PEDIATRIC EMERGENCY MEDICINE REPORTS

Practical, Evidence-Based Reviews in Pediatric Emergency Care

November 2018 VOL. 23, NO. 11

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RELIAS MEDIA

Pediatric Medication Safety

Our smallest patients are the most vulnerable to medication errors. An awareness of potential vulnerabilities when prescribing in this population is essential. The authors discuss when medication errors are particularly likely, common types of errors, and strategies to minimize the potential for errors.

— Ann M. Dietrich, MD, FAAP, FACEP

To Err Is Human was published in 1999, ironically, sooner than anticipated because of a leak by someone through the Institute of Medicine. Publicity soared around the report, given the gravity of the nature and concern regarding the high numbers of deaths secondary to medical errors within the hospital, reportedly 98,000 per year.[1] The primary motivation for investigating these errors was blame — blame for the individuals causing the errors and the problems that resulted from those errors.[1-3]

Since that time, the culture surrounding medication errors has shifted, focusing on a blame-free mentality to address and resolve the issues associated with the errors. One specialty initiating a collaborative approach to medication safety is pediatrics.[2,4] In 2018, the American Academy of Pediatrics published guidelines highlighting the importance of pediatric medication safety, emphasizing system-level recommendations for addressing and mitigating the incidence of medication errors within the pediatric environment. Although these publications provide a framework to which institutions should adhere, there remains much to learn about issues surrounding pediatric medication errors and methods to potentially increase safety, including computerized provider order entry (CPOE), clinical decision support (CDS) systems, and the use of emergency medicine (EM) clinical pharmacists at the bedside and throughout the department.[2,5-7]

The goal of this article is to discuss the reasons pediatric patients have a higher risk of experiencing medication errors and adverse events, as well as where and how these errors occur specifically within the emergency department (ED). Other aspects that will be discussed are potential interventions and practice environment changes to prevent and mitigate the incidence of drug errors and adverse events within the ED.

Severity of the Issue

Medication errors occur in all healthcare settings. They not only carry a mortality risk to patients but also result in increased healthcare costs, longer hospital stays, and significant morbidity and mortality, especially within the inpatient setting.[3,6,8-12] Intensive care units and EDs consistently have increased medication error rates compared to other areas of the hospital. Medication errors and adverse drug reactions are mutually exclusive events but can occur simultaneously in virtually any inpatient or outpatient setting.[8,11,13,14] (*See Figure 1.*) By

EXECUTIVE SUMMARY

- Medication errors occur in all healthcare settings and carry a mortality risk to patients and also result in increased healthcare costs, longer hospital stays, and significant morbidity, especially within the inpatient setting.
- By definition, a medication error is a failure in planned action related to a medication for its intended use or the occurrence of the wrong plan secondary to either the ordering, transcribing, dispensing, administering, or monitoring of the medication.
- Adverse drug reactions typically result in injury from a specific medication and can be classified as either preventable or nonpreventable.

definition, a medication error is a failure in planned action related to a medication for its intended use or the occurrence of the wrong plan secondary to either the ordering, transcribing, dispensing, administering, or monitoring of the medication.[3,11] (*See Figure 2.*) On the other hand, adverse drug reactions typically result in injury from a specific medication and can be classified as either preventable or nonpreventable.[3]

The pediatric population is particularly at risk, and errors associated with children are not a new discovery. Since the 1970s, literature has documented the higher risk among pediatric patients for medication errors.[3,5] Although awareness has increased dramatically over the last 50 years, the risk remains high, despite interventions and changes to the medical and healthcare industry.[2,6,10,14-16] One area of the hospital that remains particularly at risk is the ED, where medication error rates remain significantly higher in both adult and pediatric populations. The pediatric population carries up to a three times higher risk than the adult population when it comes to medication errors, and prescribing errors have been reported as high as 10-12%.[7-9,15] Of particular concern is the fact that this statistic has remained steady despite increasing attention and focus since the early 2000s.[2,6]

Estimates of medication errors are highly variable but have been documented to be 5-10% in pediatric inpatient settings.[2] The reason behind the high number of errors is multifactorial, given that the situations involved usually are complex and involve numerous individuals and stages of the medication delivery process. Physicians, pharmacists, nurses, and family members all are implicated, as well as failures in technology throughout the medication verification, dispensing, and administration process.[4,5,11,17] Although documentation of error rates is relatively extensive, little research has been published evaluating the risks and incidences of pediatric medication errors. What is known is that pediatric medication safety lags behind adult medication safety for a variety of reasons, namely fewer overall pediatric patients being managed and treated compared to adults.[3,18]

