standardized assessment tools, newer pharmacologic agents, improved monitoring, institutional safety protocols, the pediatric emergency physician (PEP) now advocates for and provides analgesia, anxiolysis and procedural sedation for PED patients.[3] This article focuses on the treatment spectrum available for providing procedural sedation, anxiolysis and analgesia (PSA).

Assessment through the developmental lens

Pain is subjective, making self-report the preferred method of assessment. However, when combined with anxiety of an unfamiliar situation, pain is difficult to assess accurately in infants and children. Self-reported numeric pain scales, commonly used in adults, can be applied to older children and adolescents. Self-report pain scales such as the FACES or color analog pain scales may be used in pre-school and school-aged children.[4] For infants and toddlers, in whom self-report is not appropriate, a behavioral scale such as the Face, Legs, Activity, Cry, Consolability (FLACC) scale can be substituted.[5]

Developmentally disabled children, particularly those who are non-verbal, may display increased anxiety and maladaptive reactions to pain or anxiety. Observational pain scales are available to assess pain in these children, but frequently it is the caregivers who recognize subtle changes in state or behavior that indicate discomfort in their child. PEPs should actively enlist the partnership of the parents of non-communicative patients in the assessment and re-evaluation process in the PED.

Non-pharmacologic anxiolysis

Anxiety and pain are intricately interrelated. The approach to pain must include an appreciation of anxiety, and vice versa. Beginning with a non-threatening, child-friendly environment, gearing the PED toward child and family comfort is a first step toward minimizing children's anxiety. Environmental approaches, including pictures on the walls and ceiling and the availability of books, toys, and age-appropriate videos in PSA areas, provide comfort and therapeutic distraction to anxious patients and their families.

Table 1. Commonly-used pain assessment scales in the PED

Scale	Ages
Neonatal Infant Pain Scale (NIPS)	Newborns
Face, Legs, Activity, Cry, Consolability (FLACC)	Newborns to Age 7
Faces Pain Scale*	3 years and up
Non-Communicating Children's Pain Checklist	5 years and up, non-verbal or with developmental disability
Numeric Rating Scales (0-10, e.g.)*	7 years and up
Visual Analog or Color Analog Scales*	7 years and up

*Self-reported pain scales

Children fear the unknown, including the possibility of a painful procedure. While preschool and young school-age children are not likely to respond to reasoning or detailed explanation, emotional support at an age-appropriate level reduces pain and anxiety. Older children can be comforted by a reassuring explanation of anticipated procedures.

Child life specialists are a crucial part of the PED team, providing therapeutic methods of distraction, anticipation, coping and education.[6] These specialists use books, pictures, toys, music, video, guided imagery and other tools during preparation, procedure and recovery. In the absence of a dedicated specialist, ubiquitous smart phones and tablet computers allow PEPs to enlist parents or PED staff in providing child-centered distraction such as videos or music as an adjunct to PSA. Allowing family members to remain present during procedures reduces distress, especially if the family can be enlisted to guide the patient through the procedure.

Pharmacologic anxiolytics

Even painless procedures can lead to significant anxiety in children, sometimes precluding successful completion. Procedures for which analgesia will be necessary may also require treatment of anxiety. For instance, a child with a facial laceration will require local anesthesia, but may also benefit from anxiolytics during the delicate repair. In concert with non-pharmacologic techniques, medications specifically aimed at reducing anxiety can limit a child's distress and ensure successful procedure completion.

Benzodiazepines are the most commonly used anxiolytics in the PED. Midazolam has the advantages of rapid onset and relatively brief duration, and may be given by oral, intravenous (IV) or intranasal (IN) routes. The IN route, using an atomizer and syringe, provides rapid transmucosal absorption, which bypasses hepatic first-pass metabolism, making the medication immediately bioavailable.[7,8]

Table 2. Commonly-Used Anxiolytics in the Pediatric ED

	Dose	Route
Midazolam	0.5 mg/kg	PO
	0.1 mg/kg	IV
	0.2-0.4 mg/kg	IN
Nitrous Oxide	40-70%	Inhaled

Analgesia in the PED

In addition to assessment for pain in all PED patients, protocols that call for the timely administration of pain medications, even for less severe pain, allow for earlier management.[9] Triage and nursing protocols can identify patients with pain early in their ED stays, and oral medications such as ibuprofen, acetaminophen, and even oral or IN narcotics can be administered.

