Chapter 8

Pediatric Critical Care Concerns

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Learning Objectives:

1. Discuss evolving information concerning the developmental impact of a pediatric intensive care unit (PICU) admission.
2. Understand the foundations of patient- and family-centered care and their relevance to promoting compassionate nursing care and the safety of children in the PICU
3. Understand the context of medication errors in the PICU and describe strategies to mitigate medication errors
4. Identify key priorities for nursing research as identified by an international cadre of pediatric critical care nurse scientists
5. Identify resources PICU nurses can use to increase their knowledge base and educate other nurses in the care of critically ill children

Introduction

Pediatric critical care is delivered to hundreds of thousands of children every year. Pediatric intensive care units (PICUs) are located on every continent, although not in every country. Developing countries face particular challenges in terms of adequate and appropriate staff, access to specialty care, and the availability of technology and other resources.[1] Nurses are an integral and key part of the health care team in any PICU. PICU nurses must develop a strong knowledge base in the care of critically ill children in general and a particular and in-depth knowledge of the disease processes and syndromes most commonly seen in their PICU, in their part of the world.

Fortunately, PICU nurses are skilled at establishing relationships and building bridges. They do this by sharing knowledge with their colleagues, and through programs such as the Sister PICU program developed at Boston Children's Hospital (information accessed at http://www.wfpiccs.org/projects/wfpiccs-sister-picu-program/). In keeping with that goal, this chapter aims to discuss key pediatric critical care nursing concerns and provide the reader with useful resources, regardless of where they are located in the world.

Defining Pediatric Critical Illness Across the Globe

Critical illness is a broad term that encompasses life-threatening illness requiring close and near constant attention from health care providers in a highly controlled setting.[2] In developed countries, this complex and advanced level of care typically occurs in a hospital's intensive care unit (ICU), specifically the Pediatric ICU (PICU) for the pediatric population. Critical illness usually requires the use of sophisticated monitoring devices, such as central venous and intracranial pressure catheters, as well as modes of organ support, such as hemodialysis, mechanical ventilation, and vasopressors.[3]

Historians identify critical care medicine as beginning in the 1950's, when providers employed invasive mechanical ventilation for Danish patients suffering from poliomyelitis. Students manually ventilated these patients, and the patients also received "intensified nursing support."[3] These actions resulted in decreased mortality rates, which then encouraged the establishment of the specialized units delivering a high level of surveillance that we know as ICUs.[3,4]

Just as "a child is not a small adult," the PICU is not identical to an adult ICU. While both necessitate diligent monitoring and observation, pediatric patients present challenges in their ability to compensate before abruptly deteriorating; their weight-based dosage requirements and variable metabolism; and, depending on age, developmental obstacles that prevent a concise articulation of symptoms and expression of comfort level.

However, in a developing country that may lack sophisticated equipment and highly trained specialists, critical illness becomes even more time-sensitive and difficult to treat. Sepsis, severe injuries, and respiratory failure are among the most common reasons for PICU admissions in the United States (US). Sepsis is also a frequent reason for PICU admissions internationally. In fact, worldwide, severe sepsis is the leading cause of death in children, usually as a result of multiple organ dysfunction syndrome (MODS) that leads to multiple organ failure (MOF). (NIH, CPCCRN, n.d.). Even in developed countries with plentiful resources, hospital mortality rates for pediatric cases of severe sepsis range from 30% to 60%.[5]

In order to better characterize this, Weiss et al[6] undertook a prospective cross-sectional study investigating sepsis prevalence in 128 PICUs in 26 countries with data collected at five time points in 2013 to 2104. This point prevalence study demonstrated that the prevalence of severe sepsis in children admitted to PICUs was variable by global region. In North America,

Europe, Australia, and New Zealand 6 to 8 percent of patients diagnosed with sepsis were treated in PICUs, with PICU mortality ranging from 21 to 32 %. Ten PICUs across Asia and 10 PICUs across South America reported that 6 to 8 % of patients were treated in PICUs with mortality rates of 40 % in Asia and 11 % in South America. The three South African PICUs participating in the study reported an admission rate of 25% of patients with severe sepsis with a mortality rate of 40 %. In the US pediatric severe sepsis accounts for 4.4 % of admissions to children's hospitals and 7 % of patients treated in PICUs. In China, the incidence of sepsis in China is estimated at more than 360,000 cases annually.

Related to sepsis but also considered separately, instances of particular single organ dysfunctions also lead to critical illness: illness and injury affecting cardiovascular and neurologic systems have higher mortality rates than those affecting the hepatic and renal systems.[7] Point prevalence studies conducted since 2007 in 59-120 PICUs found in 7-28 countries showed a prevalence of 10.8% for acute lung injury requiring mechanical ventilation and an 18.7% prevalence of acute critical neurologic disease, the latter of which had a 12.4% mortality rate.[6] Acute critical neurologic conditions include cardiac arrest, stroke, traumatic brain injury, brain mass, status epilepticus, spinal cord disease, and hydrocephalus. The prevalence of severe sepsis/septic shock in these studies was unavailable, potentially due to lack of consensus among sites and/or countries regarding what criteria must be fulfilled for these complicated and rapidly evolving diagnoses.

Respiratory and bloodstream infections are found in almost two-thirds of cases of severe sepsis worldwide. However, in a country like South Africa, patients concurrently battling HIV/AIDS and tuberculosis may require the resources of pediatric critical care medicine. Because critical illness syndromes such as sepsis cannot be diagnosed the same way HIV can,

data for its prevalence is not always readily available. This, in part, was the impetus for the previously referenced study by Weiss et al.[6] Relatedly, definitions for sepsis or acute lung injury are debatable and continuously revised, which further makes defining critical illness across the globe in general particularly arduous. In countries with few, if any, ICUs or ICU-level supplies and providers, critical illness only briefly exists as "critical illness" because unfortunately, it quickly progresses to death. It is for this reason, joined with the intention of studying comparative epidemiology, that critical illness is sometimes relegated to illness that is treated *within* the ICU.[3]

Developmental impact of pediatric critical illness

A PICU admission is a stressful experience for the child and for the family. Most pediatric critical care research is focused on the time period of the admission itself. But the majority of children are discharged from the PICU, and research on long term outcomes is very limited. However, in the last five years there has a significant increase in studies assessing long term sequelae, and it appears that there may be some long term effects of a pediatric critical illness. Most of the research in this area has been done at a single site or a small number of sites, so it is difficult to generalize the results, but there is sufficient evidence to warrant further studies in larger populations.