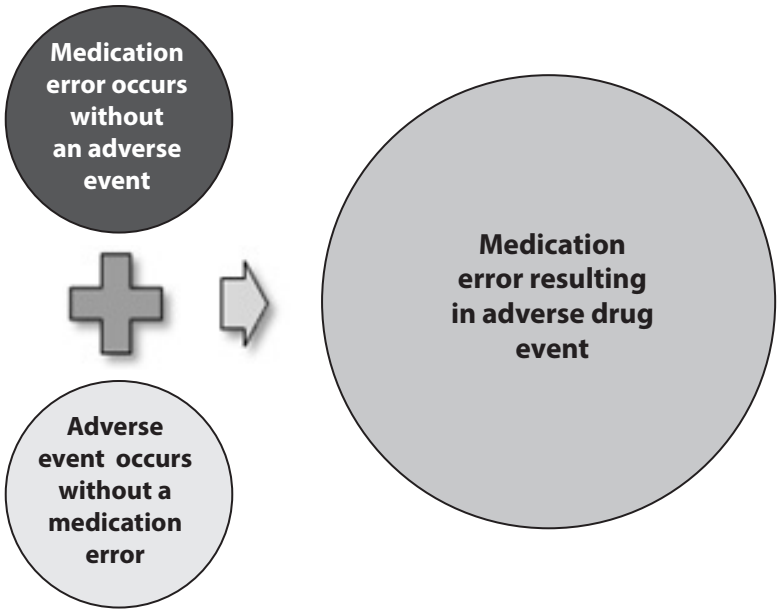
The ED environment consistently has ranked high regarding safety risk. A high volume of orders and the speed at which they are needed, combined with a lack of medical history and complex patient loads, creates the perfect environment for drug errors to occur.[4,15,19] High volumes of patients with varying acuity and inadequate staffing also have made it difficult to accommodate the high numbers of patients presenting to EDs for both critical and ambulatory care. Communication barriers and inappropriate handoffs combined with high numbers of verbal orders also contribute to the risky nature of the ED. In general, many orders are retrospective in nature, which affects the incidence and rate of medication errors in the ED due to miscommunication, incorrect doses already being administered, and lack of clarification during the drug administration process.[10,19] Retrospective orders bypass the verification step in the medication ordering process, which has obvious associated risks, since it removes an additional person to review a drug order prior to the medication being given to a patient. Although implementation of electronic medical records (EMRs) has reduced the number and incidence of prescribing errors in the pediatric population drastically, computer systems have brought unforeseen issues leading to new kinds of errors.[20]

It is no surprise that pediatric patients in the ED remain one of the populations most at risk of medication errors, with rates as high as 5.7 per 100 orders being reported.[10,21] Although incidence rates have been examined, the overall data in pediatric medication errors are lacking, especially in the ED setting. Several recent studies have been published examining 10-fold errors within pediatric intensive care units (PICU) and neonatal intensive care units.[8,16,17,19,22] Most studies are observational in nature and lack the insight into why medication errors are happening consistently in the pediatric population. One of the problems associated with an overall lack of data is errors that typically are reported voluntarily, which leads to significant underreporting. With the currently available literature, it is estimated that for every error that occurs, 1% carry a risk of significant harm and 0.24% cause significant harm to the patient.[11,15]

Quality initiatives geared toward implementing strategies to reduce the medication error rate in pediatrics were created in 2007. However, despite focused efforts toward addressing drug errors in this population, the reason for this continued incidence remains unclear.[2,6,10] The 2008 Wake Up Safe improvement initiative formed the SMART (Specific, Measurable, Achievable, Realistic, and Timely) initiative, which focused on eliminating potential harm in children undergoing anesthesia. The goal was to identify and eliminate preventable harm in children and mitigate the issues with anesthesia and medication errors.[18] Similarly, the Patient Protection and Affordable Care Act attempted to target adverse drug events that were preventable within the hospital. For every 1,000 visits to the ED, four were due to adverse events related to medication errors that potentially could be preventable.[18,23] Despite these initiatives and focused efforts, pediatric drug errors remain a problem in the ED.

Figure 1. Difference Between Medication Errors and Adverse Events

Adverse events can or cannot be prevented but have the potential to result in harm. Medication errors always are preventable and have the potential to cause significant morbidity and mortality depending on the type of error that occurs.



Types of Medication Errors and Where They Occur

By far, the most frequent types of medication errors are related to dosing. Incorrect weights used in calculating the dose, as well as miscalculations related to milligram per kilogram and milligram per body surface area during medication ordering, make dosing errors the leading issue in medication errors in the ED.[3,8,9,19,21,22,24,25] (*See Figure 3.*) As mentioned previously, the Wake Up Safe analysis found prescribing errors to be the most common type of error during the perioperative phase of anesthesia; incorrect doses or administration of the wrong dose also were common.[18] Investigators from the Wake Up Safe initiative found many of these errors occurred when fellows and residents performed the task, particularly during the administrative phase. Teaching institutions and academic medical centers carry their own set of shared risks given the nature of the environment. Despite multiple potential checks in place, less-experienced healthcare practitioners under training create a precarious work environment at risk for potentially deadly outcomes.[9,18,21]