In addition to systemic analgesics, topical analgesia can be applied in anticipation of IV cannulation, laceration repair, lumbar puncture or other procedures. Early placement of topical anesthetics can shorten procedure time and improve results. Needle-free lidocaine powder or liquid and ethyl chloride vapocoolants can further reduce IV-associated pain, and a variety of products using vibration or cooling are reported to mitigate pain from IV insertion. Concentrated sucrose solution and non-nutritive sucking have been shown to decrease the pain response in neonates and young infants.

Topical anesthetics can also be applied in anticipation of wound closure. Lidocaine, epinephrine and tetracaine (LET) can be compounded in a liquid or gel and applied to lacerations, and offers effective anesthesia for many small wounds. Alternative repair techniques are considered for appropriate wounds; cyanoacrylate wound adhesive or adhesive "butterfly" bandages may be painless substitutes for sutures.

Local anesthesia is achieved using 1-2% lidocaine or 0.25-0.5% bupivicaine. Administration causes a brief but intense stinging sensation, which can be mitigated by buffering with

Table 3. Commonly-Used Analgesics in the Pediatric ED

	Dose	Route	Comments
Topical preparations			
LET (liquid or gel)	0.175 ml/kg max 3 ml	Topical	
EMLA or LMX_4	"Small Amount"	Topical	
Local anesthetics			
1% lidocaine with epinephrine	Minimal necessary	Injected within a wound	Injection causes stinging pain. Use epinephrine with caution in areas of terminal circulation. Max: 5 mg/kg of lidocaine
Non-narcotics			
Acetaminophen	15 mg/kg	PO, PR	Max 3g/day or 75 mg/kg/day
Ibuprofen	10 mg/kg	PO	Caution in anticoagulated patients, asthmatics
Ketorolac	0.5-1 mg/kg	IV, IM	Similar to ibuprofen. Max 15-30 mg
Nitrous oxide	40-70%	Inhaled	Avoid in intracranial injury, pneumothorax, bowel obstruction
Narcotics			
Morphine	0.1-0.2 mg/kg	IV, IM, SQ	Frequent histamine release, observe for respiratory depression
Hydromorphone	0.015 mg/kg	IV, IM	
Hydrocodone	0.2 mg/kg	PO	Typically available in combination with acetaminophen
Fentanyl	1-2 mcg/kg	IV, IM, IN	Rigid chest is a rare but severe side effect. IV formulation (50 mcg/ml) can be given intranasally

SQ = subcutaneous, IM = intramuscular, IV = intravenous, IN = intranasal

sodium bicarbonate, warming to room temperature, and administering the smallest necessary dose as slowly as possible. For small lacerations, a 1 ml insulin syringe allows a slowly titrated injection through a tiny 29-gauge needle, causing less distress than a larger syringe and avoiding using more anesthetic than necessary. When possible, regional blocks may provide a broader area of anesthesia with fewer injections.[10]

Opiates, morphine being the archetypal example, are the workhorses of ED analgesia, with rapid and generally predictable absorption and onset. Monitoring for respiratory depression is recommended, though typical doses are generally safe. Morphine may cause histamine release, with flushing and pruritus, nausea and hypotension, which are less common with synthetics such as fentanyl. Fentanyl has been associated with sudden onset of chest wall rigidity, which requires aggressive treatment, including respiratory support and muscle relaxation. Naloxone may be used for reversal, given at a dose of 0.1 mg/kg IV and repeated every 2-5 minutes.

An alternative to IV opiates is IN fentanyl. Like midazolam, fentanyl becomes rapidly bioavailable when administered to the nasal mucosa using an atomizer and syringe. It has relatively rapid onset, and is less irritating to the mucosa than is midazolam. IN fentanyl can be used for brief painful procedures (e.g., I&D) or as a bridge to definitive analgesia prior to IV access.[11,12] Fentanyl may also be effective when nebulized, though there is less data using this administration.

