



Actionable Patient Safety Solution (APSS) #3D: PEDIATRIC ADVERSE DRUG EVENTS

Executive Summary Checklist

An effective program to reduce the incidence of pediatric adverse drug events (pADEs) and harm should be instituted and combine leadership strategies, software (healthcare IT), hardware (drug compounding systems, drug delivery technology, and physiological monitoring systems), and most importantly people (changes in clinical practice, protocols and education) in protecting pediatric patients by focusing on the following key tasks:

- Demonstrate board and executive leadership engagement and commitment by aligning hospital-wide strategic goals, accountability and systems to reduce pADEs.
- Create a multidisciplinary team specialized in neonatal and pediatric medicine that reports regularly to executive leadership, with a focus on pADE.
- Institute an effective software program for identifying, detecting, and reporting pADEs with analysis of the incidence and characteristics of pADEs and the near-misses.
- Deploy a closed loop medication administration system by implementing an electronic medication administration record (eMAR) and barcoding, or other auto identification technology with computerized provider order entry (CPOE) and pharmacy for medication administration.
- Institute proven interventional bundles for pADEs:
 - Standardized order sets and protocols for each admitting diagnosis;
 - CPOE with sophisticated decision support systems (DSS) including medication reconciliation, allergy checking, interaction checking, and dose range checking with alerts;
 - Enhanced pharmacy services including clinical pharmacists on rounds, implementing a double-check process as part of medication verification prior to dispensing high-risk medications, utilizing improved IV compounding tools such as bar code assisted medication preparation system (BCMP), and improving workforce skills to assure correct drug compounding and a pharmacy intervention database;
 - Ensure open communication and standardized medication handoff processes between healthcare teams at shift changes to verify medications are being administered correctly compared to the order, and that patient monitoring parameters for high alert medications are in place;
 - ‘Smart’ drug infusion pumps with drug libraries that are harmonized with order sets and enterprise formularies that include pediatric standardized drug concentrations addressing all weight ranges and are periodically updated based on review of an incident database, alert and override data;
 - Support tools to ensure that the correct concentration of drug in diluent is prepared, taking into account fluid balance for small patients and patients with fluid restrictions, and an infusion rate that is acceptable and within pump capabilities in all areas where children receive care.
- Select and implement new enterprise clinical information systems and electronic health records, verify and assess that the features of an organization’s healthcare IT system includes full support for best practices in age- and weight-specific prescribing, compounding, dispensing, and administration of pediatric medications.
- Consider relevant improvement initiatives and opportunities for collaboration in pADE reduction outside of the hospital system.
- Disseminate pediatric-specific assistive technologies such as eBroselow (or equivalent) to assure that basic capabilities to stabilize and treat acutely ill or injured children are present 24/7 throughout all environments of care.



- Ensure that the FDA Safety Communication: “Syringe Pump Problems with Fluid Flow Continuity at Low Infusion Rates Can Result in Serious Clinical Consequences” is reviewed and understood by the team.
- Utilize Continuous Quality Improvement (CQI) software from infusion pump manufacturers to monitor drug library parameters on a routine basis and to report the frequency of command overrides and alerts triggered for unsafe practices.

The Performance Gap

As reported by the Institute for Safe Medication Practices (ISMP), during a 5-year span between 2008 and 2012, there were over 45,000 adverse drug events (ADEs) reported to the US Food and Drug Administration (FDA) in children aged less than 18 years old. Of these, approximately 64% of ADEs (29,298) involved reports of a serious injury, which included 2,935 (6%) deaths, 10,032 (22%) cases that required hospitalization, 1,430 (3%) cases considered life threatening, and 816 (2%) cases of disability.¹

Preventing medication errors in pediatric patients poses unique challenges as children are particularly vulnerable to adverse outcomes from medication errors because of the need for weight-based drug dosing involving multiple calculations, dilution of stock drug solutions, immature renal and hepatic functions, and limited communication skills when experiencing side effects.^{2,3,4} In addition, drugs may be approved for marketing with limited clinical trials in children. Greater than 70% of the drugs used in pediatrics have not been studied scientifically in age-specific populations to assess patient safety.^{4,5} Most medications used in the care of children are formulated and packaged primarily for adults. The available dosage forms and concentrations appropriate for administration to neonates, infants and children are limited. Therefore, medications often must be prepared in different volumes or concentrations to accommodate delivery modalities that take into account fluid balance for small patients and patients with fluid restriction, and, if an infusion pump is required, provide an infusion rate that is acceptable and within pump capabilities. When drugs are not prepared centrally in the pharmacy (i.e., extemporaneous compounding by frontline caregivers), computational errors and admixtures that do not account stability, compatibility, or bioavailability data may represent additional challenges.⁶