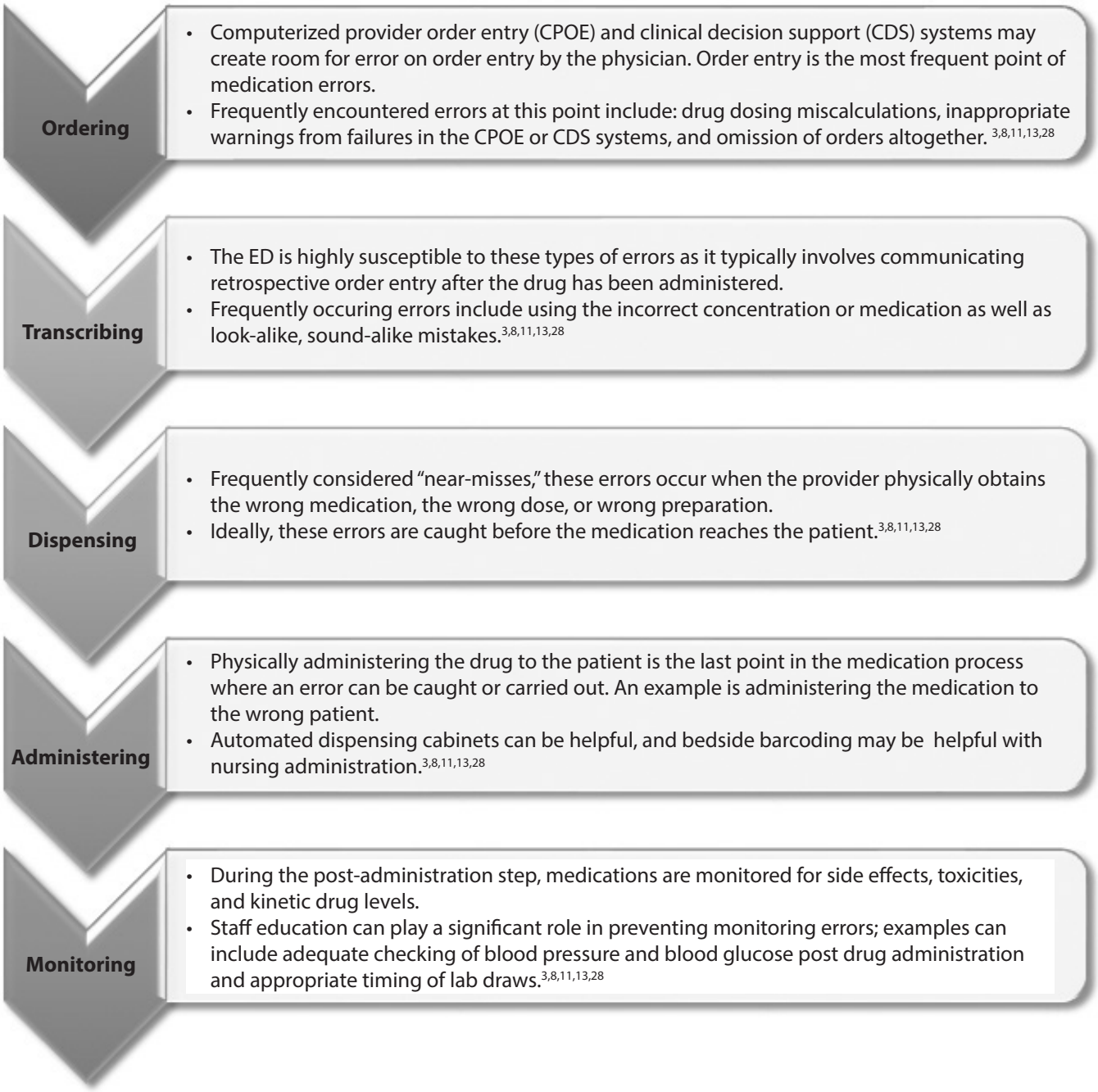
Emergency medical services (EMS) providers also are at risk for making frequent errors when managing pediatric patients. Critical patients, high volumes of doses, and requirements to convert doses from milligrams to milliliters in a fast-paced environment all play a role in the incidence of medication errors.[3,5,8,25] The locations where they frequently occur have remained consistent: the point of ordering, and at the bedside during administration.[9,11,23,27] In the prehospital setting, pediatric medication protocols and procedures may not be optimized, particularly during critical cases, leading to an increased risk of error. Retrospective analyses have shown high doses of epinephrine, the frontrunner for medication errors in the EMS setting, have been administered in doses up to 808% of the correct dose.[9] Incidence rates have not been elucidated, and the frequency with which these errors occur is relatively unknown; however, substantial danger can result. Authors of one study found that correct doses of epinephrine were given only approximately 34% of the time.

Ten-fold errors are some of the most significant errors that have been studied. They are thought to occur in up to 5-10% of pediatric patients, with a similar amount resulting in patient harm.[26] It is no surprise that deaths have been documented as a result of 10-fold errors. They remain some of the most impactful, given the wide variations in weight, age, dosing, and pharmacokinetic and pharmacodynamic variability in pediatric and neonatal patients.[9,19,21,24] In 2012, Doherty et al retrospectively examined all medication-related, 10-fold errors over a five-year time period and found that 10-fold errors occur most frequently during the prescribing and administration process as well as during the programming of drug delivery equipment. Of the medications examined, opioids were implicated most frequently, with antibiotics being the second most common. Anticoagulants were the third most frequently associated with overdose, which further highlights exactly how detrimental a potential medication error can be in the pediatric population.