Sedation in the PED

There are situations when analgesia alone is inadequate to safely care for PED patients, and prudence calls for the use of sedation. Sedation can be achieved using a pure sedative without analgesic properties (e.g., for a radiographic procedure), a sedative with some analgesic properties (e.g., for suturing a laceration) or one with strong analgesic properties (e.g., for fracture reduction). As with any medication, the PEP must weigh risks and benefits in the context of a patient's history and needs.

PEPs have the training and skills, including emergency management of pediatric airways and resuscitation, necessary to safely manage the sedated child and any potential untoward effects of sedatives.[13-16] Although serious complications are rare, it is critical that sedation providers in the PED establish and adhere to institutional guidelines for training, credentialing and provision of PSA, and refresh this training to maintain familiarity with the medications and their appropriate applications.[14,16]

Ketamine is a dissociative anesthetic with sympathomimetic effects, providing analgesia and sedation but preserving airway reflexes and cardiovascular function. This makes ketamine an attractive sedative for painful procedures.[17] While ketamine may cause some increase in oral secretions, this side effect is rarely clinically significant, though some PEPs co-administer antisialagogues.[18] Ketamine's most serious adverse effect is laryngospasm, though this too is rare. Its most common side effect, however, is nausea, for which some practitioners provide empiric antiemetics. Occasionally ketamine is associated with a non-dose-dependent dysphoric emergence reaction, and is contraindicated in those with known psychosis.

Propofol is gaining traction in PEDs as a short-acting sedative-hypnotic whose rapid onset, short duration and antiemetic effect make it ideal for many procedures.[19] While it provides no analgesia in and of itself, it can be combined with ketamine or other analgesia to achieve excellent sedation for painful procedures. In fact, when mixed and co-administered with ketamine, the total doses of either medication can be reduced.[20] When provided as a constant infusion, propofol can provide prolonged post-intubation sedation for critically ill patients who can tolerate its modest lowering of blood pressure.

Like propofol, the barbiturates, including pentobarbital, provide sedation but little or no analgesia. Adverse reactions are rare, and primarily include symptoms related to hypoventilation.

Inhaled nitrous oxide is an effective sedative used alone or in combination with analgesics. It has a rapid onset, and

Table 4. Commonly-Used Sedative Agents in the Pediatric ED

	Dose	Route	Comments
Dissociative			
Ketamine	1-2 mg/kg	IV	IM dosing less predictable, may be associated with increased incidence of laryngospasm. Nausea is common. Emergence reactions may occur.
Sedative/Hypnotics			
Propofol	1-2 mg/kg, repeat doses of 0.5 mg/kg	IV	Little/no analgesia, hypotension common but not often clinically important
Pentobarbital	2-5 mg/kg	IV	No analgesia. Respiratory depression and hypotension possible
Inhaled agent			
Nitrous oxide	40-70% admixed with oxygen	Inhaled	Some analgesia. Nausea is common
Combined Medications			
"Ketofol" 1:1 mixture of ketamine/propofol	Starting dose of 0.5-1 mg/kg of each agent	IV	Unproven benefit over ketamine alone

once removed, its effects are reversed within seconds to minutes. It provides some analgesia, making it useful for brief painful procedures. Nausea and vomiting are common but tend to be brief. The drug requires a gas scavenging system, which may limit its use to specific locations within an ED.

There is evolving pediatric experience with newer sedatives such as dexmedetomidine, which appears promising, though it may require longer induction time than similarly effective agents such as propofol.[21]

CONCLUSION

Pediatric emergency physicians are uniquely positioned to advocate for and manage pain, anxiety and distress in sick and injured children throughout the ED experience. Untreated pain and anxiety are not excusable given our understanding of pediatric pain and its lasting effects. PEPs possess a unique understanding of the modalities for pain management – including but not limited to pharmacologic choices. The PEP should understand the relative safety and efficacy of each of these modalities and should be prepared with a systematic approach to pediatric pain.

