



Pediatric Medication Safety in the Emergency Department

Lee Benjamin, MD, FAAP, FACEP,^a Karen Frush, MD, FAAP,^b Kathy Shaw, MD, MSCE, FAAP,^c Joan E. Shook, MD, MBA, FAAP,^d Sally K. Snow, BSN, RN, CPEN, FAEN,^e AMERICAN ACADEMY OF PEDIATRICS Committee on Pediatric Emergency Medicine, AMERICAN COLLEGE OF EMERGENCY PHYSICIANS Pediatric Emergency Medicine Committee, EMERGENCY NURSES ASSOCIATION Pediatric Emergency Medicine Committee

Pediatric patients cared for in emergency departments (EDs) are at high risk of medication errors for a variety of reasons. A multidisciplinary panel was convened by the Emergency Medical Services for Children program and the American Academy of Pediatrics Committee on Pediatric Emergency Medicine to initiate a discussion on medication safety in the ED. Top opportunities identified to improve medication safety include using kilogram-only weight-based dosing, optimizing computerized physician order entry by using clinical decision support, developing a standard formulary for pediatric patients while limiting variability of medication concentrations, using pharmacist support within EDs, enhancing training of medical professionals, systematizing the dispensing and administration of medications within the ED, and addressing challenges for home medication administration before discharge.

BACKGROUND

Despite a national focus on patient safety since the publication of the Institute of Medicine (now the National Academy of Medicine) report “To Err is Human” in 1999, medical errors remain a leading cause of morbidity and mortality across the United States.¹ Medication errors are by far the most common type of medical error occurring in hospitalized patients,² and the medication error rate in pediatric patients has been found to be as much as 3 times the rate in adult patients.^{3,4} Because many medication errors and adverse drug events (ADEs) are preventable,¹ strategies to improve medication safety are an essential component of an overall approach to providing quality care to children.

The pediatric emergency care setting is recognized as a high-risk environment for medication errors because of a number of factors, including medically complex patients with multiple medications who are unknown to emergency department (ED) staff, a lack of standard pediatric drug dosing and formulations,⁵ weight-based dosing,^{6,7} verbal

abstract

FREE

^aDepartment of Emergency Medicine, St Joseph Mercy Ann Arbor, Ypsilanti, Michigan; ^bDepartment of Pediatrics, School of Medicine, Duke University, Durham, North Carolina; ^cDepartment of Pediatrics, Children’s Hospital of Philadelphia, Philadelphia, Pennsylvania; ^dSection of Emergency Medicine, Department of Pediatrics, Baylor College of Medicine, Houston, Texas; and ^eRetired; Former Trauma Program Director, Cook Children’s Medical Center, Fort Worth, Texas

All authors contributed to the writing and organization of the policy statement and reviewed and support the final submission.

This document is copyrighted and is property of the American Academy of Pediatrics and American College of Emergency Physicians and their Boards of Directors. All authors have filed conflict of interest statements with the American Academy of Pediatrics. Any conflicts have been resolved through a process approved by the Board of Directors. The American Academy of Pediatrics, the American College of Emergency Physicians, and the Emergency Nurses Association have neither solicited nor accepted any commercial involvement in the development of the content of this publication.

Policy statements from the American Academy of Pediatrics benefit from expertise and resources of liaisons and internal (AAP) and external reviewers. However, policy statements from the American Academy of Pediatrics may not reflect the views of the liaisons or the organizations or government agencies that they represent.

The guidance in this statement does not indicate an exclusive course of treatment or serve as a standard of medical care. Variations, taking into account individual circumstances, may be appropriate.

Jointly published in the *Annals of Emergency Medicine*.

To cite: Benjamin L, Frush K, Shaw K, et al. AMERICAN ACADEMY OF PEDIATRICS Committee on Pediatric Emergency Medicine, AMERICAN COLLEGE OF EMERGENCY PHYSICIANS Pediatric Emergency Medicine Committee, EMERGENCY NURSES ASSOCIATION Pediatric Emergency Medicine Committee. Pediatric Medication Safety in the Emergency Department. *Pediatrics*. 2018;141(3):e20174066

orders, a hectic environment with frequent interruptions,⁸ a lack of clinical pharmacists on the ED care team,^{9,10} inpatient boarding status,¹¹ the use of information technology systems that lack pediatric safety features,¹² and numerous transitions in care. In addition, the vast majority of pediatric patients seeking care in EDs are not seen in pediatric hospitals but rather in community hospitals, which may treat a low number of pediatric patients.¹³ Studies also outline the problem of medication errors in children in the prehospital setting. A study of 8 Michigan emergency medical services agencies revealed errors for commonly used medications, with up to one-third of medications being dosed incorrectly.¹⁴ Medication error rates reported from single institutions with dedicated pediatric EDs range from 10% to 31%,^{15,16} and in a study from a pediatric tertiary care center network, Shaw et al⁶ showed that medication errors accounted for almost 20% of all incident reports, with 13% of the medication errors causing patient harm. The authors of another study examined medication errors in children at 4 rural EDs in northern California and found an error rate of 39%, with 16% of these errors having the potential to cause harm.¹⁷ The following discussion adds to the broad topic of medication safety by introducing specific opportunities unique to pediatric patients within EDs to facilitate local intervention on the basis of institutional experience and resources.