Studies showed that medication errors in pediatrics are up to three times more likely to be associated with a potential ADE compared to those reported in adults.^{2,7} Compared to other pediatric patient groups, the neonatal ICU patient group has the highest error and potential ADE rate.^{2,8} As reported in an earlier study, ADE rates in hospitalized children were substantially higher (15.7 per 1000 patient-days) than previously described.⁹ However, 22% of all ADEs could be preventable, and 17.8% could have been identified earlier.⁹

In 2001, the ISMP and the Pediatric Pharmacy Advocacy Group (PPAG) collaborated to produce the nation's first set of guidelines to reduce pediatric medication errors.¹⁰ The American Academy of Pediatrics (AAP) has also taken a lead in making recommendations to reduce errors.¹¹

¹ Institute for Safe Medication Practices. (2014), QuarterWatch (Special Report): Adverse drug events In children less than 18 years old. Retrieved from: <https://www.ismp.org/newsletters/acutecare/showarticle.aspx?id=67>

² Kaushal, Rainu, et al. "Medication errors and adverse drug events in pediatric inpatients." *Jama* 285.16 (2001): 2114-2120.

³ Steering Committee on Quality Improvement and Management and Committee on Hospital Care. Policy statement-principles of pediatric patient safety: reducing harm due to medical care. *Pediatrics*, 2011. 127(6):1199-1210.

⁴ Poole, R. L., & Carleton, B. C. (2008). Medication errors: Neonates, infants and children are the most vulnerable!. *The Journal of Pediatric Pharmacology and Therapeutics*, 13(2), 65-67.

⁵ Lindell-Osuagwu L, Korhonen MJ, Saano S, Helin-Tanninen M, Naaranlahti T, Kokki H. Off-label and unlicensed drug prescribing in three paediatric wards in Finland and review of the international literature. *J Clin Pharm Ther*. 2009;34(3):277-287.

⁶ Joint Commission. (2008). *Preventing pediatric medication errors. Sentinel Event Alert*, 39, 1-4.

⁷ Fortescue EB, Kaushal R, Landrigan CP, et al. Prioritizing strategies for preventing medication errors and adverse drug events in pediatric inpatients. *Pediatrics*. 2003;111(4 Pt 1):722-729.

⁸ Le J, Nguyen T, Law AV, Hodding J. Adverse drug reactions among children over a 10-year period. *Pediatrics*. 2006;118(2):555-562.

⁹ Takata GS, Mason W, Taketomo C, Logsdon T, Sharek PJ. Development, testing, and findings of a pediatric-focused trigger tool to identify medication-related harm in US children's hospitals. *Pediatrics*. 2008;121(4):e927-935.

¹⁰ Levine, S. R., Cohen, M. R., Blanchard, N. R. (2001). Guidelines for preventing medication errors in pediatrics. *J Pediatr Pharmacol Ther*. 6:426-442.

Closure of performance gaps and “getting to zero” medication errors will require the constant vigilance from all healthcare professionals and the commitment of hospitals and healthcare systems to implement action in the form of specific leadership, practice and technology plans. This will lead to a decrease in medication errors and a reduction in the occurrence of preventable ADEs in pediatric patients.

Leadership Plan

The hospital board, executives and other senior administrative leadership (medicine, pharmacy and nursing) must fully understand the performance gaps in reducing pADEs at their own healthcare systems. Commitment from all the leaders and stakeholders is necessary for the successful closure of these performance gaps. Leaders should endorse a comprehensive pADE reduction action plan and ensure implementation across all providers and systems. Strategic and tactical approaches that hospital leadership should endorse include the following:

- Establish pADE reduction as a strategic priority by creating a clear metric and goal that are included on the hospital-wide dashboard reviewed by the board and senior executives.
- Invest and allocate funds to:
 - Develop and maintain continuous education programs for healthcare providers with respect to pediatric clinical updates, high alert medications, pADEs monitoring and proper use of drug infusion pumps.^{12,13,14,15,16}
 - Support clinical and research programs to develop an educational forum and “Best Practices” model for healthcare providers to expand the body of knowledge in pediatric medicine.
- Encourage and support the use of a simple, real-time pADE reporting system.¹⁵
- Review accurate, up-to-date pADE data at least monthly.¹⁵
 - Charter a committee or task force to review the reported data at the hospital and unit levels, generate and implement strategies for improvement, analyze barriers and regularly report to executive leadership.¹⁵
- Expect a comprehensive root cause analysis of all pADEs that involve serious patient harm. The analysis should include the root cause of the medication error, feedback to the individual linked to the error, implementation of time-bound and evidence-based changes to avoid similar pADEs, and widespread sharing of lessons learned.¹⁵
- Support the development of a lessons learned program to raise awareness among providers across the spectrum of medication delivery about pADE events, risks and improvement efforts using longitudinal data, individual events and near misses.
- Assess staffing and ensure an adequate number of medical, nursing and pharmacy staff specially trained to prescribe, prepare, dispense, and administer medications to children.^{11,17}

¹¹ Stucky ER, American Academy of Pediatrics Committee on Drugs, and American Academy of Pediatrics Committee on Hospital Care. Prevention of medication errors in the pediatric inpatient setting. *Pediatrics*, 2003. 112(2): p. 431-436.

¹² Manias E, Kinney S, Cranswick N, Williams A, Borrott N. Interventions to reduce medication errors in pediatric intensive care. *Ann Pharmacother*. 2014;48(10):1313-1331.

¹³ Cimino MA, Kirschbaum MS, Brodsky L, Shaha SH, Child Health Accountability I. Assessing medication prescribing errors in pediatric intensive care units. *Pediatr Crit Care Med*. 2004;5(2):124-132.

¹⁴ Keiffer S, Marcum G, Harrison S, Teske DW, Simsic JM. Reduction of medication errors in a pediatric cardiothoracic intensive care unit. *J Nurs Care Qual*. 2015;30(3):212-219.

¹⁵ Stump LS. Re-engineering the medication error-reporting process: removing the blame and improving the system. *Am J Health Syst Pharm*. 2000;57 Suppl 4:S10-17.

¹⁶ Wolf ZR. Medication Errors Involving the Intravenous Administration Route: Characteristics of Voluntarily Reported Medication Errors. *J Infus Nurs*. 2016;39(4):235-248.

- Promote and enhance collaborative communication among all disciplines participating in neonatal and pediatric patient care, including pharmacy staff, patients and families.⁷
- Consider relevant improvement initiatives and opportunities for collaboration in pADE reduction outside of the pediatric hospital system such as ECLIPSE,¹⁸ FDA-ASHP Standardize for Safety (S4S) Initiatives and OCHSPS.
- Implement and disseminate assistive technologies that support community practitioners as they stabilize, treat and transfer neonates and children in higher levels of care.

Practice Plan

- Standardize pediatric medication treatments and usage, as well as the processes for drug administration in pediatric patients. Some strategies include the following:
 - Establish and maintain a functional pediatric formulary system with policies for drug evaluation, selection and therapeutic use.^{6,11}
 - Develop and optimize a smart infusion pump drug library with explicit support for intravenous therapy for pediatric patients.^{19,20}
 - Prevent timing errors in medication administration by standardizing the number of days considered in all pediatric protocols upon deciding a treatment start date (e.g., Day 0 or Day 1).⁶
 - Weigh all pediatric patients in kilograms at the time of admission or as soon as possible (i.e., within four hours of admission) in an emergency situation since weight is used to calculate most dosing for children.⁶
 - Standardize and limit the number of concentrations and dosage strengths of high alert medications to the minimum needed to reduce potential medication errors.^{6,21,22,23,24} High alert medications for pediatric patients should be generated by individual hospitals based on their types of pediatric population, infrastructure and unique features.^{25,26}
 - Develop age-related treatment algorithms to guide providers to the correct dosing appropriate for the age of the pediatric patient.

¹⁷ Catlin A. Pediatric medical errors part 2: case commentary. A source of tremendous loss. *Pediatr Nurs.* 2004;30(4):331-333, 335.

¹⁸ Blandford A, Furniss D, Lyons I, et al. Exploring the Current Landscape of Intravenous Infusion Practices and Errors (ECLIPSE): protocol for a mixed-methods observational study. *BMJ Open.* 2016;6(3):e009777.