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Disclosures

None

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Multicenter Pediatric Emergency Medicine Research and Rhode Island

THOMAS H. CHUN, MD, MPH

ABSTRACT

Multicenter clinical research studies are often needed to address issues of generalizability, conditions with low incidence, adequate statistical power, and potential study bias. While pediatric research networks began work in the 1950s, and Rhode Island physicians have contributed to many of these studies, pediatric emergency medicine (PEM) collaboratives are relative newcomers. Since the mid-1990s, Rhode Island pediatricians have contributed to multicenter studies of diabetic ketoacidosis, bronchiolitis, asthma, quality of PEM care, meningitis, brief interventions for substance use disorders, point-of-care ultrasound, and pre-hospital triage protocols.

In 2011, Rhode Island Hospital joined the Pediatric Emergency Care Applied Research Network, the first federally funded pediatric emergency medicine network of its kind. Its mission is to perform high quality, high impact PEM research. Since joining the network, Rhode Island Hospital has quickly become a productive and valued member of the network, portending a bright future for multicenter PEM research in the Ocean State.

KEYWORDS: pediatric, multicenter, research, PECARN

THE NEED FOR MULTICENTER PEDIATRIC RESEARCH

High quality medical research must successfully address many challenges. Single-center studies frequently encounter problems with generalizability as patient, geographic, and socioeconomic factors frequently bias results. Such studies may also suffer from lack of statistical power, to either definitively answer a clinical question or provide estimates with reasonable statistical confidence. Pediatric research often faces the additional conundrums of conditions or outcomes with low incidence, a wide range of severity of illness or injury, and the ethical, legal and logistic considerations of obtaining assent and consent of minors and their parents. All of these factors complicate and pose barriers to rigorous pediatric studies.

Multicenter studies offer a potential solution. The benefits of multicenter trials include the ability to recruit a larger number of and more diverse participants from a variety of geographic locations, and the possibility of evaluating the effect of practice variation between sites. It is likely that genetic, ethnic, environmental, psychosocial, and cultural factors all make significant contributions to observed medical phenomena. Multicenter trials may be the only method for properly investigating these effects, and providing robust, generalizable clinical data.

The first national pediatric multicenter networks were formed by oncologists in the 1950s, rheumatologists in the 1970s, and neonatologists in the 1980s. To address research in primary care settings, regional pediatric research collaboratives formed in Rochester, NY, and Chicago, IL, in the 1970s and 1980s respectively, ultimately resulting in the formation of the PROS (Pediatric Research in Office Settings) by the American Academy of Pediatrics (AAP) in 1985.[1] Since their inception, Rhode Island pediatricians and investigators have contributed to numerous studies in the neonatology, hematology-oncology and PROS networks, and have recently begun to collaborate with critical care networks as well.[2,3]

Multicenter Pediatric Emergency Medicine Research

Beginning in the mid-1990s, members of the AAP's Section of Emergency Medicine formed the Pediatric Emergency Medicine Collaborative Research Committee (PEM-CRC), which has subsequently produced numerous multicenter studies, on broad ranging topics, from career satisfaction, diabetic ketoacidosis, infectious diseases, and cardiac arrhythmias, to appendicitis clinical prediction rules.[4-10] To further address the need for and challenges of high quality pediatric emergency medicine research, in 2001 the Emergency Medical Services for Children (EMSC) branch of the Maternal and Child Health Bureau of the Health Resources and Services Administration (HRSA) funded proposals to "demonstrate the value of an infrastructure or network…to conduct investigations on the efficacy of treatments,…including those preceding the arrival of children to the hospital." As a result of this request, the Pediatric Emergency Care Applied Research Network (PECARN) was born.[11,12]

Table 1.