Early data suggests that there may be negative effects on neurocognitive development. Two small studies of children admitted to the PICU for septic shock found a significant proportion of the children had decreased cognitive functioning.[9,10] Bronner et al found the effect more pronounced in children admitted at a younger age.[9] The aspects of cognitive functioning impacted in these two studies were memory, IQ, and executive functioning which involves reasoning and problem solving. In some children attention was also impacted. [9,10] van Zellem and

colleagues[11] studied children admitted to the PICU with meningococcal septic shock at 4 years after PICU discharge and found similar impairments of neurocognitive functioning. In an effort to tease out associated factors, they examined the use and dose of opioids, benzodiazepines and pentobarbital. Opioids and pentobarbital were both associated with poor test performance on IQ, specifically verbal scores and vocabulary, as well as attention and executive functioning. Other small studies have identified issues with strength and motor function as well as cognitive deficits.[12]

It is important to remember that these are small studies suggesting a possible trend, but larger studies in more diverse populations are needed to see if there is a real association. However, it does provide support for the use of nurse managed sedation protocols which allow the downward titration of sedation infusions as well as increase, to ensure the child remains on the lowest possible dose needed to achieve a sedation target goal.

Immediate Stabilization of the Distressed Pediatric Patient

As previously discussed, sepsis is a leading cause of death in critically ill pediatric patients and one of the primary reasons children are admitted to PICUs throughout the world.[6,13] A second common cause of PICU admissions and pediatric morbidity and mortality is traumatic injury, including burns. Recommendations for the initial management of these patients are found in guidelines developed by international groups of experts. The primary guidelines discussed here will be the Pediatric Advanced Life Support (PALS) guidelines,[14,15] developed by the American Heart Association (AHA) in collaboration with the International Liaison Committee on Resuscitation (ILCOR) as represented by an international group of pediatric resuscitation experts, and the Clinical Practice Parameters for Hemodynamic Support of Pediatric and

Neonatal Septic Shock: 2007 update from the American College of Critical Care Medicine (ACCM).[16] The Surviving Sepsis 2013 Pediatric Guidelines also summarize the ACCM data. [17]

The Surviving Sepsis Campaign[18] was developed in early 2000 in response to recognition that sepsis was a significant and growing problem worldwide and affected patients of all ages.[19] The explicit goal of the campaign, published in 2002, was to reduce mortality from sepsis by 25% in 5 years. The initiative is led by the Society of Critical Care Medicine (US) and the European Society of Intensive Care Medicine with leadership also provided by the International Sepsis Forum. The initial guidelines have been updated several times, most recently in 2015, and the website provides pediatric-specific guidelines and several tools for education and quality improvement. There are several reports in the literature of how ICUs in less well-resourced countries, including PICUs, have successfully implemented the ACCM/Surviving Sepsis guidelines.[20]

Early recognition of shock in children is linked with improved outcomes.[14,21-24] Close, careful and ongoing assessment is the cornerstone of managing children in shock, regardless of the etiology. If the initial interaction with the child is at the time of presentation, use of the Pediatric Assessment Triangle, part of the AHA pediatric emergency management programs including PALS, is a very useful and rapid tool.[25] It involves rapid assessment of three parameters. The first is general observation: does the child look sick or not sick? This is based on a rapid observation of the child's tone, interactiveness, ability to focus and/or track, and the presence or absence of verbal communication. In the infant, strength of cry is observed. The second is quick assessment of respiratory status looking at abnormal position to facilitate breathing, abnormal airway sounds (stridor, wheezing, muffled voice, grunting) and work of breathing. The presence of retractions, nasal flaring and abnormal breathing all contribute to the

"sick" categorization. Finally, a quick visual assessment of skin perfusion, specifically the presence of pallor, mottling or cyanosis result in a "sick" determination. If any of the categories meet the criteria for "sick" categorization, emergency management should be rapidly instituted. This is particularly useful for Emergency Department nurses who are responsible for triage of incoming patients, but is also useful in mass-casualty situations for rapid sorting.

Assessing for the presence and degree of shock is key, as it directs appropriate treatment. The ACCM pediatric guidelines include the following criteria for the identification of septic shock: fever, tachycardia and vasodilation plus a change in mental status and/or other signs of inadequate tissue perfusion. Guidelines are provided for age specific heart rate (HR) thresholds. The threshold for newborns through one year is 120-180 beats per minute (bpm); over 1 year to 2 years 120-160 bpm, over 2 years to 7 years 100-140 bpm; and over 7 years to 15 years 90-140 bpm. In addition to HR, peripheral perfusion as identified by mental status, capillary refill time (CRT), presence and quality of peripheral pulses and extremity temperature is used to follow treatment effectiveness.[16]

The ACCM sepsis guidelines stress that the goal should be rapid initiation of treatment and a goal has been set that reaching the threshold heart rate for age, normalizing blood pressure and achieving a CRT of ≤ 2 seconds should occur in the first hour. It is also key to begin antibiotics within the first hour.[16]

As soon as assessment identifies the presence of likely septic shock, high flow oxygen should be initiated and vascular access should be obtained. If intravenous (IV) access cannot be achieved quickly, an intraosseous needle should be placed. Rapid boluses of 20 mL/kg of isotonic saline should be given unless the child presents with rales or hepatomegaly. The guidelines indicate that total volumes of up to or more than 60 mL/kg may be required. In the

child requiring large amounts of volume, inserting a second IV or a central venous catheter should be considered.[14,16]

