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Improving Pediatric Medication Safety
Part II: Evaluating Strategies to Prevent Medication Errors

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The Joint Commission Sentinel Event Alert (SEA) on preventing medication errors in children highlighted several key suggestions for improving medication safety, including increasing standardization, incorporation of greater oversight of the medication use process by trained personnel, and expanded use of technology.[1] Many of the recommendations were based on the results of studies and consensus papers published within in the last five years.[2,3] This issue of *Pediatric Pharmacotherapy* will review these publications and discuss their potential impact on pediatric health care organizations.

Systems Analysis

One of the primary tenets of the Joint Commission SEA was the need for health care organizations to thoroughly evaluate current medication management processes and to take a systematic approach to analyzing medication errors.[1] After two incidents involving heparin overdoses in neonates were made public, many hospitals reviewed their medication handling practices in the neonatal intensive care unit (NICU). In a recent issue of *The Journal of Pediatric Pharmacology and Therapeutics*, Arimura and colleagues described their institution's multidisciplinary approach to preventing this type of error.[4] Their plan highlights several key features of an effective systems analysis. It was 1) timely- their initial response took place the same day as the announcement of the second incident, 2) collaborative - they involved pharmacy, nursing, and medical personnel in the process from the beginning, and 3) thorough - involving removal of concentrated heparin from the NICU, adding heparin to their high-alert medication list, changing to pre-filled heparin syringes, and providing education to all staff members about the potential for heparin dosing errors.

Another example of assessing medication error risk was published by Kunac and Reith.[5] They review the failure mode and effects analysis (FMEA) conducted at their institution to identify potential sources of medication errors in their NICU. The most pressing issue identified was a lack of medication safety training for the staff, with the second being problems with drug administration. In addition to providing a list of recommendations for improving safety in the NICU, this article provides a good introduction to the FMEA process for new clinicians.

Computerized Prescriber Order Entry

The implementation of computerized prescriber order entry (CPOE) has been one of the most widely studied medication error prevention strategies to date.[6] Within the pediatric literature alone, there have been over a dozen reports of CPOE utilization in inpatient, clinic, and emergency department settings. Benefits of CPOE include the avoidance of illegible handwriting and transcription errors, prevention of order component omissions (missing the dosing frequency, etc), as well as the ability to incorporate dose-checking programs, drug information, allergy or drug interaction alerts, and evidence-based clinical decision support.

Potts and colleagues published one of the earliest papers on CPOE use in a pediatric setting.[7] They compared medication errors before and after implementation of CPOE in a 20-bed pediatric intensive care unit (PICU). The rate of potential adverse drug events (ADEs) declined from 2.2 to 1.3 per 100 orders. Medication prescribing errors dropped from 30.1 to 0.2 per 100 orders and rules violations (use of non-standard abbreviations or trailing zeroes) decreased from 6.8 to 0.1 per 100 orders. The overall error reduction rate was 95.9%.

In 2007, Holdsworth and colleagues reported similar results in pediatric inpatients (both in the PICU and on general pediatrics units).[8] They compared ADEs and potential ADEs during a 6-month period after implementing a CPOE system with historical data from an equivalent period prior to CPOE implementation. A total of 1,197 admissions prior to CPOE and 1,210 admissions following implementation were evaluated. The

number of preventable ADEs declined from 46 to 26 after implementation. This resulted in a reduction in the rate of ADEs from 3.8 to 2.2 per 100 admissions, with a relative risk of 0.56 (95% CI: 0.34-0.91). The number of potential ADEs dropped from 94 to 35. This produced a decline in the rate of potential ADEs from 7.9 to 2.9 per 100 admissions, with a relative risk of 0.37 (95% CI: 0.25-0.55). Both ordering and dispensing errors decreased. The number of significant ADEs, including those considered life-threatening, was also reduced. The authors found that some types of errors, such as under-dosing of analgesics, were not reduced by CPOE.

Three additional CPOE studies were published earlier this year.[9-11] Taylor and colleagues examined medication administration variances in their NICU before and after installation of CPOE.[9] Variances decreased from 19.8% to 11.6% after implementation. Those related to administration of a drug at the wrong time (the most frequent type of error) declined from 9.9 to 6.7%. The authors concluded that the CPOE system had a significant impact on error prevention, but additional measures were needed to further reduce drug administration errors.

Walsh and colleagues focused on the utility of CPOE in preventing non-intercepted serious medication errors (those errors not caught by pharmacy or nursing prior to reaching the patient).[10] They evaluated a sample of medication orders written within 7 months prior to and 9 months after introducing CPOE. There was a total of 156 medication errors in the 12,672 orders evaluated, including 70 non-intercepted serious errors. Over the study period, the authors found a 7% decline in the number of non-intercepted serious medication errors after implementation of CPOE, but no resulting change in the rate of injuries related to these errors. They suggested that the low rate of error reduction resulting from CPOE implementation, compared to earlier studies, may reflect their difficulties with developing pediatric dosing in a CPOE system designed primarily for adults.

The utility of CPOE has also been assessed in the pediatric clinic setting. Jani and colleagues assessed the prescribing error rate in their nephrology clinic before and after implementation of electronic prescribing.[11] The error rate with handwritten prescriptions was 77.4%. It dropped to 4.8% after electronic prescribing was initiated. Much of the improvement was related to the elimination of illegible handwriting. The number of prescriptions that were missing essential information dropped from 73.3% to 1.4%.