STRATEGIES FOR IMPROVEMENT

A multidisciplinary expert panel was convened by the Emergency Medical Services for Children program and the American Academy of Pediatrics (AAP), through its Committee on Pediatric Emergency Medicine, to discuss challenges related to pediatric medication safety in

the emergency setting. The panel included emergency care providers, nurses, pharmacists, electronic health record industry representatives, patient safety organization leaders, hospital accreditation organizations, and parents of children who suffered ADEs. The panel outlined numerous opportunities for improvement, including raising awareness of risks for emergency care providers, trainees, children, and their families; developing policies and processes that support improved pediatric medication safety; and implementing best practices to reduce pediatric ADEs. Specific strategies discussed by the panel, as well as recent advances in improving pediatric medication safety, are described.

Decreasing Pediatric Medication Prescribing Errors in the ED

Computerized Physician Order Entry

Historically, the majority of pediatric medication errors were associated with the ordering phase of the medication process. Specific risks related to pediatric weight-based dosing include not using the appropriate weight,⁶ performing medication calculations based on pounds instead of the recognized standard of kilograms,⁶ and making inappropriate calculations, including tenfold dosing errors.^{18–20} Childhood obesity introduces further opportunity for dosing error. In addition to the lack of science to guide medication dosing in patients with obesity,²¹ frequent underdosing²² is reported, and currently available resuscitation tools are commonly imprecise.²³ Furthermore, there are limited opportunities for prescription monitoring or double-checking in the ED setting, and many times calculations are performed in the clinical area without input from a pharmacist.⁹ The implementation of computerized physician order entry (CPOE) and clinical decision support (CDS) with electronic prescribing

have reduced many of these errors, because most CPOE systems obviate the need for simple dose calculation. However, CPOE systems have not fully eliminated medication errors. Commercial or independently developed CPOE systems may fail to address critical unique pediatric dosing requirements.^{12,24} Kilogram-only scales are recommended for obtaining weights, yet conversion to pounds either by the operator or electronic health record may introduce opportunity for error into the system. In addition, providers may override CDS, despite its proven success in reducing errors.^{16,25} Prescribers frequently choose to ignore or override CDS prescribing alerts, with reported override rates as high as 96%.²⁶ Allowing for free text justification to override alerts for nonformulary drugs may introduce errors. The development of an override algorithm can help reduce user variability.²⁷ As the use of CPOE increases, one can expect that millions of medication errors will be prevented.²⁸ For EDs that do not use CPOE, preprinted medication order forms have been shown to significantly reduce medication errors in a variety of settings and serve as a low-cost substitute for CPOE.^{29–32}

Standardized Formulary

The Institute of Medicine (now the National Academy of Medicine) recommends development of medication dosage guidelines, formulations, labeling, and administration techniques for the pediatric emergency care setting.⁵ Unfortunately, there are currently no universally accepted, pediatric-specific standards with regard to dose suggestion and limits, and dosing guidelines and alerts found in CPOE are commonly provided by third-party vendors that supply platforms to both children's and general hospitals. The development of a standard pediatric formulary, independent of an adult-focused

system, can reduce opportunities for error by specifying limited concentrations and standard dosage of high-risk and frequently used medications, such as resuscitation medications, vasoactive infusions, narcotics, and antibiotics, as well as look-alike and sound-alike medications.³³ A standard formulary will allow for consistent education during initial training and continuing medical education for emergency care providers, creating a consistent measure of provider competency. At least 1 large hospital organization has successfully implemented this type of change.³⁴ In addition, the American Society of Health-System Pharmacists is working with the Food and Drug Administration to develop and implement national standardized concentrations for both intravenous and oral liquid medications.³⁵

ED Pharmacists

Currently, many medications are prepared and dispensed in the ED without pharmacist verification or preparation because many EDs lack consistent on-site pharmacist coverage.^{9,36} In a survey of pharmacists, 68% reported at least 8 hours of ED coverage on weekdays, but fewer than half of EDs see this support on weekends, with a drastic reduction in coverage during overnight and morning hours.³⁷ The American College of Emergency Physicians (ACEP) supports the integration of pharmacists within the ED team, specifically recognizing the pediatric population as a high-risk group that may benefit from pharmacist presence.³⁸ The Emergency Nurses Association (ENA) supports the role of the emergency nurse as well as pharmacy staff to efficiently complete the best possible medication history and reduce medication discrepancies.^{39,40} The American Society of Health-System Pharmacists suggests that ED pharmacists may help verify and prepare high-risk medications, be available to

prepare and double-check dosing of medications during resuscitation, and provide valuable input in medication reconciliation, especially of medically complex children whose medications and dosing may be unknown to ED staff and who present without a medication list or portable emergency information form.⁴¹ Medically complex patients typify the difficulty with medication reconciliation, with an error rate of 21% in a tertiary care facility.⁴² In this study, no 1 source from the parent, pharmacy, and primary provider group was both available and appropriately sensitive or specific in completing medication reconciliation. Pharmacist-managed reconciliation has had a positive impact for admitted pediatric patients and may translate to the emergency setting.^{43,44} ED pharmacists can also help monitor for ADEs, provide drug information, and provide information regarding medication ingestions to both providers and patients and/or families.⁴⁵