Weight-based or body surface area (BSA) dosing errors may result in an infinite number of possible doses in the pediatric population, particularly because the majority of CPOE focuses on adult rather than pediatric dosing.[8,22,24] Despite the decrease in adverse events through CPOE modifications, there remains evidence to suggest CPOE potentially can increase the risk of errors when entering orders.[9,19,21]

Ordering and prescribing medications represent approximately 71% of total errors, and communication issues or failures thereof resulted in a multitude of errors related to dosing and nurse administration.[11] EMR and CPOE with CDS systems have had a profound effect on the incidence of medication errors; however, they are not always foolproof.[20] In 2018, Tolley et al studied errors related to CPOE and found many issues involved with computer screen display, dropdown menus and auto-population, wording, default settings, non-intuitiveness, inflexible ordering, repeat prescriptions, and automated processes. They identified several other factors related to pediatric medication errors, including lack of drug dosing alerts, failure to detect calculation errors, generation of inappropriate dosing alerts, warnings based on incorrect drug indications, inability of software to calculate weight-based

Figure 2. The Medication Process From Ordering to Administration and Mechanisms That Can Occur and Can Lead to Medication Errors[3,8,11,13,34]



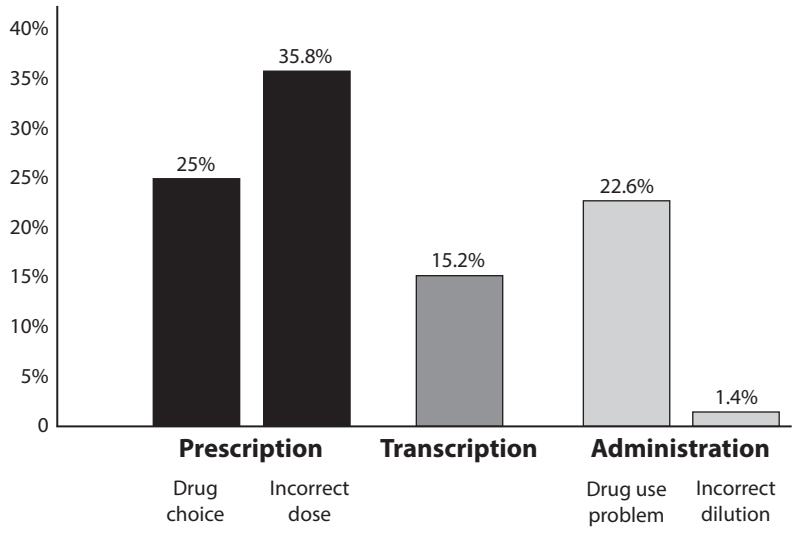
doses, and inappropriate drug duplication alerts as a result of system failure to consider route of administration.[13]

Moreover, overriding alert systems and warnings that clinicians put in place through CDS systems has resulted in significant medication errors that occur during the prescribing and transcribing phases. These types of errors have increased dramatically since the implementation of EMRs, CPOE, and CDS systems.[28-32] Although alert systems like CDS and CPOE have attempted to mitigate the incidence of medication errors by alerting physicians to possible drug ordering problems, it has been reported that up to 90% of warnings are overridden, with allergies being at the top of the list of drug alerts that are disregarded.[28,29,31,32]

Although overriding the alerts usually is associated with the clinician's evaluation of the risk vs. benefit to the patient, the appropriateness of warnings requires constant evaluation, with prescribers frequently ignoring these alerts because of adequate patient monitoring or clinical irrelevance of the actual alert.[29,32] The more frequently these warnings are disabled, the less effective

Figure 3. Frequency and Type of Medication Errors That Occurred in an Emergency Department

Weight-based dosing errors are the most frequent type of error, with 10-fold dosing errors having the potential to lead to significant morbidity and mortality. Transcription errors by physicians utilizing CPOE are also common, and alert fatigue and overriding warnings are the next most frequent. Administration errors either by nursing or incorrect programming of automated infusion systems and monitoring are also frequent.



Source: Zeraatchi A, Talebian MT, Nejati A, Dashti-Khavidaki S. Frequency and types of the medication errors in an academic emergency department in Iran: The emergent need for clinical pharmacy services in emergency departments. *J Res Pharm Pract* 2013;2:118-122.

these alerts become.[28-30] Inadequate software mechanisms for effective communication between CDS and CPOE systems lead to an inability to "turn off" certain alert functionalities for physicians. These warning systems frequently arise from commercial-based knowledge that does not translate to clinical practice in which patients are adequately monitored.[28] Some systems do allow the alerts to be turned off; however, this may not always be feasible to the degree preferred.[28,29] In combination and excess, these factors frequently lead to "cognitive overload" for the prescriber and "desensitization" to responses and alerts in place, resulting in errors and adverse drug events.[29]

Similarly, calculation processes and preparation entail significant possibilities for error, given that infant weights can double within the first six months of life, leaving providers less familiar with doses and available products to use.[9,11,23,27] Although parents tend to be the most helpful resource for determining accurate weights in pediatric patients, illiteracy and verbal instructions can further potentiate the incidence and risk for error. An estimated 15% of English-speaking adults reportedly cannot interpret bottle labels, leading to significant over- and underdosing in the outpatient setting and potentially leading to increased ED visits.[5,23] Shehab et al conducted a study to determine the number of ED visits related to adverse events secondary to medication prescriptions. They found four adverse drug reactions per 1,000 patient visits over a one-year period. Unfortunately, these researchers only examined the adult population, so it is unclear how many pediatric visits may be related to similar issues in the outpatient setting.