Fluid boluses followed by reassessment should continue until heart rate, blood pressure and perfusion have normalized, and urine output is ≥ 1 ml/kg/hour, or rales or hepatomegaly develop. If volume resuscitation is not effective, or hepatomegaly or rales develop an inotrope should be initiated, typically dopamine or epinephrine. Although inotrope administration via a central route is preferred the guidelines indicate that low dose dopamine or epinephrine may be given via a second peripheral IV line. Use of a carrier fluid to dilute rapidly deliver the drug, along with close observation of the IV site are critical. In the child with continued refractory shock who is at risk for absolute adrenal insufficiency, hydrocortisone may be given. [14,16]

During the initial treatment phase, respiratory status should be closely monitored. Increased work of breathing, hypoventilation and markedly impaired mental status are all indications for intubation. Placement of central vascular access may also require intubation. It is important that volume resuscitation be initiated before intubation or sedative administration in order to avoid hypotension.[16]

The final recommended therapy, if available, is the use of extracorporeal membrane oxygenation for children with continued refractory shock and respiratory failure. During this initial fluid resuscitation it is also important to assess for and correct hypoglycemia and hypocalcemia, but it is also key to avoid hyperglycemia, using a target for serum glucose of ≤ 180 mg/dl (10 mmol/l).[16] The most recent guidelines are available at: http://www.survivingsepsis.org/Guidelines

Shock is also frequently a presenting symptom in children with traumatic injuries, and a systematic process of assessment and management is also key in the child with trauma. The

elements of the pediatric trauma algorithm are completion of a primary survey, during which life threating injuries are identified and treatment is rapidly instituted; a secondary survey, in which all injuries are identified and treatment is instituted as appropriate, and finally determination of ongoing care needed. The primary survey is organized around the pneumonic ABCDE, although in reality Airway, Breathing, and Circulation are typically assessed and managed simultaneously. Impaired circulation is identified using the same assessment parameters described for the child with septic shock: heart rate, blood pressure, peripheral perfusion, urine output. In the case of traumatic injury, hemorrhage is also likely, and sources of bleeding are assessed for as part of the Circulation survey. C also represents cervical spine assessment, which is important in the child, as cervical spine injuries are more common in children than adults, particularly after motor vehicle collisions or falls.[14, 26]

D represents disability, or neurological status. Children are at high risk for head trauma and ongoing monitoring of neurological status using the Glasgow Coma Scale or in the emergency setting, the AVPU (alert, verbal, responds to pain only, unresponsive) scale is critical. Assessment for neurovascular injury is also important. E represents both exposure, to identify sources of significant bleeding and injuries not readily apparent as well as environment. Small children particularly are at risk for hypothermia and the environment should be managed to prevent ongoing heat loss.[14,26]

Key elements in the care of the pediatric trauma patient include identifying and rapidly managing life-threatening injuries, including shock and respiratory failure; avoiding hypothermia and in the child with a head injury avoiding hyperthermia. Volume resuscitation and control of bleeding are important aspects of treating shock. Additionally, hyperglycemia should be avoided

in the pediatric trauma patient, particularly the child with head trauma, as hyperglycemia has been associated with worse neurological outcomes in this population.[14, 26,27]

Children with burn injuries are a special subpopulation of pediatric trauma patients. This population is also at risk for shock due to increased fluid loss through the burned areas. For this reason appropriate calculation of the extent of the burn, using a tool such as the Lund-Browder chart, is done in order to calculate fluid resuscitation requirements. Rapid and complete fluid resuscitation and careful attention to ongoing assessment of circulatory status is key. Children with burn injuries may be at increased risk for respiratory failure due to airway edema after thermal injury or circumferential chest burns which constrict chest expansion. If respiratory assessment reveals drooling, oropharyngeal edema, the presence of soot, or poor chest expansion further respiratory support will be required. Additionally, due to disruption of the skin, children with burns are at increased risk of hypothermia.[14,28]

Care of the distressed pediatric patient, regardless of the underlying cause relies on a few key factors. Skilled initial assessment, rapid and appropriate management, and ongoing assessment of response to therapy are key. Specialty organizations such as SCCM, the European Society of Pediatric and Neonatal Critical Care, the American Academy of Pediatrics, the Pediatric Trauma Society, and the American Burn Association and the International Society for Burn Injuries provide guidelines to assist in ensuring appropriate care for pediatric patients.

Child- and Family-centered Care and its Impact on Patient Safety

The patient-centered care philosophy began in 1969 with the goal of assessing the patient's vision about on the quality of care received in the hospital. This has evolved over the years to a broader concept encompassing the family, and in 1990, the term "Patient-and family-centered care" (PFCC) emerged. In order to support family-centered care, the Institute for

Family-Centered Care was created, promoting the following principles: respect and dignity for the patient and family; shared information between the patient, family and healthcare team; and patient (when possible or appropriate) and family participation in decision-making and collaboration.[29]

PFCC explicitly identifies the importance of involving the family and patient as essential members of the healthcare team. In the majority of situations where a child has a serious health condition, this involvement has positive therapeutic effects on recovery and benefits for the family and staff.[30,31] However, this practice is still in the process of being incorporated into practice by many PICUs across the globe.[32,33] In general, healthcare organizations strive to follow the principles of PFCC. The Institute of Medicine, Institute for Healthcare Improvement, and the American Academy of Pediatrics work in conjunction with the leadership of hospitals and other healthcare organizations to facilitate the involvement of the patient and the family as involved members of the team, in order to advance the practice of PFCC.[29, 34-36]

It is known that nursing professionals often spend the most time with the patient and family during a hospital admission, and thus can ensure PFCC is at the center of nursing practice. The incorporation of PFCC into the nurse's practice facilitates holistic and safe care. In 2003 the Society of Pediatric Nurses and the American Nurses Association published *Family-Centered Care: Putting It into Action: The SPN/ANA Guide to Family-Centered Care*. The handbook provides practice recommendations to assist with incorporating PFCC into the care of all pediatric patients across all settings. The recommendations are based on a framework that recognizes the mutual beneficial partnership that should exists between patients, families and healthcare professionals and are organized around the eight elements of family-centered care.[34,37]