PECARN Nodes and Sites	
GLEMSCRN **Great Lakes EMSC Research Network** • University of Michigan, Ann Arbor, MI • Children's Hospital of Michigan, Detroit, MI • Nationwide Children's Hospital, Columbus, OH	HOMERUN **Hospitals of the Midwest Emergency Research Node** • Cincinnati Children's Hospital, Cincinnati, OH • Washington University, St. Louis, MO • Children's Hospital of Wisconsin, Milwaukee, WI
PEM-NEWS **Pediatric Emergency Medicine-Northeast, West & South** • Children's Hospital of New York, New York, NY • Children's Hospital of Colorado, Denver, CO • Texas Children's Hospital, Houston, TX	PRIME **Pediatric Research in injuries and Medical Emergencies** • University of California, Davis, CA • Children's Hospital of Philadelphia, Philadelphia, PA • Primary Children's Medical Center, Salt Lake City, UT
PRIDENET **Pittsburgh, Rhode Island, Delaware Network** • Children's Hospital of Pittsburgh, Pittsburgh, PA • Hasbro Children's Hospital, Providence, RI • A.I. duPont Hospital for Children, Wilmington, DE	WBCARN **Washington, Boston, Chicago Applied Research Node** • Children's National Medical Center, Washington, DC • Children's Hospital of Boston, Boston, MA • Lurie Children's Hospital, Chicago, IL
CHaMP E-RNC **Charlotte, Houston, Milwaukee Prehospital EMS Research Node** • Milwaukee County EMS, Milwaukee, WI • Mecklenburg EMS Agency, Charlotte, NC • Houston Fire Department EMS, Houston, TX	

PECARN emergency departments (ED's) currently care for over 900,000 children and adolescents annually, with over-representation of minorities and underserved populations. Since its inception, PECARN has produced more than 150 publications, abstracts and presentations at national meetings.

PECARN's infrastructure funding has been renewed three times by HRSA. In the most recent funding cycle of 2011, PECARN reorganized to 18 major academic pediatric centers across the country, centered around 6 research "nodes," each consisting of 3 affiliated hospitals. An entirely new node was added, PRIDENET – the **P**ittsburgh, **R**hode **I**sland, and **De**laware **Net**work, marking Hasbro Children's Hospital and Brown University's entry into PECARN. Since joining PECARN, Hasbro Children's Hospital has quickly become a high performing site, consistently enrolling high percentages of eligible participants and contributing high quality data on these participants. The most recent addition to PECARN was a demonstration EMSC node in 2013.

The formation of the AAP's PEM-CRC and PECARN subsequently spawned similar organizations across the world, including PERC (Pediatric Emergency Research Canada),[13] PREDICT (Pediatric Research in Emergency Departments International Collaborative Australia and New Zealand),[14] and REPEM (Research in European Paediatric Emergency Medicine).[15] In 2009, these networks joined together to form the consortium of PERN, Pediatric Emergency Research Networks.[16,17] Together, PERN ED's care for over 2 million pediatric patients per year, in over 100 hospitals, in 4 of the 6 World Health Organization regions. They also recently published their first global pediatric emergency research study.[18]

While PECARN and other research networks offer the potential of an increased participant pool, multicenter networks face important challenges, including the possibility of variations in data collection, inter-rater reliability, protocol compliance, and the significant expense of maintaining such networks. Multicenter studies are complex and time-consuming undertakings, requiring painstaking preparation, detailed, comprehensive, and unambiguous study protocols, clearly delineated roles and responsibilities of study personnel, and coordinated IRB approval across multiple institutions. The success of networks hinge on all sites having adequately trained and committed research personnel, who collect and transmit study data in a timely and efficient manner.[1,19]

RHODE ISLAND'S CONTRIBUTION TO MULTICENTER PEDIATRIC EMERGENCY MEDICINE RESEARCH

Since joining PECARN, we have participated in 4 exciting studies, each of which has the potential to revolutionize care of children and adolescents.

RNA "Biosignatures" for Febrile Infants

Neonates with fever are at increased risk of serious bacterial infections (SBI), and routinely undergo invasive testing

of blood, urine, and cerebrospinal fluid. Because current laboratory testing strategies cannot rapidly or consistently distinguish which patients have bacterial or viral illnesses, many infants are admitted for 24-48 hours of observation. Assessing host response to infections may be an accurate, ground-breaking and novel method for determining the etiology of a febrile infant's fever.[20] Microarray analysis of very small amounts of blood, in which "biosignatures" of transcriptional leukocyte RNA may reliably differentiate between bacterial and viral pathogens.