¹⁹ Manrique-Rodriguez S, Sanchez-Galindo A, Fernandez-Llamazares CM, et al. Developing a drug library for smart pumps in a pediatric intensive care unit. *Artif Intell Med.* 2012;54(3):155-161.

²⁰ Manrique-Rodriguez S, Sanchez-Galindo A, Fernandez-Llamazares CM, et al. Smart pump alerts: all that glitters is not gold. *Int J Med Inform.* 2012;81(5):344-350.

²¹ Irwin D, Vaillancourt R, Dalglish D, et al. Standard concentrations of high-alert drug infusions across paediatric acute care. *Paediatr Child Health.* 2008;13(5):371-376.

²² Hilmas E, Sowan A, Gaffoor M, Vaidya V. Implementation and evaluation of a comprehensive system to deliver pediatric continuous infusion medications with standardized concentrations. *Am J Health Syst Pharm.* 2010;67(1):58-69.

²³ 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.

²⁴ Larsen GY, Parker HB, Cash J, O'Connell M, Grant MC. Standard drug concentrations and smart-pump technology reduce continuous-medication-infusion errors in pediatric patients. *Pediatrics.* 2005;116(1):e21-25.

²⁵ Doherty C, Mc Donnell C. Tenfold medication errors: 5 years' experience at a university-affiliated pediatric hospital. *Pediatrics.* 2012;129(5):916-924.

²⁶ Glanzmann C, Frey B, Meier CR, Vonbach P. Analysis of medication prescribing errors in critically ill children. *Eur J Pediatr.* 2015;174(10):1347-1355.

- Age- and weight-related developmental changes in pediatric patients affect the medication use process of specific drugs, and should be taken into consideration. The age-related treatment algorithms will be useful in preventing the use of medications outside the intended patient population.
 - Use reputable, reliable references and protocols to help standardize pediatric medication therapies.
 - Participate and track the progress of the FDA-ASHP Standardize for Safety Initiative.
 - Evaluate clinical guidelines and protocols on a routine basis for sustainability and safety, especially when limited safety and/or efficacy data are available in the pediatric population.
- Develop and implement a pediatric trigger toolkit that will electronically identify high risk medications based on the therapeutic levels, dosages and pADEs.
 - Alignment of the trigger toolkit with clinical protocols specific for the medication.
 - Utilization of an ADE trigger tool method to identify possible adverse events have been shown to ensure more patient safety events compared to voluntary reporting.^{27,28}
 - The pediatric trigger toolkit is effective at identifying ADEs and reducing the frequency of sentinel events for hospitalized pediatric populations.⁹
- Create a pediatric multidisciplinary team. This team's responsibilities will include the following:
 - Achieve hospital-wide pADE reduction goals;
 - Monitor accurate, up-to-date pADE metrics;
 - Ensure outstanding event reporting systems, root cause analyses, lessons learned processes and improvement strategies for pADE reduction;
 - Benchmark the adequacy of the features of the individual hospital's medication safety practices and clinical information systems against the proven best practices, identify gaps, and make recommendations.
- Collaborate in a multidisciplinary team (e.g., physicians, pharmacists and nurses) to promote and endorse accountability and responsibility in reporting pADEs from all healthcare providers.^{29,30}
 - For example, a pharmacy-driven ADE reporting approach, embraced by nurses and physicians, was shown to improve ADE reporting and avoid inconsistency in the information gathered.²⁹
 - Develop and ensure comprehensive specialty training for all practitioners involved in the care of pediatric patients, as well as continuous education programs for healthcare providers to stay current and knowledgeable in medications and treatment of pediatric conditions, and be familiar with the ongoing pADE tracking and reporting systems.^{6,11}
 - Collaborate with the Informatics Technology team to develop and customize CPOE order sets to help standardize care and medication therapy for specific pediatric disease states.³¹
 - Develop a team of experts (e.g., physician, pharmacist and nurse) to train healthcare providers at their hospital on how to use the smart infusion pumps with customized pediatric drug libraries.²⁰

²⁷ Burch KJ. Using a Trigger Tool to Assess Adverse Drug Events in a Children's Rehabilitation Hospital. *J Pediatr Pharmacol Ther.* 2011;16(3):204-209.