Dedicated pharmacists can be integrated through various methods, such as hiring dedicated pharmacy staff for the ED,⁷ having these staff immediately available when consulted, or having remote telepharmacy review of medication orders by a central pharmacist.^{46,47} Although further research is needed on the potential outcomes on medication safety and return on investment when a pharmacist is placed in the ED, current experience reveals improvements in medication safety when a pharmacist is present.⁴⁸ Studies from general EDs reveal significant cost savings as well,⁴⁹ with the authors of 1 study in a single urban adult ED identifying more than \$1 million dollars of cost avoidance in only 4 months.⁵⁰

Training in Pediatric Medication Safety

Dedicated training in pediatric medication safety is highly variable in

the curricula of professional training programs in medical, nursing, and pharmacy schools.⁵¹ Although national guidelines support the training of prehospital personnel with specific pediatric content and safety and error-reduction training,⁵² a nearly 35% prehospital medication error rate for critical medications for pediatric patients remains.¹⁴ At the graduate medical education level, the curricula of pediatric and emergency medicine residency programs and pediatric emergency medicine fellowship programs do not define specific requirements for pediatric medication safety training.^{53–55} The same is true for pharmacy programs.⁵⁶ Although schools of pharmacy include pediatric topics in their core curricula, pediatric safety advocates believe there is an opportunity for enhanced and improved training.⁵⁷

Experts in pediatric emergency care from the multidisciplinary panel recommend development of a curriculum on pediatric medication safety that could be offered to all caregivers of children in emergency settings. A standard curriculum may include content such as common medication errors in children, systems-improvement tools to avoid or abate errors, and the effects of developmental differences in pediatric patients. Demonstrating competency on the basis of this curriculum is 1 means by which institutions may reduce risks of medication errors.

Decreasing Pediatric Medication Administration Errors in the ED

The dispensing and administration phases serve as final opportunities to optimize medication safety. Strategies to reduce errors include standardizing the concentrations available for a given drug, having readily available and up-to-date medication reference materials, using premixed intravenous preparations when possible, having automated

dispensing cabinets with appropriate pediatric dosage formulations, using barcoded medication administration,⁵⁸ having pharmacists and ED care providers work effectively as a team, and having policies to guide medication use.^{59,60} Although yet to be studied in the ED environment, smart infusion pumps have shown promise in other arenas in reducing administration errors for infusions.⁶¹

Nurses are held accountable by each state's nurse practice act for the appropriateness of all medications given. Nursing schools teach the 5 rights of medication administration: the right patient, the right medication, the right dose, the right time, and the right route.⁶² Elliott and Liu⁶³ expand the 5 rights to include right documentation, right action, right form, and right response to further improve medication safety. Simulated medication administration addresses opportunities beyond those captured within these rights and may have implications within the ED.⁶⁴ Additionally, given the association of medication preparation interruptions and administration errors,⁶⁵ the use of a distraction-free medication safety zone has been shown to enhance medication safety.^{66,67} Implementation of an independent 2-provider check process for high-alert medications, as suggested by The Joint Commission, also reduces administration errors.⁶⁸ Both the Institute for Safe Medication Practices and The Joint Commission provide excellent guidance on these topics.⁶⁹

Decreasing Pediatric Medication Errors in the Home

Recognizing and addressing language barriers and health literacy variability in the ED can affect medication safety in the home. Nonstandardized delivery devices continue to be used in the home, and dosing error rates of greater than 40% are reported.⁷⁰ Advanced counseling and instrument provision

in the ED are proven to decrease dosing errors at home.⁷¹ Pictograms provided to aide in medication measurement have also been shown to decrease errors and may be considered as part of discharge instructions.⁷² The AAP supports policy on the use of milliliter-only dosing for liquid medications used in the home and suggests that standardized delivery devices be distributed from the ED for use with these medications.⁷³ As the body of literature regarding health literacy evolves, further addressing these issues in real time may influence out-of-hospital care.

SUMMARY

Pediatric medication safety requires a multidisciplinary approach across the continuum of emergency care, starting in the prehospital setting, during emergency care, and beyond. Key areas for medication safety specific to pediatric care in the ED include the creation of standardized medication dosing guidelines, better integration and use of information technology to support patient safety, and increased education standards across health care disciplines. The following is a list of specific recommendations that can lead to improved pediatric medication safety in the emergency care setting.

RECOMMENDATIONS

1. Create a standard formulary for pediatric high-risk and commonly used medications;
2. standardize concentrations of high-risk medications;
3. reduce the number of available concentrations to the smallest possible number;
4. provide recommended precalculated doses;
5. measure and record weight in kilograms only;

6. use length-based dosing tools when a scale is unavailable or use is not feasible;
7. implement and support the availability of pharmacists in the ED;
8. use standardized order sets with embedded best practice prescribing and dosing range maximums;
9. promote the development of distraction-free medication safety zones for medication preparation;
10. implement process screening, such as a 2-provider independent check for high-alert medications;
11. implement and use CPOE and CDS with pediatric-specific kilogram-only dosing rules, including upper dosing limits within ED information systems;
12. encourage community providers of children with medical complexity to maintain a current medication list and an emergency information form to be available for emergency care;
13. create and integrate a dedicated pediatric medication safety curriculum into training programs for nurses, physicians, respiratory therapists, nurse practitioners, physician assistants, prehospital providers, and pharmacists;
14. develop tools for competency assessment;
15. dispense standardized delivery devices for home administration of liquid medications;
16. dispense milliliter-only dosing for liquid medications used in the home;
17. employ advanced counseling such as teach-back when sharing medication instructions for home use; and

18. use pictogram-based dosing instruction sheets for use of home medications.