This practice is important, as the goal is to promote the health and well-being of children and families in difficult times, such as during an intensive care admission. In addition, when implemented effectively, PFCC will improve recovery and patient and family satisfaction.[38]

The PFCC approach is focused on respect for cultural values, acknowledging the previous experiences of each individual, emphasizing attitudes of partnerships, encouraging shared decision-making, and recognition of the roles and strengths of each family member. When consistently implemented, PFCC can facilitate increasing competence of children and young adults in taking responsibility for their own health.[38]

Patient Safety Promotion in the PICU: Strategies Used

Beginning in 2007, the National Patient Safety Foundation and The Joint Commission began encouraging healthcare organizations to adopt guidelines promoting interdisciplinary work and collaboration in order to improve patient safety and care quality. A significant component of this strategy promoted the development of a culture of safety within the hospital, especially within the PICU.[39-41]

Additionally, a campaign developed by the World Health Organization called "Patients for Patient Safety" detailed the importance of each patient's participation in promoting their own safety. Key to this campaign is the assumption that when the patient participates in the process of care through collaborative practice and patient-centered care, they become able to promote their own safety.[42,43] However, many factors hinder such participation, especially in health systems in which patient autonomy is culturally opposed, due to a paternalistic attitude and resistance of the healthcare professional to shared decision making. An additional challenge

related to pediatric patients may be promoting respect for the child's autonomy and involving the child in care and decision-making as appropriate.[44,45]

This difficulty can be understood, because care must be individualized based on the patient and family's specific needs. Some strategies proposed by PFCC proponents in order to overcome this situation are related to the involvement of the patient and family, emphasizing that they should be encouraged to participate as allies in patient safety, which will reduce the stress and anxiety of children and improving the family's satisfaction with care. [34,35,46] Studies suggest additional ways to promote child and family-centered care such as:

- Promote information sharing and effective communication between families and professionals. [47-51]
- Include patients and families in interdisciplinary discussions at the bedside, such as patient care rounds. [47-51]
- Use tools or checklists that promoting safer care which also foster parental involvement in the care of their child.[47,52]
- Provide family assistance to ensure the family's physical needs such as accommodation, food and hospital expenses are met. This can reduce the stress of parents while their child remains in the PICU.[53]
- Provide family assistance to ensure the biological, psychological, social and spiritual needs of the child and family are met.[54]
- Create a Commission or Advisory Committee related to PFCC and appoint family members as leaders who are able to participate effectively in the work of the Commission or Committee. These individuals may also serve on subcommittees and working groups dealing with operational issues such as how to involve families in planning their child's

health care and assistance in ways to provide support to other patient and family programs.[34,35,46,55]

- Provide education and support for patients, family and family-centered care team and share complete and accurate information in order to participate in care and decision making. [29,55]
- Follow up with children and their families after PICU discharge in order to identify unmet needs and evaluate care in order to propose effective improvements.

Efforts to implement PFCC in the PICU can also include open visitation, family presence during invasive procedures, and family conferences.[30]

Many professionals are knowledgeable about PFCC, however, the stress of the PICU environment and care specific to seriously ill children can cause PFCC to become less of a priority. When this occurs, the benefit of PFCC is not realized and patient outcomes and parent satisfaction are negatively impacted.[48] In this situation it is important that the health institution seek ways to assist the team in providing holistic care focused on the patient and family, minimizing errors of omission in PFCC and promoting the child's safety.

Patient Safety Issues in the PICU

Considering all sources of error that may occur during a healthcare encounter, medication errors (ME) are the most common and also the most frequent cause of adverse events (AE) and harm.[56,57] This is concerning because in the pediatric patient medications are usually dosed based on weight; this increases the opportunity for harm.

In the past, medication errors in children were reported in case series or individual reports. The possibility of systematic evaluation of error rates in this population occurred only recently,[58] however the incidence of harm due to ME and AE is well documented among

hospitalized patients in general. Research has shown that the potential risk for ME within the pediatric inpatient population is about three times more frequent than with adults, and when ME do occur they have a much higher risk of death than do adults. This is in part due to the narrow margin of error for fluid or medication dosing.[59]

Evidence suggests that for each ME that harms an adult patient, there are 100 undetected errors. Approximately one in every 100 ME results in what is known as an adverse drug event, in which a patient is harmed or dies as a result of drug administration or omission. Keeping in mind how many inpatient medication orders are written each day, the number of pediatric ME in the PICU is likely to be surprising.[60] In the PICU the staff provides complex care that is high risk, and involves the administration of multiple medication doses. This presents numerous opportunities for failure or near misses related to fluids and medications.[61]

Studies have also shown which children are most vulnerable to ME. At risk groups include children younger than two years and children admitted to the PICU or neonatal ICU (NICU). NICU patients are particularly at risk due to their small size. Children seen in the Emergency Department, especially if they are seriously ill or seen in the hours from 4:00 am to 8:00 am or on weekends, children receiving chemotherapy, or miscellaneous IV medications and those whose weight has not been documented are also particularly vulnerable.[60]

According to the results of a literature review, the average ME rate identified was 105.9 ME per 1000 patient-days in adult ICU patients and 24.1 ME per 1000 patient-days in the NICU and PICU.[62] This difference may be attributed to the detection method used to identify the ME and also variability in how ME were defined and classified in the different studies.[63]

In 2009 the World Health Organization (WHO) published the Conceptual Framework for the International Classification for Patient Safety. The goal of this document was to encourage

standardization and to provide a mechanism to provide a method to organize and compare patient safety data and information between disciplines, institutions and across borders all over the world, in order to identify potential safety issues and provide opportunities to learn from ME.[64]