²⁸ Call RJ, Burlison JD, Robertson JJ, et al. Adverse drug event detection in pediatric oncology and hematology patients: using medication triggers to identify patient harm in a specialized pediatric patient population. *J Pediatr.* 2014;165(3):447-452.e4.

²⁹ Crowther DM, Buck ML, McCarthy MW, Barton VW. Improving Pediatric Adverse Drug Event Reporting through Clinical Pharmacy Services. *J Pediatr Pharmacol Ther.* 2011;16(4):285-290.

³⁰ Stratton KM, Blegen MA, Pepper G, Vaughn T. Reporting of medication errors by pediatric nurses. *J Pediatr Nurs.* 2004;19(6):385-392.

³¹ Potts AL, Barr FE, Gregory DF, Wright L, Patel NR. Computerized physician order entry and medication errors in a pediatric critical care unit. *Pediatrics.* 2004;113(1 Pt 1):59-63.



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- Develop and standardize a smooth and effective communication process for hand-offs (e.g. using a checklist)^{32,33} upon patient transfer to a different unit within the hospital, and upon the transitions of care within and outside clinical settings.^{34,35,36}
- Ensure adequate pharmacy services for pediatric patients to reduce medication errors and ADEs.¹² The strategies proposed by the American College of Clinical Pharmacy (ACCP) and PPAG include:³⁷
 - Elevating the minimum expectations for pharmacists entering pediatric practice,
 - Standardizing pediatric pharmacy education,
 - Expanding the current number of pediatric clinical pharmacists,
 - And creating an infrastructure for development of pediatric clinical pharmacists and clinical scientists.
- Develop and implement pharmacist-managed admission medication histories and medication reconciliation process for pediatric patients, which have shown to prevent potentially significant adverse drug reactions and have a positive impact on patient care.³⁸
- Develop and implement a discharge prescription review program, led by a clinical pharmacist (with pediatric training preferred), to ensure the medication doses are equivalent to those prepared in the hospital. This is an effective method for reducing prescribing errors in pediatric patients during transition of care.³⁹
- Implement pharmacist-driven processes, such as developing a double- and triple-check system for high alert medications to ensure the “5 Rights”, appropriate medication selection, and accurate excipients, dose and concentrations of liquid medications prior to compounding and dispensing them.
- Develop an education forum for community healthcare providers (e.g., physicians, pharmacists and nurses) about appropriate prescribing and dispensing medications for pediatric patients.⁴⁰
- Disseminate pediatric-specific assistive technologies such as eBroselow (or equivalent) to assure that basic capabilities to stabilize and treat acutely ill or injured children are present 24/7 throughout all environments of care.⁴¹

³² Robins HM, Dai F. Handoffs in the Postoperative Anesthesia Care Unit: Use of a Checklist for Transfer of Care. *AANA J.* 2015;83(4):264-268.

³³ Halasyamani L, Kripalani S, Coleman E, et al. Transition of care for hospitalized elderly patients--development of a discharge checklist for hospitalists. *J Hosp Med.* 2006;1(6):354-360.

³⁴ Manias E, Gerdtz M, Williams A, Dooley M. Complexities of medicines safety: communicating about managing medicines at transition points of care across emergency departments and medical wards. *J Clin Nurs.* 2015;24(1-2):69-80.

³⁵ Manias E, Gerdtz MF, Weiland TJ, Collins M. Medication use across transition points from the emergency department: identifying factors associated with medication discrepancies. *Ann Pharmacother.* 2009;43(11):1755-1764.

³⁶ Apker J, Mallak LA, Gibson SC. Communicating in the "Gray zone": Perceptions about emergency physician-hospitalist handoffs and patient safety. *Acad Emerg Med.* 2007;14(10):884-894.

³⁷ Bhatt-Mehta V, Buck ML, Chung AM, et al. Recommendations for meeting the pediatric patient's need for a clinical pharmacist: a joint opinion of the Pediatrics Practice and Research Network of the American College of Clinical Pharmacy and the Pediatric Pharmacy Advocacy Group. *Pharmacotherapy.* 2013;33(2):243-251.

³⁸ 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.

³⁹ Christiansen SR, Morgan JA, Hilmas E, Shepardson A. Impact of a prescription review program on the accuracy and safety of discharge prescriptions in a pediatric hospital setting. *J Pediatr Pharmacol Ther.* 2008;13(4):226-232.