LEAD AUTHORS

Lee Benjamin, MD, FAAP, FACEP
Karen Frush, MD, FAAP
Kathy Shaw, MD, MSCE, FAAP
Joan E. Shook, MD, MBA, FAAP
Sally K. Snow, BSN, RN, CPEN, FAEN

AAP COMMITTEE ON PEDIATRIC EMERGENCY MEDICINE, 2017–2018

Joseph Wright, MD, MPH, FAAP, Chairperson
Terry Adirim, MD, MPH, FAAP
Michael S.D. Agus, MD, FAAP
James Callahan, MD, FAAP
Toni Gross, MD, MPH, FAAP
Natalie Lane, MD, FAAP
Lois Lee, MD, MPH, FAAP
Suzan Mazor, MD, FAAP
Prashant Mahajan, MD, MPH, MBA, FAAP
Nathan Timm, MD

LIAISONS

Andrew Eisenberg, MD – *American Academy of Family Physicians*
Cynthia Wright Johnson, MSN, RN – *National Association of State Emergency Medical Service Officials*
Cynthiana Lightfoot, BFA, NRP – *AAP Family Partnerships Network*
Charles Macias, MD, MPH, FAAP – *Emergency Medical Service for Children Innovation and Improvement Center*
Brian Moore, MD, MPH, FAAP – *National Association of Emergency Medical Service Physicians*
Diane Pilkey, RN, MPH – *Maternal and Child Health Bureau*
Katherine Remick, MD, FAAP – *National Association of Emergency Medical Technicians*
Mohsen Saidinejad, MD, MBA, FAAP, FACEP – *ACEP*
Sally Snow, RN, BSN, CPEN, FAEN – *ENA*
David Tuggle, MD, FAAP – *American College of Surgeons*

FORMER AAP COMMITTEE ON PEDIATRIC EMERGENCY MEDICINE MEMBERS, 2012–2016

Alice Ackerman, MD, MBA
Thomas Chun, MD, MPH, FAAP
Gregory Conners, MD, MPH, MBA, FAAP
Edward Conway, Jr, MD, MS, FAAP
Nanette Dudley, MD, FAAP
Joel Fein, MD
Susan Fuchs, MD, FAAP
Marc Gorelick, MD, MSCE
Natalie Lane, MD, FAAP
Charles Macias, MD, MPH, FAAP
Brian Moore, MD, FAAP

Steven Selbst, MD
Kathy Shaw, MD, MSCE, Chair (2008–2012)
Joan Shook, MD, MBA, FAAP, Chair (2012–2016)
Joseph Wright, MD, MPH, FAAP

STAFF

Sue Tellez
Tamar Margarik Haro

ACEP PEDIATRIC EMERGENCY MEDICINE COMMITTEE, 2016–2017

Madeline Joseph, MD, FACEP, Chair
Kiyetta Alade, MD
Christopher Amato, MD, FACEP
Jahn T. Avarello, MD, FACEP
Steven Baldwin, MD
Isabel A. Barata, MD, FACEP, FAAP
Lee S. Benjamin, MD, FACEP
Kathleen Berg, MD
Kathleen Brown, MD, FACEP
Jeffrey Bullard-Berent, MD, FACEP
Ann Marie Dietrich, MD, FACEP
Phillip Friesen, DO
Michael Gerardi, MD, FACEP, FAAP
Alan Heins, MD, FACEP
Doug K. Holtzman, MD, FACEP
Jeffrey Homme, MD, FACEP
Timothy Horeczko, MD, MSCR
Paul Ishimine, MD, FACEP
Samuel Lam, MD, RDMS
Katharine Long
Kurtis Mayz, JD, MD, MBA
Sanjay Mehta, MD, Med, FACEP
Larry Mellick, MD
Aderonke Ojo, MD, MBBS
Audrey Z. Paul, MD, PhD
Denis R. Pauze, MD, FACEP
Nadia M. Pearson, DO
Debra Perina, MD, FACEP
Emory Petrack, MD
David Rayburn, MD, MPH
Emily Rose, MD
W. Scott Russell, MD, FACEP
Timothy Ruttan, MD, FACEP
Mohsen Saidinejad, MD, MBA, FACEP
Brian Sanders, MD
Joelle Simpson, MD, MPH
Patrick Solari, MD
Michael Stoner, MD
Jonathan H. Valente, MD, FACEP
Jessica Wall, MD
Dina Wallin, MD
Muhammad Waseem, MD, MS, FACEP
Paula J. Whiteman, MD, FACEP
Dale Woolridge, MD, PhD, FACEP