Another initiative addressing ME reporting is the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP). This United States based council, created in 1995, is made up of both consumer and medical organizations. NCC MERP adopted a Medication Error Index and algorithm which is used to classify an error according to the severity of the outcome, promoting standardization in reporting of ME. The index considers factors such as whether the error reached the patient, if the patient was harmed, and to what degree. It is hoped that standardization will help health care practitioners and institutions measure and publish their practice and be able to compare their indicators to other organizations.[65]

Classifying ME in a standard fashion may address the challenge of detecting the cause of the failure or ME that occurred in the health care setting. Identifying the underlying cause of ME remains a relevant opportunity for improving care in the PICU and the current mechanisms involve passive notification of ME. Voluntary incident reporting is the most common source of ME tracking. However, in general, incident reports have a number of inadequacies including underreporting, a dependence on a positive cultural norm that encourages reporting and the potential that the reports are not sensitive and representative.[61]

Buckley and colleagues[66] demonstrated their findings using direct observation of the medication administration process to identify ME in a PICU. They affirm that this method is more assertive than the passive notification. This function can be performed by a clinical pharmacist, encompassing the observation of the practice (procedure), analyses of the prescribing orders and also the audit of the patient medical record.

Another active search resource called the Trigger Tool was developed by the Institute for Healthcare Improvement (IHI) and Premier (a health care alliance comprising 1600 hospitals across the US). This tool is used in retrospective chart review to detect possible adverse drug events (ADE). The modified technique has been tested in 86 hospitals and consists of a checklist of high-alert drugs, antidotes, blood test values, transfer abruptly to high level care and or abrupt stop orders which serve as sentinels that something could be wrong and causing harm to any patient. A list of triggers and processes identified is available in the IHI website and can be used to systematically track ME in the PICU with a consist sensitivity.[67]

Sharek et al aimed in their study to actively track both potential ME (near misses) and ME resulting in real harm in the NICU. Their results showed that only 8% of ME were identified using traditional voluntary reporting methods, but trigger tools appeared efficient and effective at identifying AE.[68]

The investment of significant effort to measure AE must result in ‘’learning’’ on the part of the organization. This is done by analyzing what has occurred, identifying the root causes and developing an effective action plan to mitigate the source of error. Some authors have suggested use of Six Sigma methodology to decrease MEs by analyzing medication administration processes. The framework is described by the pneumonic DMAIC, which stands for Define, Measure, Analyze, Improve and Control to systematize effective processes.[69]

It is important to recognize that erring is a human characteristic, and a multi-step process provides several points where an ME may occur in the PICU. Errors may occur at any point from the time the drug is sourced from the pharmacy until monitoring of clinical effects after medication administration has occurred. In addition to the resources previously discussed, the

American Academy of Pediatrics (AAP) has issued a policy statement on "Principles of Pediatric Patient Safety" that must be considered when evaluating safety practices in the PICU.[70]

Developing a culture of safety is fundamental in this process, which encompasses using a systemic approach instead of blaming individual people. A key element of a culture of safety is a non-punitive environment. In general, ME are not the result of an individual action but the product of a chain of events triggered by a poorly designed system.[62]

High-reliability organizations recognize variability as a constant and are focused on minimizing that variability and its effects. As in aviation, the goal is to be constantly attentive and committed to avoiding failures such as giving a wrong dose of medicine. Behaviors such as creating a complete picture of the steps involved in a process, demonstrating a commitment to resilience; deferring to team members with expertise; and having awareness of systems-based practices.

According to the AAP,[70] the optimal culture of safety requires an organization that supports four key elements: reporting, being just, being flexible, and learning. A reporting culture collects, analyzes, and disseminates data about medical errors and AE. A just culture focuses on a systems approach to human fallibility while holding accountable those who intend to harm or intentionally fail to adhere to policies and procedures designed to keep patients safe. A flexible culture is capable of adapting effectively to changing demands. Finally, a learning culture has the competence and the will to make the right conclusions on the basis of safety information and to implement changes when needed. A culture of safety promotes compassionate disclosure of its mistakes to those who have suffered harm from those mistakes.[70]

In the last ten years, some strategies to prevent AE and specifically ME in the PICU have been reported in many research reports. Specific actions are being implemented in PICUs and have demonstrated satisfactory results, including:

- Implement a mechanism for accurate patient identification
- Use checklists and fast hugs in multidisciplinary rounds
- Involve patients and families in care, by including in them in clinical decision making and in multidisciplinary rounds, taking into consideration their culture and language preference
- Implement an electronic medical records (EMR) including
    - computerized provider order entry (CPOE)
    - a clinical decision support functionality customized for pediatric and neonatal patients
    - an electronic medication administration record encompassing double-checks at the bedside, or forcing functions such as mandated bar-code scanning before the drug administration, with specific alerts for allergies and weight,
    - clinical documentation within the EMR
    - a data repository
    - results reporting
    - other component systems such as pharmacy (pharmacy attention and medication reconciliation) and laboratory[16-17]
- Implement automatic pharmacy systems with automatic devices for the distribution of medicines, preferably in unitary doses

- Implementation of an effective and a collaborative multidisciplinary partnership focused on pediatric patient safety
- The use of Multidisciplinary Clinical Protocols with an available pediatric specialized team to develop and implement the protocols
- Constant training of the multidisciplinary team about technical issues such as equipment, smart pumps, protocols and behavioral issues like disclosures using realist simulations, for example
- Effective participation of the leader in initiatives for patient-safety projects such as creating a tracking system, using knowledge of organizational goals and external agency mandates to target changes with wider impact
    - Standardization on selection of equipment, acquisition of technologic materials, risk scales, and pain scales
    - Decrease or to extinguish the use of verbal prescribed orders (only used in emergency situations)
    - Implementation of statements and policies guiding medication administration by mothers and relatives in the PICU
    - Implementation of assertive and safety communication tools such as SBAR[17] (Situation- Background-Assessment-Recommendation); a tool to frame handoff conversations to ensure that staff are sharing concise and focused information

Efforts to improve patient safety are a priority in most settings, however there is still much to be done. MEs continue to occur every day in every health care environment. Proactive leadership in the context of the PICU is a crucial and fundamental premise needed to facilitate the improvement of the quality of care and pediatric patient safety. There are many implications

for practice and research in this field which can bring improved care to better assist our patients and principally do no harm.