Similarly, at the bedside administration phase in the ED, errors have been shown to occur frequently. Dabaghzadeh et al found 63% of errors occurred during the administration phase.[17] They reviewed 203 errors over a 180-day time period in an observational study in the ED. Their results conflicted with prior reports in which the prescribing phase was implicated more frequently than the administration phase. However, the type can vary depending on the institution and protocols in place.[17]

While caring for critically ill pediatric patients, providers may experience an increased "cognitive load" when managing resuscitations, particularly because of the complexity of medication dosing and the use of multiple medications, with less evidence-based support in pediatrics.[9,24] Excessive mental fatigue, increased nighttime hours, and noncompliance with protocols or handoffs also have been implicated in increasing the risk and incidence of pediatric errors in the ED.[9,11,24]

Methods to Reduce Medication Errors

Several strategies have been implemented over the last several years to reduce medication errors. The advent of CPOE and EMR to monitor and assist with entering orders in "bundles" has been implemented to decrease errors. Additional interventions, including enhancing situational awareness, implementing handoff programs, and limiting resident work hours, have provided further mechanisms to assist with reducing pediatric medication errors.[2,3,6,10,14,19,33,34]

The use of CPOE has improved the ease and nature of medication entry at the point of the physician or provider. The overall goal for CPOE is to reduce and eliminate the need for verbal and written orders, particularly when incorporated with CDS.[2,3,6,10,11,14,27,33,34] While not completely free from errors, CPOE can reduce the number of medication errors drastically. Several studies and meta-analyses have evaluated this effect, showing risk reductions ranging from 13% to 99%. In 2013, Radley et al evaluated CPOE and the effect on medication errors and found a 48% reduction in the number of medication errors after the transition.[21]

Despite the reduction in errors, limitations remain with CPOE systems at the provider level, since the provider must use the correct patient and dose when prescribing and ordering through the EMR. However, there is little published research regarding the use of CPOE in combination with CDS.[7] As mentioned, CPOE carries inherent

risks, particularly when it comes to prescribing. Therefore, CPOE incorporation in conjunction with CDS typically is encouraged. CDS incorporates basic to advanced guidance, including: drug-allergy checking, antibiotic stewardship, dosing guidelines, guideline compliance, drug-drug interactions, duplicate therapy notifications, and renal insufficiency issues.[7,11,20] Although some literature suggests that individually CPOE and CDS may not mitigate errors, in conjunction, they have been shown to reduce the number of errors in the hospital system by up to 20%. Several studies have demonstrated significant reduction in adverse drug events when these systems are used in combination.[7,19]

Similarly, in 2015, Sethuraman et al found that medication prescription errors were reduced by 29% when CDS was added to the existing CPOE system in their pediatric ED. The primary reduction in adverse events was associated with antibiotics and dosing errors. Incorporating "quick lists" also has been suggested, with one study demonstrating a significant drop in the rate of errors from 18 per 100 to 1.9 per 100, and similar results with a reduction in errors by approximately 55%.[11,35]

A variety of commercial and locally created systems can drastically influence the number of errors to which an institution may be susceptible. In addition, specific functionalities that are part of the CPOE and CDS systems themselves potentially could lead to errors during order entry.[12,13] The more specific a CPOE and CDS system is to an institution, the greater the likelihood that it will have a positive effect on the number of errors.[12,13]

In 2017, Kadmon et al evaluated the before-and-after effects of a CPOE system revision in a PICU over a two-year time frame. They examined the rate of prescription errors and found an increase by approximately 2% initially after the implementation of CPOE; after a revision with the introduction of CDS, they found a 1% reduction during the following one-year period. The adverse drug event rate dropped by almost 1%, suggesting initial implementation of CPOE may result in errors from a prescribing and order standpoint, but ultimately may lead to a reduction in errors long-term when adequate CDS systems are implemented.