FORMER ACEP PEDIATRIC EMERGENCY MEDICINE COMMITTEE MEMBERS, 2012–2016

Joseph Arms, MD
Richard M. Cantor, MD, FACEP
Ariel Cohen, MD

Carrie DeMoor, MD
James M. Dy, MD
Paul J. Eakin, MD
Sean Fox, MD
Marianne Gausche-Hill, MD, FACEP, FAAP
Timothy Givens, MD
Charles J. Graham, MD, FACEP
Robert J. Hoffman, MD, FACEP
Mark Hostetler, MD, FACEP
Hasmig Jinivizian, MD
David Markenson, MD, MBA, FACEP
Joshua Rocker, MD, FACEP
Brett Rosen, MD
Gerald R. Schwartz, MD, FACEP
Harold A. Sloas, DO
Annalise Sorrentino, MD, FACEP
Orel Swenson, MD
Michael Witt, MD, MPH, FACEP

STAFF

Loren Rives, MNA
Dan Sullivan
Stephanie Wauson

ENA PEDIATRIC COMMITTEE, 2016–2017

Tiffany Young, BSN, RN, CPNP, 2016 Chair
Joyce Foresman-Capuzzi, MSN, RN, CNS, 2017 Chair
Rose Johnson, RN
Heather Martin, DNP, MS RN, PNP-BC
Justin Milici, MSN, RN
Cam Brandt, MS, RN
Nicholas Nelson, MS RN, EMT-P

BOARD LIAISONS

Maureen Curtis-Cooper, BSN, RN, 2016 Board Liaison
Kathleen Carlson, MSN, RN, 2017 Board Liaison

STAFF

Marlene Bokholdt, MSN, RN

ABBREVIATIONS

AAP: American Academy of Pediatrics
ACEP: American College of Emergency Physicians
ADE: adverse drug event
CDS: clinical decision support
CPOE: computerized physician order entry
ED: emergency department
ENA: Emergency Nurses Association

DOI: <https://doi.org/10.1542/peds.2017-4066>

Address correspondence to Lee Benjamin, MD, FAAP, FACEP. E-mail: lbenjamin@epmg.com

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

Copyright © 2018 by the American Academy of Pediatrics

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: No external funding.

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

REFERENCES

1. Institute of Medicine, Committee on Quality of Health Care in America. In: Kohn LT, Corrigan JM, Donaldson MS, eds. *To Err is Human: Building a Safer Health System*. Washington, DC: National Academies Press; 1999
2. Leape LL, Brennan TA, Laird N, et al. The nature of adverse events in hospitalized patients. Results of the Harvard Medical Practice Study II. *N Engl J Med*. 1991;324(6):377–384
3. Kaushal R, Bates DW, Landrigan C, et al. Medication errors and adverse drug events in pediatric inpatients. *JAMA*. 2001;285(16):2114–2120
4. Woo Y, Kim HE, Chung S, Park BJ. Pediatric medication error reports in Korea adverse event reporting system database, 1989-2012: comparing with adult reports. *J Korean Med Sci*. 2015;30(4):371–377
5. Institute of Medicine, Committee of the Future of Emergency Care in the US Health System. *Emergency Care for Children: Growing Pains*. Washington, DC: National Academies Press; 2006
6. Shaw KN, Lillis KA, Ruddy RM, et al; Pediatric Emergency Care Applied Research Network. Reported medication events in a paediatric emergency research network: sharing to improve patient safety. *Emerg Med J*. 2013;30(10):815–819
7. Rinke ML, Moon M, Clark JS, Mudd S, Miller MR. Prescribing errors in a pediatric emergency department. *Pediatr Emerg Care*. 2008;24(1):1–8
8. Berg LM, Källberg AS, Göransson KE, Östergren J, Florin J, Ehrenberg A. Interruptions in emergency department work: an observational and interview study. *BMJ Qual Saf*. 2013;22(8):656–663
9. Thomasset KB, Faris R. Survey of pharmacy services provision in the emergency department. *Am J Health Syst Pharm*. 2003;60(15):1561–1564
10. Cesarz JL, Steffenhagen AL, Svenson J, Hamedani AG. Emergency department discharge prescription interventions by emergency medicine pharmacists. *Ann Emerg Med*. 2013;61(2):209–14.e1
11. Patanwala AE, Warholak TL, Sanders AB, Erstad BL. A prospective observational study of medication errors in a tertiary care emergency department. *Ann Emerg Med*. 2010;55(6):522–526
12. American Academy of Pediatrics: Task Force on Medical Informatics. Special requirements for electronic medical record systems in pediatrics. *Pediatrics*. 2001;108(2):513–515
13. Gausche-Hill M, Schmitz C, Lewis RJ. Pediatric preparedness of US emergency departments: a 2003 survey. *Pediatrics*. 2007;120(6):1229–1237
14. Hoyle JD, Davis AT, Putman KK, Trytko JA, Fales WD. Medication dosing errors in pediatric patients treated by emergency medical services. *Prehosp Emerg Care*. 2012;16(1):59–66
15. Kozer E, Scolnik D, Macpherson A, et al. Variables associated with medication errors in pediatric emergency medicine. *Pediatrics*. 2002;110(4):737–742
16. Sard BE, Walsh KE, Doros G, Hannon M, Moschetti W, Bauchner H. Retrospective evaluation of a computerized physician order entry adaptation to prevent prescribing errors in a pediatric emergency department. *Pediatrics*. 2008;122(4):782–787
17. Marcin JP, Dharmar M, Cho M, et al. Medication errors among acutely ill and injured children treated in rural emergency departments. *Ann Emerg Med*. 2007;50(4):361–367, 367.e1–367.e2
18. Glover ML, Sussman JB. Assessing pediatrics residents' mathematical skills for prescribing medication: a need for improved training. *Acad Med*. 2002;77(10):1007–1010
19. Lesar TS. Tenfold medication dose prescribing errors. *Ann Pharmacother*. 2002;36(12):1833–1839
20. Doherty C, Mc Donnell C. Tenfold medication errors: 5 years' experience at a university-affiliated pediatric hospital. *Pediatrics*. 2012;129(5):916–924
21. Harskamp-van Ginkel MW, Hill KD, Becker KC, et al; Best Pharmaceuticals for Children Act—Pediatric Trials Network Administrative Core Committee. Drug dosing and pharmacokinetics in children with obesity: a systematic review [published correction appears in *JAMA Pediatr*. 2015;169(12):1179]. *JAMA Pediatr*. 2015;169(7):678–685
22. Miller JL, Johnson PN, Harrison DL, Hagemann TM. Evaluation of inpatient admissions and potential antimicrobial and analgesic dosing errors in overweight children. *Ann Pharmacother*. 2010;44(1):35–42
23. Young KD, Korotzer NC. Weight estimation methods in children: a systematic review. *Ann Emerg Med*. 2016;68(4):441–451.e10
24. Zorc JJ, Hoffman JM, Harper MB. IT in the ED: a new section of Pediatric Emergency Care. *Pediatr Emerg Care*. 2012;28(12):1399–1401