Figure 2 is an example of such biosignatures.

Figure 2.

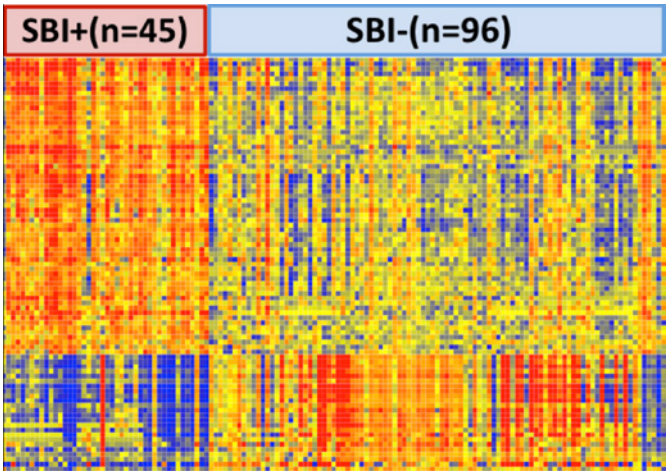

Image courtesy of Prashant Mahajan, MD, MPH, MBA

Each column represents an individual patient, each row represents a different leukocyte indicator gene. The red color signifies over-expression of a gene, while blue color indicates under-expression of that gene. As is easily seen in the picture, SBI-positive and SBI-negative patients appear to have very different biosignatures. Preliminary analyses (personal communication from study investigators) suggest that bacterial infections over-express inflammatory genes and under-express interleukin genes, while viral infections have the opposite pattern. If validated, this technology may dramatically alter how febrile neonates are evaluated and managed.

Diabetic Ketoacidosis and Cerebral Edema

Cerebral edema (CE) is a well known and the most feared complication of diabetic ketoacidosis (DKA).

Old studies suggested that intravenous (IV) fluids were the underlying cause of cerebral injury in DKA. However, DKA research from the last decade has shown that IV fluid administration is not associated with CE. Cerebral hypoperfusion and reperfusion injuries play a key role in DKA-related brain injury. A wide spectrum of CE is often present both before and during treatment for DKA. Neurologic symptoms can be present in the absence of radiologically detectable CE, and even mild DKA may result in long-term neurocognitive deficits.[21]

Based on these data and to address this vexing question, PECARN is currently investigating whether the type and rate of IV fluid administration affect both short- and long-term neurocognitive outcomes of DKA (National Institute of Child Health and Human Development, U01 HD062417). Utilizing a 2x2 factorial design, the study varies the amount of IV fluids given (10 vs 20 cc/kg initial bolus), the rate at which they are given (rapid deficit replacement over 36 hours vs slower replacement over 48 hours), and the type of IV fluid (0.45% vs 0.9% saline). The primary outcome of the study is the occurrence of Glasgow Coma Scale < 14 (15 being normal); the secondary outcomes are incidence of overt CE, and neurocognitive assessments while hospitalized and at 3 month follow-up. The study has a planned enrollment of 1,500 participants. When completed, this study will likely contribute significant, robust data towards answering the question of whether any of these IV fluid regimens either exacerbate or protect against DKA-related cerebral injury.

Figure 3. Diffusion weighted MRI, cytotoxic cerebral edema.