Other interventions that have improved the ED medication safety environment significantly include automated dispensing cabinets and bar-coding systems. Automated dispensing cabinets help with computerized patient profiles and allow nurses to review medications prior to administration similarly to bar-coding systems. The bedside bar codes allow for unique identifiers for medications and patients, which help during the drug administration phase where scanning can assist nurses with identification of wrong doses or medications prior to administration.[2,6,10,11]

Pharmacists are vital components of the healthcare system and are involved heavily with optimization of medication therapy; robust literature supports positive patient outcomes when pharmacists are incorporated into the healthcare team.[36] The incorporation of clinical pharmacists into healthcare systems provides a verification and check to any medication ordered in the hospital, although they traditionally were more involved with distribution processes.[36,37] (*See Figure 4.*) In the ED, pharmacist involvement and interventions have proven to be invaluable by providing the ultimate consult service for medication therapy and bedside assistance, with both assessment and management of complex patients encountered frequently.[36,38]

Multiple studies have demonstrated the benefit of having clinically trained EM pharmacists, especially with regard to providing education to medical and nursing staff, promoting clinical research, and decreasing resource utilization.[2,3,6,10,11,27,33,34] A pharmacist in the ED can assist nursing and other medical staff with training on how to use and administer medications as well as how to monitor them.[2,6,11] Clinical outcomes related to antimicrobial stewardship and door-to-treatment windows for stroke and myocardial infarctions have been shown to be affected by EM pharmacists. In addition, medication safety can be improved significantly.[36] Drug errors, which frequently occur in the ED, can be intercepted and corrected by EM pharmacists. A multicenter, prospective study of four academic and community EDs identified more than 300 medication errors that were caught during a 1,000-hour time period. Another multicenter, prospective, observational study identified more than 500 drug errors intercepted by EM pharmacists during an 800-hour time period.[36,39,40] The most frequently encountered drug errors included incorrect dosing, drug omission, and incorrect frequencies, which can result in clinically significant morbidity and mortality, particularly in the pediatric population.[36] The literature also has highlighted the effect a pharmacist can have in the ED on error reductions, from the point of order entry through every step in the medication process down to drug administration.[17,20,34,36-38,41,42]

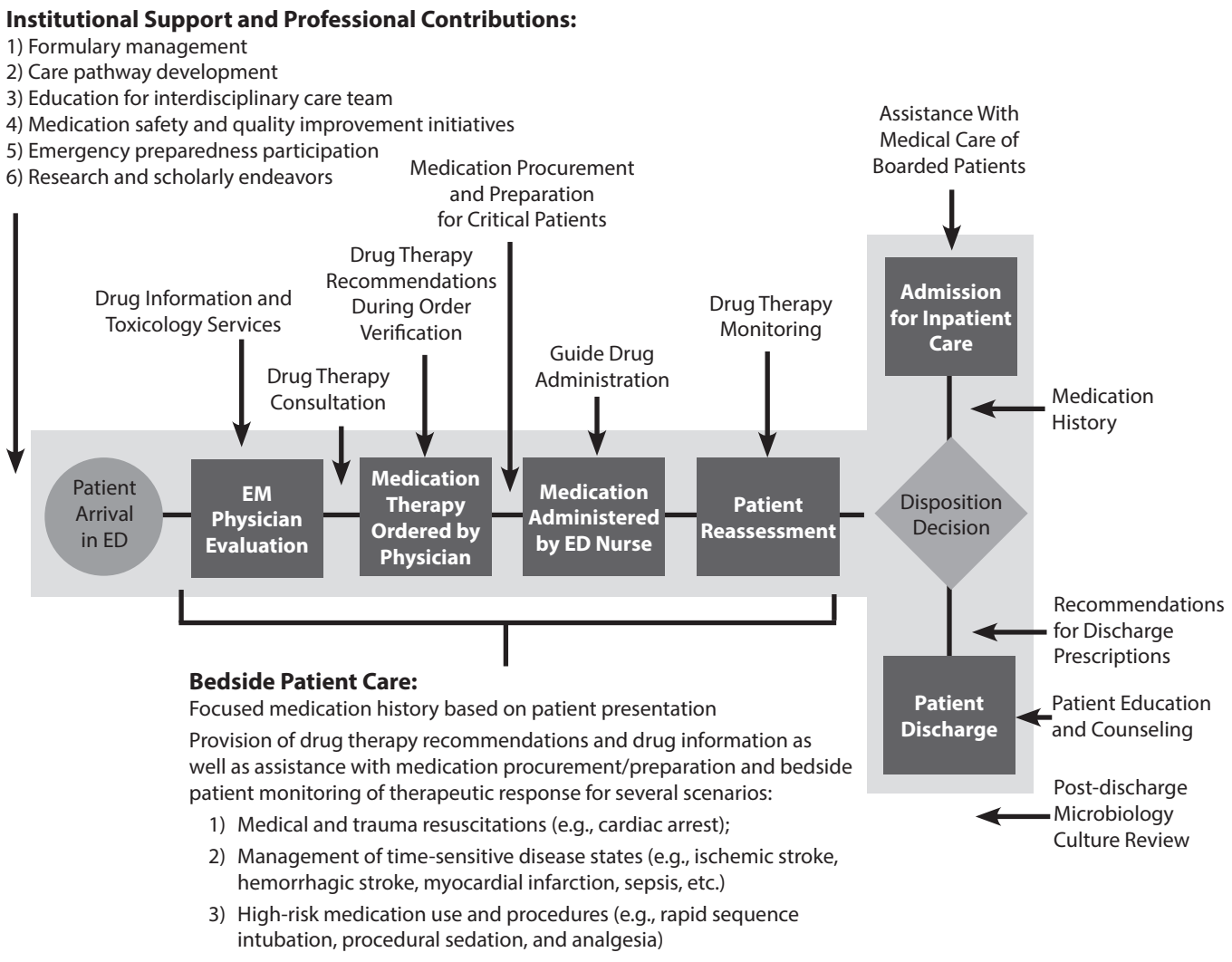
Several studies have demonstrated that EM pharmacist presence improves patient safety and the care of medically complex pediatric patients, as well as contributes significant cost savings and cost avoidance.[2,38] In 2005, Ling et al found that more than 600 interventions made by EM pharmacists during a four-month period resulted in almost $200,000 in cost avoidance.[43] In a 2007 study, Lada et al found that over a similar time frame, more than 1,000 EM pharmacist interventions led to more than $1 million in cost avoidance.[44] Another study completed over a six-month period showed cost savings of more than $800,000 from more than 9,000 interventions made by EM pharmacists.[45] Interventions frequently captured in these studies included drug information and recommended initiation, dose adjustments, nursing questions, and formulary interchanges.[36,45]