⁴⁰ Benavides S, Huynh D, Morgan J, Briars L. Approach to the pediatric prescription in a community pharmacy. *J Pediatr Pharmacol Ther.* 2011;16(4):298-307.

Technology Plan

Suggested practices and technologies are limited to those proven to show benefit or are the only known technologies with a particular capability. As other options may exist, please send information on any additional technologies, along with appropriate evidence, to info@patientsafetymovement.org.

Technology has significantly advanced in the last decade within the healthcare setting with development of Electronic Health Records (EHR), CPOE, barcode medication administration (BCMA), bar code assisted medication preparation system (BCMP) and smart pump infusion technology. Multiple studies in pediatrics have demonstrated a decrease in both prescribing errors and ADEs after implementing these technologies.^{12,24,42,43,44,45,46,47,48,49,50} However, most of these systems are designed for use in adult patients and customization is often needed to ensure optimal use in pediatric patients.^{31,51}

- Work with the multidisciplinary healthcare team to develop, improve and optimize the pADE-reporting systems to identify, target, track and monitor pADEs.
- Embed a pediatric trigger toolkit in the CPOE as an alert system for prescribers when medications are ordered out of range or are duplicate therapies.^{9,27,28}
- Develop and optimize real-time surveillance systems to identify high risk/high alert medications and to optimize pediatric patient outcomes via mitigation of pADEs.
- Standardize equipment and measurement systems throughout the institution, such as smart infusion pumps and accurate weight scales for pediatric patients.¹¹

⁴¹ Damhoff HN, Kuhn RJ, Baker-Justice SN. Medication preparation in pediatric emergencies: comparison of a web-based, standard-dose, bar code-enabled system and a traditional approach. *J Pediatr Pharmacol Ther.* 2014;19(3):174-181.

⁴² Morriss FH, Jr., Abramowitz PW, Nelson SP, et al. Effectiveness of a barcode medication administration system in reducing preventable adverse drug events in a neonatal intensive care unit: a prospective cohort study. *J Pediatr.* 2009;154(3):363-368.e1.

⁴³ Tourel J, Delage E, Lebel D, et al. Smart pump use in pediatric patients. *Am J Health Syst Pharm.* 2012;69(19):1628-1629.

⁴⁴ Mason JJ, Roberts-Turner R, Amendola V, Sill AM, Hinds PS. Patient safety, error reduction, and pediatric nurses' perceptions of smart pump technology. *J Pediatr Nurs.* 2014;29(2):143-151.

⁴⁵ Morriss FH, Jr., Abramowitz PW, Nelson SP, Milavetz G, Michael SL, Gordon SN. Risk of adverse drug events in neonates treated with opioids and the effect of a bar-code-assisted medication administration system. *Am J Health Syst Pharm.* 2011;68(1):57-62.

⁴⁶ Hardmeier A, Tsourounis C, Moore M, Abbott WE, Guglielmo BJ. Pediatric medication administration errors and workflow following implementation of a bar code medication administration system. *J Healthc Qual.* 2014;36(4):54-61; quiz 61-3.

⁴⁷ King WJ, Paice N, Rangrej J, Forestell GJ, Swartz R. The effect of computerized physician order entry on medication errors and adverse drug events in pediatric inpatients. *Pediatrics.* 2003;112(3 Pt1):506-509.

⁴⁸ Leung AA, Denham CR, Gandhi TK, et al. A safe practice standard for barcode technology. *J Patient Saf.* 2015;11(2):89-99.

⁴⁹ Manrique-Rodriguez S, Sanchez-Galindo AC, Fernandez-Llamazares CM, Calvo-Calvo MM, Carrillo-Alvarez A, Sanjurjo-Saez M. Safe intravenous administration in pediatrics: A 5-year Pediatric Intensive Care Unit experience with smart pumps. *Med Intensiva.* 2016;40(7):411-421.

⁵⁰ Rinke ML, Bundy DG, Velasquez CA, et al. Interventions to reduce pediatric medication errors: a systematic review. *Pediatrics.* 2014;134(2):338-360.

⁵¹ Ruano M, Villamanan E, Perez E, Herrero A, Alvarez-Sala R. New technologies as a strategy to decrease medication errors: how do they affect adults and children differently? *World J Pediatr.* 2016;12(1):28-34.