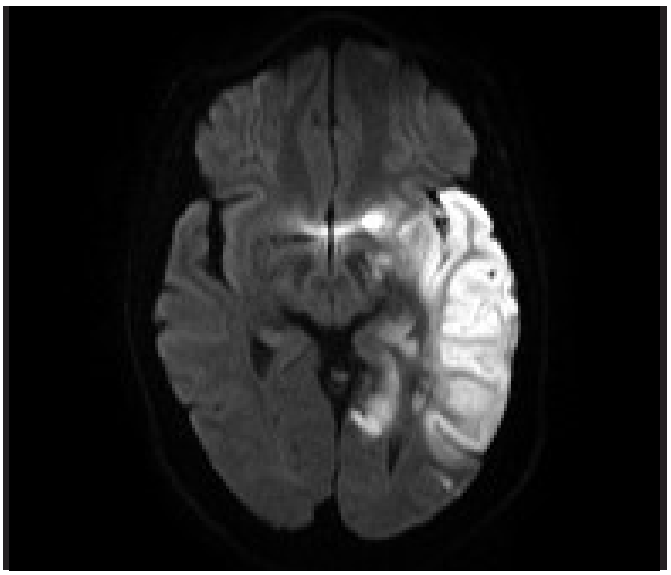

Image courtesy of Jerrold Boxerman, MD and Jeffrey Rogg, MD

PECARN Core Data Project

While many federal agencies collect epidemiologic data on emergency department visits, pediatric specific data has been lacking. To address this deficit, from 2002 to the present, PECARN has compiled data on all patient visits to participating ED's into a single database, the PECARN Core Data Project (PCDP). Using PCDP data, PECARN has been able to drill down into its specific epidemiologic database and perform more granular epidemiologic analyses as compared to other large database studies of pediatric ED visits, identifying patterns related to patient age (e.g., ED visits, hospital admission, and mortality) and the most common conditions for which patients sought care (i.e., infectious diseases, asthma, and mental health conditions).[22,23] Such data is important in helping inform institutions with needs assessments

and resource planning, providing a rigorous basis for epidemiologic reporting and research, as well as developing clinically and epidemiologically sensible diagnostic grouping systems for ED visits by children and adolescents.[24]

PECARN investigators currently seek to advance the use of clinical and epidemiologic data, by extracting more detailed information from electronic health records (Agency for Healthcare Research and Quality, R01 HS020270). The aims of this study are to identify variation in clinical performance and outcomes, with the ultimate goal of improving both patient and quality of care by identifying clinically relevant, evidence-based benchmarks and vastly improving the evaluation of healthcare delivery. If successful, the project would also represent a quantum leap forward in the abstraction of clinical data from electronic health records.

NIAAA Two-Question Screen

Alcohol use is a significant contributor to adolescent morbidity and mortality. It may result in long-term anatomic and neuropsychologic changes and is a strong predictor of adult alcohol use disorders. Given this public health burden, in 2011 the National Institute of Alcohol Abuse and Alcoholism (NIAAA) developed and published a practitioner's guide to assist pediatricians in screening for and intervening in adolescent alcohol use.[25] NIAAA recommends asking adolescents two simple, brief questions about their alcohol use and their friends' experiences with alcohol. NIAAA also believes that these two questions may also reliably predict risk of other substance use and problem behaviors.

The 2 questions as well as the NIAAA practitioner guide can both be downloaded for free from NIAAA at: http://www.niaaa.nih.gov/Publications/EducationTrainingMaterials/Pages/YouthGuide.aspx

To further validate the NIAAA two-question screen and to investigate whether it has predictive ability for other adolescent risky behaviors, shortly after publishing their practitioner's guide, NIAAA released a funding opportunity (RFA-AA-12-008) to study these questions. Utilizing the PECARN network, James Linakis PhD, MD, and Anthony Spirito, PhD, researchers at Rhode Island Hospital and Brown University respectively, received one of these awards (NIAAA, R01 AA021900). The NIAAA two-question screen is currently being tested in 16 PECARN EDs, with a planned study enrollment of 5,000 adolescents, 1,600 of whom will be followed for 2 years. This study will capture a broad cross-section of U.S. adolescents and will generate very robust and generalizable data in terms of age, gender, race and ethnicity, level of alcohol use, and geographic diversity. If valid screening tools are identified, this study has the potential to offer pediatric practitioners a rapid and efficient method for identifying high-risk adolescents.

CONCLUSION

In just a few short years, pediatric emergency medicine research in Rhode Island has significantly grown. Diverse studies, with the potential to dramatically change and improve clinical practices, are now being performed in our state. Joining the PECARN network is an exciting opportunity to continue this growth in research productivity, as well as for new collaborative studies.

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Disclosures
None

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