In 2017, McAllister et al examined the effect an EM clinical pharmacist would have on advanced cardiac life support (ACLS) compliance during resuscitations, as well as the potential cost savings. They found increased compliance with ACLS and reduction in medication errors and improved cost avoidance through interventions during adult resuscitations. Although this study only involved adult patients, it supports the idea that having an EM pharmacist in the pediatric ED would be beneficial in a multitude of ways.[4]

Other national and international organizations support the use of pharmacists in the ED.[2,10,17,19,24] The American College of Emergency Physicians (ACEP) supports the integration of EM pharmacists into the ED team and specifically recognizes

Figure 4. Suggested Workflow of the EM Clinical Pharmacist in the ED

Suggested workflow of the EM clinical pharmacist within the ED from patient arrival through management in the ED, followed by disposition, and either discharge or admission. EM clinical pharmacists should be and typically are utilized in formulary management, evidence-based practice adherence and research, and bedside consultation. Clinical responsibilities may vary slightly by institution but should involve the above tasks to enhance and manage pediatric medication safety.



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pediatric populations to be the highest risk group that would benefit from their presence and involvement at the bedside. ACEP released a policy statement in 2016 advocating for the critical role of a pharmacist to ensure "efficient, safe, and effective medication use in the ED."[38] The Emergency Nurses Association also supports the role of pharmacy staff to help reduce medication errors and assist with teaching nursing related to drug information and administration. Similarly, the American Society of Health-System Pharmacists also suggests having EM pharmacists present to assist with order verification, prepare high-risk medications, and be available to double-check dosing during resuscitative efforts.[2,10,24] Yet, despite the robust literature and clear benefit from having EM pharmacists present, less than 1% of all U.S. hospitals have a pharmacist in the ED.[2]

Some tools that have become commonplace in the ED have allowed for further areas of study and development of novel strategies for enhanced medication safety in pediatrics. The Broselow Pediatric Emergency Tape has revolutionized the way practitioners evaluate and estimate the weight of children for procedures and medications.[2,6,24] The Broselow Tape is validated and allows relatively reliable methods for estimating medications and equipment, such as endotracheal tubes, when compared to age-related selection methods.[24] The use of correct doses of epinephrine has been shown to increase by two-fold

when using Broselow Tape; however, limitations include the fact that doses still must be calculated and dispensed accurately using stock-type solutions of medications during resuscitations.

In 2015, Moreira et al conducted a prospective, randomized, crossover study using color-coded syringes in a simulated pediatric cardiac arrest scenario. They based their premade, color-coded syringe on the Broselow Tape. By using a prefilled, color-coded syringe system, nursing and physician teams administered medications significantly faster and more accurately compared to non-color-coded prefilled syringes. The results suggest use of color-coded syringes systems may mitigate errors and enhance medication administration and accuracy in pediatric resuscitations and cardiac arrests. Eliminating the additional step of calculation would reduce the likelihood of error in a high-stress clinical scenario.[24]

Similarly, the pharmaceutical industry has helped tremendously with modifying medication labeling, implementing look-alike/sound-alike (LASA) medication warnings, Tall Man lettering, and appropriate sig labeling to reduce prescription errors in the inpatient and outpatient setting.[46-50] Automated systems in various CPOE and CDS systems, as well as automated dispensing cabinets, can help detect potential LASA errors to prevent prescribing or administering errors.[49] Tall Man lettering uses different-cased labeling, thus allowing emphasis on differences in drug names. This practice has been recommended for use by the FDA and other medication safety organizations to minimize confusing LASA drug names and improve perception and accuracy of medication prescribing, dispensing, and administering.[47,48]

Accurate documentation and efficiency also have been examined with the use of medical scribes and their implications with improving the CPOE and documentation process.[51-53] However, The Joint Commission prohibits the use of scribes with CPOE entry because of the removal of the CDS system during this process, hence increasing the risk of potential error from miscommunication. However, if the scribe is a licensed practitioner, this practice may improve communication and reduce potential medical errors by improving efficiency and accuracy of orders in the ED.[53] The overall effect and potential reduction in errors from use of medical scribes requires further investigation at this point, but it may serve as a potential area of improvement from a medication safety perspective.[51-55]