25. Kirk RC, Li-Meng Goh D, Packia J, Min Kam H, Ong BK. Computer calculated dose in paediatric prescribing. *Drug Saf.* 2005;28(9):817–824
26. van der Sijs H, Aarts J, Vulto A, Berg M. Overriding of drug safety alerts in computerized physician order entry. *J Am Med Inform Assoc.* 2006;13(2):138–147
27. Her QL, Seger DL, Amato MG, et al. Development of an algorithm to assess appropriateness of overriding alerts for nonformulary medications in a computerized prescriber-order-entry system. *Am J Health Syst Pharm.* 2016;73(1):e34–e45
28. Radley DC, Wasserman MR, Olsho LE, Shoemaker SJ, Spranca MD, Bradshaw B. Reduction in medication errors in hospitals due to adoption of computerized provider order entry systems. *J Am Med Inform Assoc.* 2013;20(3):470–476
29. Kozer E, Scolnik D, MacPherson A, Rauchwerger D, Koren G. Using a preprinted order sheet to reduce prescription errors in a pediatric emergency department: a randomized, controlled trial. *Pediatrics.* 2005;116(6):1299–1302
30. Larose G, Bailey B, Lebel D. Quality of orders for medication in the resuscitation room of a pediatric emergency department. *Pediatr Emerg Care.* 2008;24(9):609–614
31. Broussard M, Bass PF III, Arnold CL, McLarty JW, Bocchini JA Jr. Preprinted order sets as a safety intervention in pediatric sedation. *J Pediatr.* 2009;154(6):865–868
32. Burmester MK, Dionne R, Thiagarajan RR, Laussen PC. Interventions to reduce medication prescribing errors in a paediatric cardiac intensive care unit. *Intensive Care Med.* 2008;34(6):1083–1090
33. Institute for Safe Medication Practices. ISMP medication safety alert. Progress with preventing name confusion errors. 2007. Available at: <https://www.ismp.org/newsletters/acutecare/articles/20070809.asp>. Accessed November 16, 2016
34. Murray KL, Wright D, Laxton B, Miller KM, Meyers J, Englebright J. Implementation of standardized pediatric i.v. medication concentrations. *Am J Health Syst Pharm.* 2014;71(17):1500–1508
35. American Society of Health-System Pharmacists. ASHP awarded FDA contract to improve safety of intravenous and oral liquid medications: standardization contract is part of FDA’s Safe Use Initiative [press release]. Available at: <https://www.ashp.org/news/2017/02/09/16/44/standardize-4-safety-initiative-releases-final-iv-recommendations-for-medication-safety>. Accessed November 16, 2016
36. Shaw KN, Ruddy RM, Olsen CS, et al; Pediatric Emergency Care Applied Research Network. Pediatric patient safety in emergency departments: unit characteristics and staff perceptions. *Pediatrics.* 2009;124(2):485–493
37. Thomas MC, Acquisto NM, Shirk MB, Patanwala AE. A national survey of emergency pharmacy practice in the United States. *Am J Health Syst Pharm.* 2016;73(6):386–394
38. American College of Emergency Physicians. Clinical pharmacist services in the emergency department. 2015. Available at: <https://www.acep.org/clinical--practice-management/clinical-pharmacist-services-in-the-emergency-department/>. Accessed November 16, 2016
39. Johnston R, Saulnier L, Gould O. Best possible medication history in the emergency department: comparing pharmacy technicians and pharmacists. *Can J Hosp Pharm.* 2010;63(5):359–365
40. Emergency Nurses Association. Position statement: role of the emergency nurse in medication reconciliation. Des Plaines, IL: Emergency Nurses Association; 2015. Available at: https://www.ena.org/docs/default-source/resource-library/practice-resources/position-statements/roleofednurseinmedicationreconciliation.pdf?sfvrsn=8c413f53_8. Accessed November 29, 2016
41. American Academy of Pediatrics; Committee on Pediatric Emergency Medicine and Council on Clinical Information Technology; American College of Emergency Physicians; Pediatric Emergency Medicine Committee. Policy statement—emergency information forms and emergency preparedness for children with special health care needs. *Pediatrics.* 2010;125(4):829–837
42. Stone BL, Boehme S, Mundorff MB, Maloney CG, Srivastava R. Hospital admission medication reconciliation in medically complex children: an observational study. *Arch Dis Child.* 2010;95(4):250–255
43. Provine AD, Simmons EM, Bhagat PH. Establishment and evaluation of pharmacist-managed admission medication history and reconciliation process for pediatric patients. *J Pediatr Pharmacol Ther.* 2014;19(2):98–102
44. Gardner B, Graner K. Pharmacists’ medication reconciliation-related clinical interventions in a children’s hospital. *Jt Comm J Qual Patient Saf.* 2009;35(5):278–282
45. American Society of Health-System Pharmacists. ASHP guidelines on emergency medicine pharmacist services. Available at: <https://www.ashp.org/-/media/assets/policy-guidelines/docs/guidelines/emergency-medicine-pharmacist-services.ashx?la=en&hash=6503B2C3B0F5382A00FD3FCC9190E803D6C4BA2F>. Accessed November 16, 2016
46. Scott DM, Friesner DL, Rathke AM, Doherty-Johnsen S. Medication error reporting in rural critical access hospitals in the North Dakota Telepharmacy Project. *Am J Health Syst Pharm.* 2014;71(1):58–67
47. Cole SL, Grubbs JH, Din C, Nesbitt TS. Rural inpatient telepharmacy consultation demonstration for after-hours medication review. *Telemed J E Health.* 2012;18(7):530–537
48. Patanwala AE, Sanders AB, Thomas MC, et al. A prospective, multicenter study of pharmacist activities resulting in medication error interception in the emergency department. *Ann Emerg Med.* 2012;59(5):369–373
49. Aldridge VE, Park HK, Bounthavong M, Morreale AP. Implementing a comprehensive, 24-hour emergency department pharmacy program. *Am J Health Syst Pharm.* 2009;66(21):1943–1947