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- Ensure best practices are used for syringe pumps with medications requiring low infusion rates (<5 mL per hour) to prevent medication errors.^{52,53}
- Ensure that the FDA Safety Communication: “Syringe Pump Problems with Fluid Flow Continuity at Low Infusion Rates Can Result in Serious Clinical Consequences” is reviewed and understood by pharmacists who dispense drugs for use in programmable syringe pumps, by clinical engineers and technicians who maintain programmable syringe pumps, and by caregivers who use or who train users on programmable syringe pumps.⁵²
 - Promote eLearning modules on this topic,⁵⁴ prepared by Massachusetts General Hospital, are freely available at syringeinfusionsafety.org as referenced by the FDA in the Safety Communication.
- Implement and optimize bar coded medication process for pediatric medication products (e.g., multi-dose or unit-dose vials, compounded, and/or repackaged).^{48,55}
 - Use a bar code assisted medication preparation system (BCMP) for intravenous sterile compounding in pharmacy, such as Baxter’s DoseEdge Pharmacy Workflow Manager, BD’s Cato™ Medication Workflow Solutions, and Omnicell’s i.v.SOFT® Assist.
 - Use the eBroselow System (or equivalent) as an electronic aid to assist those who compound drugs extemporaneously, in achieving compliance with standardized concentrations that respect fluid balance considerations for small patients and patients with fluid restriction, and are compatible with the performance envelope of drug infusion pumps.⁴¹
 - Use the Codonics Safe Label System,⁵⁶ or the BD Intelliport Medication Management System, to assure correct source vial identification, container preparation, and Joint Commission- compliant labeling of drugs given by IV push or infusion in the perioperative environment.⁵⁷
- Utilize Continuous Quality Improvement (CQI) software from infusion pump manufacturers to monitor drug library parameters on a routine basis and to report the frequency of command overrides and alerts triggered for unsafe practices.^{58,59}
 - Analyze and proactively respond to identified issues from smart pump data to minimize use of basic mode.
- Develop systems to perform gap and root cause analyses to improve patient and medication safety.

⁵² U.S. Food & Drug Administration. Syringe Pump Problems with Fluid Flow Continuity at Low Infusion Rates Can Result in Serious Clinical Consequences: FDA Safety Communication. August 26, 2016.

<http://www.fda.gov/medicaldevices/safety/alertsandnotices/ucm518049.htm>

⁵³ Sherwin CM, Medlicott NJ, Reith DM, Broadbent RS. Intravenous drug delivery in neonates: lessons learnt. *Arch Dis Child*. 2014;99(6):590-594.

⁵⁴ Massachusetts General Hospital Anesthesia, Critical Care and Pain Medicine. Syringe Infusion Pumps: How they operate and the clinical implications. <https://www.phscpd.org/activities/activity-detail/syringe-infusion-pumps-how-they-operate-and-the-clinical-implications>

⁵⁵ ASHP Foundation. Implementing a bar coded medication safety program: Pharmacist's toolkit. 2004.

<http://www.ashpfoundation.org/mainmenucategories/education/specialprograms/barcodeguide.aspx>

⁵⁶ Jelacic S, Bowdle A, Nair BG, Kusulos D, Bower L, Togashi K. A System for Anesthesia Drug Administration Using Barcode Technology: The Codonics Safe Label System and Smart Anesthesia Manager. *Anesth Analg*. 2015;121(2):410-421.

⁵⁷ Nanji KC, Patel A, Shaikh S, Seger DL, Bates DW. Evaluation of Perioperative Medication Errors and Adverse Drug Events. *Anesthesiology*. 2016;124(1):25-34.

⁵⁸ Ohashi K, Dykes P, McIntosh K, Buckley E, Wien M, Bates DW. Evaluation of intravenous medication errors with smart infusion pumps in an academic medical center. *AMIA Annu Symp Proc*. 2013;2013:1089-1098.

⁵⁹ Bergon-Sendin E, Perez-Grande C, Lora-Pablos D, et al. Smart pumps and random safety audits in a Neonatal Intensive Care Unit: a new challenge for patient safety. *BMC Pediatr*. 2015;15:206.



- With technology prevalent in healthcare, physicians, pharmacists and nurses should use both synchronous and asynchronous forms of communication to improve medication safety at the transitional points of care.^{7,34}
- Develop and optimize communication technology across healthcare settings, providers and caregivers of the pediatric patients via secured HIPAA-protected lines (e.g., telemedicine and apps).

Workgroup

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