Priorities for Research/Future Directions

Pediatric critical care as a specialty is still fairly young. The first PICU was opened in Sweden in 1955. Ten years later, the second was opened in the United States.[4] A critical mass of research addressing care of the PICU population developed in the 1980's, and nursing research specific to the care of critically ill children has increased in the last two decades, but many questions are yet to be answered.

This issue was most recently addressed by Tume and colleagues in 2014 at the Seventh World Congress on Pediatric Intensive and Critical Care. A one day open consensus conference was used to identify and prioritize research questions important to the practice of pediatric critical care nursing. Each member of a panel of nine international nurse researchers developed three research questions aimed at addressing gaps in knowledge in various pediatric critical care nursing practice domains. A total of 27 questions were presented to the 33 attendees of the conference. The attendees represented ten countries: Australia, Brazil, Canada, Denmark, The Netherlands, South Africa, Switzerland, Turkey, the United Kingdom, and the United States.[74]

After three rounds of group voting, four research questions were identified as the most important. The first was "identifying nursing interventions that directly impact the child and family's experience during the withdrawal of life support." Second was "evaluating the long-term psychosocial impact of a child's critical illness on family outcomes." Third in priority was "articulating core nursing competencies that prevent unstable situations from deteriorating into crises", and the final priority identified was "describing the level of nursing education and

experience in pediatric critical care that has a protective effect on the mortality and morbidity of critically ill children."[74]

Two other recent surveys have also addressed this question using the Delphi survey technique. In 2012 Tume et al used an electronic Delphi study to establish pediatric intensive care nursing research priorities in twenty European countries.[75] Seven statements, related to end-of-life care, decision making around forgoing and sustaining treatment, prevention of pain, education and competencies for pediatric intensive care nurses, reducing healthcare-associated infections, identifying appropriate nurse staffing levels, and implementing evidence into nursing practice were ranked highest. In 2007 to 2008, Ramelet et al conducted a Delphi study to identify National PICU nursing research priorities in Australia and New Zealand. After three survey rounds, priorities identified were: patient issues related to neurological care; pain, sedation, and comfort; best practice at the end of life; and ventilation strategies. In addition, two nurse-focused priorities were also identified.[76] Both of these studies tended to focus more on clinical skills rather than a larger vision for future the future of PICU nursing, but as in the international survey, these groups also identified pain management, sedation, and comfort measures as important research topics.

Although the results of these three studies are not completely in alignment, pain and sedation, end-of-life care, and PICU nursing competencies are themes that emerge as important for each of these groups. This suggests that these are areas ripe for further nursing research.

In addition to nursing specific research, PICU nurses have the opportunity to collaborate with other disciplines in developing new knowledge and improving the care of PICU patients. In developed countries in particular, where PICU survival rates are increasing, new physical, cognitive, and psychological challenges can emerge after discharge. Post-Intensive Care

Syndrome (PICS) is a relatively new term describing these challenges, which can range from muscle weakness to depression. While studies are still few in number for the incidence of PICS, some research estimates that a third to a half of ICU patients experience PICS.[77-80] Data is sparse in general and specifically for the PICU population and PICU. A potentially important direction for pediatric critical illness research would be to examine patients with and without PICS at specific times along the post-discharge trajectory. What are risk factors and possible intervention or *pre*-vention strategies for a pediatric population so diverse, variable, and developmentally fluctuating? Just as pediatric critical care must address not only the emotional needs of the patient, but those of his or her family, this research should also include the effect of PICS on the family of the pediatric patient.

While the PICU must be a sterile, controlled, and often austere environment, it is also a home, however temporary, for a child who is sensitive to the surrounding sights and sounds. Future research should focus on how to create and support a comfortable and healing milieu, and how such a milieu affects patient outcomes and patient satisfaction. Additional research priorities could also include identifying more satisfactory modes of pain management while minimalizing adverse effects and excessive sedation, the effectiveness of telemedicine, especially in underserved areas, and how best to allocate limited resources for critical care in developing countries.

Infants, children and adolescents continue to require critical care in ever increasing numbers around the globe. Significant work is ongoing internationally with the goal of improving outcomes for critically ill children, particularly in the areas of sepsis and trauma. Several consistent research priorities have been identified as important for nursing, and nurse scientists have a real opportunity to continue their important work, as well as to collaborate with

their colleagues in both nursing and other disciplines internationally. Taking advantage of these opportunities for collaboration will be key in minimizing the negative consequences of critically illness for children and their families around the globe.

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Supplemental Tables

Table 1: Educational and program resources for pediatric critical care nurses

American Heart Association Courses International Services: http://www.international.heart.org/en/contact-us			
Course	Target Audience	Web Information	Notes
Basic Life Support	All members of the healthcare team caring for children	https://acls.com/pals-certification	Available as an online course
Pediatric Advanced Life Support (PALS)®	Emergency and ICU staff	http://cpr.heart.org/AHAECC/CPRAndECC/Training/HealthcareProfessional/Pediatric/UCM_476258_PALS.jsp	Supported by the American Association of Pediatrics
Pediatric Advanced Emergency Assessment, Recognition and Stabilization (PEARS)®	Pre-hospital and general care nurses	http://cpr.heart.org/AHAECC/CPRAndECC/Training/HealthcareProfessional/Pediatric/UCM_476633_PEARS.jsp	
American Academy of Pediatrics International Services: http://www2.aap.org/nrp/global.html			
Neonatal Resuscitation Program	Hospital staff caring form newborns at delivery	http://www2.aap.org/nrp/about.html	Jointly sponsored with the American Heart Association
Emergency Nurses Association International Information: https://www.ena.org/membership/International/Pages/Default.aspx			
Trauma Nurse Core Course	Nurses providing emergency trauma care	https://www.ena.org/education/ENPC-TNCC/tncc/Pages/aboutcourse.aspx	International courses available
Course in Advanced Trauma Nursing	Experienced emergency nurses	https://www.ena.org/education/catn/Pages/default.aspx	On-line course
Emergency Nursing Pediatric Course	Nurses providing emergency care	https://www.ena.org/education/ENPC-TNCC/enpc/Pages/aboutcourse.aspx	International courses available
Other Organizations			