50. Lada P, Delgado G Jr. Documentation of pharmacists' interventions in an emergency department and associated cost avoidance. *Am J Health Syst Pharm.* 2007;64(1):63–68
51. Warholak TL, Queiruga C, Roush R, Phan H. Medication error identification rates by pharmacy, medical, and nursing students. *Am J Pharm Educ.* 2011;75(2):24
52. US Department of Transportation, National Highway Traffic Safety Administration. National emergency medical services education standards. DOT HS 811 077A. Available at: www.ems.gov/pdf/811077a.pdf. Accessed November 16, 2016
53. Accreditation Council for Graduate Medical Education. ACGME program requirements for graduate medical education in pediatrics. Available at: https://www.acgme.org/Portals/0/PFAssets/ProgramRequirements/320_pediatrics_2017-07-01.pdf. Accessed January 10, 2018
54. Accreditation Council for Graduate Medical Education. ACGME program requirements for graduate medical education in emergency medicine. Available at: https://www.acgme.org/Portals/0/PFAssets/ProgramRequirements/110_emergency_medicine_2017-07-01.pdf. Accessed January 10, 2018
55. Accreditation Council for Graduate Medical Education. ACGME program requirements for graduate medical education in pediatric emergency medicine. Available at: https://www.acgme.org/Portals/0/PFAssets/ProgramRequirements/114_emergency_med_peds_2017-07-01.pdf?ver=2017-05-18-091501-330. Accessed January 10, 2018
56. Accreditation Council for Pharmacy Education. ACPE accreditation standards and guidelines for the professional program in pharmacy leading to the doctor of pharmacy degree. Available at: <https://acpe-accredit.org/pdf/Finals2007Guidelines2.0.pdf>. Accessed November 16, 2016
57. Emergency Medical Services for Children/National Resource Center. Pediatric patient safety toolbox. Available at: <https://emscimprovement.center/resources/toolboxes/pediatric-patient-safety-toolbox/>. Accessed November 16, 2016
58. Poon EG, Cina JL, Churchill W, et al. Medication dispensing errors and potential adverse drug events before and after implementing bar code technology in the pharmacy. *Ann Intern Med.* 2006;145(6):426–434
59. Rinke ML, Bundy DG, Velasquez CA, et al. Interventions to reduce pediatric medication errors: a systematic review. *Pediatrics.* 2014;134(2):338–360
60. ED-based pharmacists make a big dent in medication errors. *ED Manag.* 2014;26(8):91–94
61. Manrique-Rodríguez S, Sánchez-Galindo AC, López-Herce J, et al. Impact of implementing smart infusion pumps in a pediatric intensive care unit. *Am J Health Syst Pharm.* 2013;70(21):1897–1906
62. Nugent P, Vitale BA. In: Nugent PM, Vitale BA, eds. *Fundamentals of Nursing: Content Review Plus Practice Questions*. Philadelphia, PA: F.A. Davis Company; 2013:361–362
63. Elliott M, Liu Y. The nine rights of medication administration: an overview. *Br J Nurs.* 2010;19(5):300–305
64. Pauly-O'Neill S. Beyond the five rights: improving patient safety in pediatric medication administration through simulation. *Clin Simul Nurs.* 2009;5(5):e181–e186
65. Westbrook JI, Woods A, Rob MI, Dunsmuir WT, Day RO. Association of interruptions with an increased risk and severity of medication administration errors. *Arch Intern Med.* 2010;170(8):683–690
66. Anthony K, Wiencek C, Bauer C, Daly B, Anthony MK. No interruptions please: impact of a No Interruption Zone on medication safety in intensive care units. *Crit Care Nurse.* 2010;30(3):21–29
67. United States Pharmacopeial Convention. Physical environments that promote safe medication use. Revision bulletin. 2010. Available at: http://www.uspnf.com/sites/default/files/usp_pdf/EN/USPNF/c1066.pdf. Accessed November 16, 2016
68. The Joint Commission. Preventing pediatric medication errors. *Sentinel Event Alert.* 2008;(39):1–4
69. American Hospital Association, Health Research and Educational Trust, Institute for Safe Medication Practices. Pathways for medication safety: looking collectively at risk. Available at: www.ismp.org/tools/pathwaysection2.pdf. Accessed November 16, 2016
70. Yin HS, Dreyer BP, Ugboaja DC, et al. Unit of measurement used and parent medication dosing errors. *Pediatrics.* 2014;134(2). Available at: www.pediatrics.org/cgi/content/full/134/2/e354
71. Yin HS, Dreyer BP, Moreira HA, et al. Liquid medication dosing errors in children: role of provider counseling strategies. *Acad Pediatr.* 2014;14(3):262–270
72. Chan HK, Hassali MA, Lim CJ, Saleem F, Tan WL. Using pictograms to assist caregivers in liquid medication administration: a systematic review. *J Clin Pharm Ther.* 2015;40(3):266–272
73. American Academy of Pediatrics, Committee on Drugs. Metric units and the preferred dosing of orally administered liquid medications. *Pediatrics.* 2015;135(4):784–787