Other strategies that have been suggested include fixed-dose prescribing and order sets through CPOE, particularly with regard to opioids.[2,6,10,14,16] Removing the calculation step and identifying high-risk medications, such as anticoagulants and opioids, as well as determining dosing recommendations and indications for potentially life-threatening drugs, can help minimize calculation errors.[2,6] Similarly, restricting the number of concentrations readily available and limiting solutions with the same active ingredient with different dilutions would allow a higher degree of safety and quality control throughout an entire institution, not just within the pediatric ED.[2,6,10]

Medication error reporting remains an integral part of continuous process improvement, particularly in the inpatient setting. Reporting of actual errors does occur; however, errors remain tremendously underreported secondary to the culture surrounding medication errors.[25,27,56] Fear of punitive actions is a significant reason for the under-reporting of errors; however, error incidents and near misses help hospital leadership identify areas in which current systems have broken down or are in danger of breaking down. This provides a clear line of sight into opportunities to make the hospital, not just the pediatric ED, a safer place. All staff should be encouraged to maintain a sense of responsibility to report any medication errors or safety concerns they see to help improve current systems and promote a culture of safety.[16,19,22,25]

Additional tactics include training in medication safety and incorporating required experiences in fellowships and residencies, as they currently are not a requirement for these types of programs.[10,19,24] Enhanced education regarding medication errors and risks within the pediatric population, in addition to other interventions including bar coding, CPOE, and CDS, would reduce the likelihood of error further. Conducting patient safety rounds with senior physicians and nursing staff, typically at least once during each shift, also have been shown to be beneficial. The goal of these meetings is to discuss potential safety concerns of staff and prospectively resolve any issues or problems in the medication ordering and use process.[27,56] Theoretically, using a prospective medication safety process can enhance the culture by creating a blame-free environment and encouraging changes to improve pediatric medication safety and prevent and address system-wide issues.[2,6,27,5,10,15,35]

Conclusion

Pediatric medication safety and errors remain an ongoing issue, particularly within the ED. Many factors, including disparities in weight, and limited research in medications specifically for pediatric patients, place pediatric patients at an exceptionally high risk for medication errors.[57] Although the ED remains a high-risk environment for medication errors, the pediatric ED is at an even higher risk. Despite implementation of CPOE and CDS systems across the nation, continuing education for all healthcare staff, and incorporating clinical ED-trained pharmacists to mitigate the effect and severity of errors, minimizing pediatric medication errors will be a constant challenge. Although many tools and novel strategies to help combat this issue are available, hyper-vigilance and continued monitoring and evaluation for systemwide breakdowns from the point of order entry and prescribing to administration at the bedside will be required. Further research is needed both in pediatric medicine and in medication safety, as well as in mechanisms to identify specific methods to target medication errors in the pediatric ED. However, until a foolproof system is implemented, a multifactorial approach to monitoring and addressing medication processes in the most vulnerable patient population will be required.[2,3,6,20,57]

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CME/CE Questions

1. Which type of medication error is the most common type occurring in the pediatric population?
   a. Prescribing
   b. Dosing
   c. Monitoring
   d. Administration
2. What patient parameter frequently is implicated or incorrectly used when calculating a pediatric dose?
   a. Body surface area
   b. Creatinine clearance
   c. Weight
   d. Age
3. With regard to dosing in the pediatric population, what characteristics change most frequently within the first several years of life that specifically affect medication doses?
   a. Kidney function
   b. Liver function
   c. Height and weight
   d. Pharmacokinetic profiles
4. Aside from the emergency department, which other location ranks high for pediatric medication errors?
   a. Intensive care unit
   b. Outpatient clinics
   c. Home health centers
   d. Rehabilitation centers
5. Which type of medication most frequently is associated with dosing errors in pediatric EDs?
   a. Opioids
   b. Anticoagulants
   c. Antibiotics
   d. Antihypertensives
6. Which two interventions, when used in combination, have been shown to reduce the incidence of pediatric medication errors?
   a. Clinical pharmacists and CPOE
   b. CPOE and CDS
   c. CDS and Broselow Tape measurements
   d. Bedside bar coding and CPOE

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Pediatric Emergency Medicine Report	1082-3344	10/1/2018
4. Issue Frequency	5. Number of Issues Published Annually	6. Annual Subscription Price
Monthly	12	$399.00

7. Complete Mailing Address of Known Office of Publication *(Not printer) (Street, city, county, state, and ZIP+4®)*
111 Corning Rd, Ste 250, Cary, NC 27518

Contact Person: Joshua Scalzetti
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Pediatric Emergency Management Reports	September 2018

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7. Which drug is frequently dosed incorrectly prior to arrival in the ED by EMS?
   a. Atropine
   b. Dopamine
   c. Epinephrine
   d. Dextrose

8. When a physician receives a warning about a patient having an allergy to a medication in a similar class but overrides the warning, what type of error is implicated?
   a. Alert fatigue
   b. Dosing error
   c. CDS system malfunction
   d. Transcribing errors

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