American Association of Critical Care Nurses Clinical Practice Resource Links	Acute and critical care nurses	http://www.aacn.org/wd/practice/content/clinicalpracticelinks.pcms?menu=practice	Pediatric and neonatal resources
Acute Assessment and Management of Pediatric Trauma	Trauma team members	https://depts.washington.edu/pedtraum/	Harborview Medical Center, Seattle, Washington, USA
AfterPICU.com	Patients and Families following a critical illness	http://www.afterpicu.com/	MAQ Curley, PhD, RN
Marthaaqcurley.com	PICU nurses	http://www.marthaaqcurley.com/	Access to PICU assessment tools such as the Braden Q and SBS
OPENPediatrics	Global community caring for children	http://openpediatrics.org/clinician_resources_category/nurse/	International web-based forum for
Pediatric Delirium website	PICU nurses	http://www.icudelirium.org/pediatric.html	Vanderbilt University Medical Center
PedsCCM Learning ICU Fundamentals course	Targeted to medical residents, appropriate for experienced ICU nurses	http://www.learnicu.org/Fundamentals/RICU/Pages/default.aspx	Supported through the Society of Critical Care Medicine
World Federation of Critical Care Nurses Resource Page	Critical care nurses	http://wfccn.org/resources	
WFPICCS Educational Resources	Global critical care team members	http://www.wfpiccs.org/education/doctors-nurses/documents/	World Federation of Pediatric Intensive & Critical Care Societies
WFPICCS Video Library	Global critical care team members	http://www.wfpiccs.org/education/doctors-nurses/video-library/	World Federation of Pediatric Intensive & Critical Care Societies
WHO Guidelines on Basic Newborn Resuscitation	Healthcare team members	http://apps.who.int/iris/bitstream/10665/75157/1/9789241503693_eng.pdf?ua=1	World Health Organization

	assisting with deliveries		

Table 2: Basic Pediatric Critical Care Equipment Listing

Basic Critical Care Equipment/Supplies:	
Medications ❍ atropine ❍ adenosine ❍ amiodarone ❍ antiemetic agents ❍ calcium chloride ❍ dextrose (D10W, D50W) ❍ epinephrine (1:1000; 1:10 000 solutions) ❍ lidocaine ❍ magnesium sulfate ❍ naloxone hydrochloride ❍ procainamide ❍ sodium bicarbonate (4.2%, 8.4%) ❍ topical, oral, and parenteral analgesics ❍ antimicrobial agents (parenteral and oral) ❍ anticonvulsant medications ❍ antidotes (common antidotes should be accessible to the ED) ❍ antipyretic drugs ❍ bronchodilators ❍ corticosteroids ❍ inotropic agents ❍ neuromuscular blockers ❍ sedatives ❍ vaccines ❍ vasopressor agents	**Respiratory** **endotracheal tubes** ❍ uncuffed 2.5 mm ❍ uncuffed 3.0 mm ❍ cuffed & uncuffed 3.5 mm ❍ cuffed & uncuffed 4.0 mm ❍ cuffed & uncuffed 4.5 mm ❍ cuffed & uncuffed 5.0 mm ❍ cuffed & uncuffed 5.5 mm ❍ cuffed 6.0 mm ❍ cuffed 6.5 mm ❍ cuffed 7.0 mm ❍ cuffed 7.5 mm ❍ cuffed 8.0 mm **stylets for endotracheal tubes** ❍ pediatric ❍ adult **laryngoscope blades** ❍ straight: 0 ❍ straight: 1 ❍ straight: 2 ❍ curved: 2 ❍ straight: 3 ❍ curved: 3 ❍ laryngoscope handle **magill forceps** ❍ pediatric ❍ adult **nasopharyngeal airways** ❍ infant ❍ child ❍ adult **oropharyngeal airways** ❍ size 0

Vascular Access

arm boards

❍ infant ❍ child ❍ adult

catheter-over-the-needle device

❍ 14 gauge
❍ 16 gauge
❍ 18 gauge
❍ 20 gauge
❍ 22 gauge
❍ 24 gauge

intraosseous needles or device

❍ pediatric ❍ adult

umbilical vein catheters

❍ 3.5F ❍ 5.0F

central venous catheters

❍ 4.0F
❍ 5.0F
❍ 6.0F
❍ 7.0F

intravenous solutions

❍ normal saline
❍ dextrose 5% in normal saline
❍ dextrose 10% in water

IV administration sets

❍ with calibrated chambers and extension tubing and/or infusion devices with ability to regulate rate and volume of infusate

General Equipment

❍ patient warming device
❍ intravenous blood/fluid warmer
❍ weight scale in kilograms (not pounds)
❍ tool or chart that incorporates weight (in kilograms) and length to determine equipment size and correct drug dosing
❍ age appropriate pain scale-assessment tools