Pediatric Medication Safety in the Emergency Department

Lee Benjamin, Karen Frush, Kathy Shaw, Joan E. Shook, Sally K. Snow,
AMERICAN ACADEMY OF PEDIATRICS Committee on Pediatric Emergency
Medicine, AMERICAN COLLEGE OF EMERGENCY PHYSICIANS Pediatric
Emergency Medicine Committee and EMERGENCY NURSES ASSOCIATION
Pediatric Emergency Medicine Committee
Pediatrics 2018;141;

DOI: 10.1542/peds.2017-4066 originally published online March 1, 2018;

Updated Information & Services

including high resolution figures, can be found at:
<http://pediatrics.aappublications.org/content/141/3/e20174066>

References

This article cites 57 articles, 23 of which you can access for free at:
<http://pediatrics.aappublications.org/content/141/3/e20174066.full#ref-list-1>

Subspecialty Collections

This article, along with others on similar topics, appears in the following collection(s):

Current Policy

http://classic.pediatrics.aappublications.org/cgi/collection/current_policy

Committee on Pediatric Emergency Medicine

http://classic.pediatrics.aappublications.org/cgi/collection/committee_on_pediatric_emergency_medicine

Emergency Medicine

http://classic.pediatrics.aappublications.org/cgi/collection/emergency_medicine_sub

Permissions & Licensing

Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at:

<https://shop.aap.org/licensing-permissions/>

Reprints

Information about ordering reprints can be found online:
<http://classic.pediatrics.aappublications.org/content/reprints>

Pediatrics is the official journal of the American Academy of Pediatrics. A monthly publication, it has been published continuously since . Pediatrics is owned, published, and trademarked by the American Academy of Pediatrics, 141 Northwest Point Boulevard, Elk Grove Village, Illinois, 60007. Copyright © 2018 by the American Academy of Pediatrics. All rights reserved. Print ISSN:

American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN™



PEDIATRICS®

OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

Pediatric Medication Safety in the Emergency Department

Lee Benjamin, Karen Frush, Kathy Shaw, Joan E. Shook, Sally K. Snow,
AMERICAN ACADEMY OF PEDIATRICS Committee on Pediatric Emergency
Medicine, AMERICAN COLLEGE OF EMERGENCY PHYSICIANS Pediatric
Emergency Medicine Committee and EMERGENCY NURSES ASSOCIATION
Pediatric Emergency Medicine Committee

Pediatrics 2018;141;

DOI: 10.1542/peds.2017-4066 originally published online March 1, 2018;

The online version of this article, along with updated information and services, is
located on the World Wide Web at:

<http://pediatrics.aappublications.org/content/141/3/e20174066>

Pediatrics is the official journal of the American Academy of Pediatrics. A monthly publication, it has been published continuously since . Pediatrics is owned, published, and trademarked by the American Academy of Pediatrics, 141 Northwest Point Boulevard, Elk Grove Village, Illinois, 60007. Copyright © 2018 by the American Academy of Pediatrics. All rights reserved. Print ISSN:

American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN™