❍ size 1
❍ size 2
❍ size 3
❍ size 4
❍ size 5

suction catheters

❍ infant ❍ child ❍ adult
❍ yankauer suction tip

tracheostomy tubes

❍ 2.5 mm
❍ 3.0 mm ❍ 3.5 mm
❍ 4.0 mm ❍ 4.5 mm
❍ 5.0 mm ❍ 5.5 mm

bag-mask device, self-inflating

❍ infant: 450 ml
❍ adult: 1000 ml

masks to fit bag-mask device adaptor

❍ neonatal ❍ infant
❍ child ❍ adult

laryngeal mask airway

❍ size: 1 ❍ size: 1.5
❍ size: 2 ❍ size: 2.5
❍ size: 3 ❍ size: 4
❍ size: 5

clear oxygen masks

❍ standard infant
❍ standard child
❍ standard adult
❍ partial nonrebreather infant
❍ nonrebreather child
❍ nonrebreather adult

nasal cannulas

❍ infant ❍ child ❍ adult

nasogastric tubes

❍ neonate: 5F
❍ infant: 8F
❍ child: 10F
❍ adult: 14-18F

Specialized Pediatric Trays or Kits

❍ lumbar puncture tray
❍ infant/pediatric 22 gauge needles

Monitoring Equipment

blood pressure cuffs
❍ neonatal

❍ adult 18-21 gauge needles ❍ supplies/kit for patients with difficult airway ❍ supraglottic airways of all sizes ❍ laryngeal mask airway ❍ needle cricothyrotomy supplies ❍ surgical cricothyrotomy kit ❍ tube thoracostomy tray **chest tubes:** ❍ infant: 10-12F ❍ child: 16-24 F ❍ adult: 28-40 F ❍ urinary catheterization kits and urinary (indwelling) catheters, 6F–22F	❍ infant ❍ child ❍ adult-arm ❍ adult-thigh ❍ doppler ultrasonography devices ❍ electrocardiography monitor/ defibrillator with pediatric and adult capabilities including pads/paddles ❍ hypothermia thermometer ❍ pulse oximeter with pediatric and adult probes ❍ continuous end-tidal CO2 monitoring device

Adapted from: The AAP, ACEP, ENA, EMSC National Resource Center, and Children's National Medical Center (2010) Guidelines for the Care of Children in Emergency Department Checklist. Available at: https://www.ena.org/about/position/jointstatements/Documents/GuidelinesfortheCareofChildreninED2010.pdf. Accessed on: 12/2/2015.

Questions/Case Studies

1. A key requirement of all PICUs is:
    a. The ability to provide extracorporeal membrane oxygenation (ECMO)
    b. A nursing and resident fellowship program
    c. Nursing staff skilled in the care of critically ill children who provide close monitoring and surveillance
    d. A transport team

2. A concerning long term effect of a pediatric critical illness is:
    a. Failure to thrive
    b. Decreased cognitive functioning such as problems with attention or memory
    c. Premature onset of puberty
    d. Food aversion

3. Which of the following statements is incorrect?
    a. The Institute for Family-Centered Care was created in 1992.
    b. Respect and dignity, shared information, participation and collaboration are the most important principles supporting patient- and family-centered care.
    c. The term "patient- and family-centered care" shows the importance of involving the family and patient as essential members of the health team.
    d. The philosophy of patient- and family-centered care currently can be found in all health institutions across the globe, and is a focus of health professionals seeking to promote and improve the safety of children in the PICU.

e. The WHO campaign called "Patient to Patient Safety" revealed the importance of each patient's participation in promoting of their own safety.

Case Study

JP, three years old, was admitted to the emergency room with dry cough often accompanied by respiratory distress and cyanosis of the lips. Pertussis was diagnosed, and the child was admitted to the Pediatric ICU for observation. Care provided, in addition to medications, was the provision of oxygen support as needed for paroxysmal cough, and the provision of comfort to JP, as well as support to JP's parents. JP's mother remained at her son's bedside full time, and did not receive ongoing information from the healthcare team. She became anxious, tearful, and did not feel secure with the care provided by the team. She felt the team did not attend to JP during his moments of crisis (coughing spells). JP's mother did not understand the pathology, treatment and necessary care related to pertussis. In addition, there was no other family member available to provide JP's mother with breaks away from the bedside, and she did not feel comfortable leaving JP alone. JP's father was not able to visit because the visiting hours of the hospital were not compatible with his work schedule.

4. In thinking about the above case, which of the strategies listed below could be used in this unit to promote a careful focus on the child and family?

    1. Consider the mother as an ally in the quest for patient safety and quality of care
    2. Emphasize the role of family as a partner in care and recognize the strengths of JP's mother in the child's recovery

3. Invite JP's mother to participate in meetings, task forces and discussions involving family-centered care
4. Make efforts to implement child- and family-centered care in the PICU, including open visitation
5. Ensure that information updates are provided regularly to JP's mother; assess the effectiveness of the communication
6. Promote participation by JP's mother's in interdisciplinary team discussions at the bedside

a) Statements 2, 3, 4, 5, & 6 are correct
b) Statements 4 and 5 are incorrect
c) All statements are correct
d) Only statements I, II, III and VI are correct
e) Statements 1, 3, 5, & 6 are correct

Case study: Marie is a 6 month old child who has been well up until the past few days. Her mother brings Marie to the clinic because Marie has had a fever for two days, and could not be awakened from her afternoon nap. Your "quick look" assessment of Marie reveals that her tone is floppy, she is not focusing or interacting with her mother or with you, her face is flushed, and she does not seem to be having difficulty breathing. You obtain the following vital signs: heart rate of 200; systolic blood pressure of 75 mm Hg; respiratory rate of 35, with mild retractions. A thorough assessment of Marie's peripheral perfusion reveals a capillary refill time of 3-4 seconds, feet cool to the touch, and pedal pulses weaker than her femoral pulses. In addition, she

is responding only to painful stimulus. When you listen to breath sounds, her respirations are increased in rate, and she does not have rales. The team feels that Marie is demonstrating signs of septic shock.

5. Which of the following lists the initial interventions for septic shock in the appropriate order?
   a. **Initiate high flow oxygen; obtain vascular access; begin a rapid boluses of 20 mL/kg of isotonic saline; reassess heart rate, blood pressure, perfusion, urine output**
   b. Initiate high flow oxygen; obtain vascular access; begin dopamine; reassess heart rate, blood pressure, perfusion, urine output
   c. Intubate the patient; obtain vascular access; begin dopamine; reassess heart rate, blood pressure, perfusion, urine output
   d. Initiate oxygen by nasal cannula; obtain vascular access; begin dopamine; reassess heart rate, blood pressure, perfusion, urine output