While all of these studies have demonstrated a reduction in the rate of medication errors, CPOE is not without its disadvantages.[12] Typing mistakes, selection of the incorrect drug or dose due to closely spaced or difficult to read text, and decimal errors continue to occur in these systems, despite attempts to improve formatting and graphics. In addition, dose-checking programs and the flexibility to address unusual intravenous (IV) drug concentrations or extemporaneous formulations are not available in all systems. Institutions considering CPOE should carefully evaluate the system's ability to meet the needs of pediatric health care providers.

Standardization and Smart Pump Technology

The 2007 Joint Commission National Patient Safety Goals call for standardization of medications, including those given IV, in order to reduce preparation and administration errors.[13] While many pediatric institutions initially struggled to replace the commonly used "rule of 6" for calculating infusions of vasoactive agents, the availability of programmable infusion pumps has made the transition less difficult. These devices (also called "smart pumps") allow users to program a library of common medication concentrations and set appropriate dosing limits.

In 2005, Larsen and colleagues described their experience with the implementation of both standard drug concentrations and smart pump technology.[14] The authors compared pre- and post-intervention data, based on voluntary medication error reports, over a 2 year period. There was a 73% reduction in the number of reported errors with continuous medication infusions during the study period. This resulted in an absolute risk reduction of 3.1 to 0.8 per 1000 doses. Pharmacy medication preparation errors dropped from 0.66 to 0.16 per 1,000 doses and the number of 10-fold errors decreased from 0.41 to 0.08 per 1,000 doses. The authors concluded that their interventions resulted in a significant reduction in errors related to the preparation and administration of continuous infusions in the pediatric setting. They suggest that the use of new technology may allow health care providers working in complex settings to provide safer patient care.

In order to optimize the use of this new technology, most institutions have found it useful to establish collaborative multidisciplinary groups to set concentration and dosing standards and develop educational programs. Without the appropriate preparation, adoption of the system can be slow and training incomplete, which may result in an increase in medication administration errors related to incorrect pump programming.

Improved Oversight and Prescriber Education

In their 1987 study of pediatric medication errors, Folli and colleagues concluded that pediatric clinical pharmacists could play a valuable role in the detection and prevention of errors.[15] To quote the authors, "Close review of every drug order by pharmacists specializing in pediatric pharmacotherapy can prevent medication-related disasters." Twenty years later, the role of pharmacists in pediatric medication management is one of the key recommendations in the Joint Commission SEA.

Over a dozen studies have been published since the Folli study that document the value of having pharmacists with pediatric training involved in medication order review and dispensing.[16] Wang and colleagues described the types of errors intercepted by pediatric clinical pharmacists within their system prior to the implementation of CPOE.[17] The authors evaluated 16,938 orders, all reviewed by pediatric clinical pharmacists. A total of 865 errors were identified, resulting in a medication error rate of 5.2 per 100 orders, similar to that reported by other investigators. Seventy-eight percent of the potentially harmful errors were intercepted at the time of ordering. None of the errors occurring at the time of drug administration were intercepted, accounting for half of the preventable adverse drug events occurring during the study. While pharmacist order review prevented most of the errors detected, the authors acknowledged that it did not allow for intervention at the time of drug administration.

While pharmacist oversight of medication ordering and preparation is valuable for all patients, it may be of greatest benefit in the neonatal and pediatric population. The need for dose calculations, the wide range of patient weights, and the need to alter dosage formulations to suit young children increase the risk for error. In a retrospective study by Chan and Kotzin comparing the interventions made by pharmacists in pediatric and adult patients, the pediatric pharmacists made significantly more interventions.[18] Over a 4-year period, there were 706 interventions in children and 379 in adults. This resulted in a rate of 75.3 interventions per 10,000 orders written for children and 4.8 interventions per 10,000 adult orders.

In addition to incorporating pharmacist review of medication orders, the Joint Commission has recommended increased training for prescribers. While the need for additional training is well known, there has been little research into teaching methods or assessment of prescriber competency. In 2007, Conroy and colleagues surveyed 15 hospitals within the United Kingdom about their system for teaching resident physicians about medication error prevention.[19] Thirteen hospitals gave a formal presentation, but only one of those two institutions followed it with a test. The two remaining hospitals provided only a test. This survey reinforces the need for well-designed educational programs and validated assessment tools to aid hospitals in training of new prescribers.

Parent Involvement

In the final section of recommendations, the Joint Commission highlighted the importance of educating and involving families in medication safety. This area was also the focus of a 2003 statement from the United States Pharmacopeia (USP) Center for the Advancement of Patient Safety, as well as the Agency for Healthcare Research and Quality.[20,21] Based on the frequency of incorrect dose calculations identified in an earlier assessment of their MEDMARX® database, the USP statement urged parents to know their child's weight in kg and to confirm the weight documented on their child's records.[20] In addition, parents were encouraged to be more involved in their child's care by:

- Providing health care professionals with a current list of all their child's medications, including prescription and over-the-counter (OTC) medications, vitamins, or other dietary supplements.
- Ensuring that their child's medical team knows their child's allergy history.
- Asking for information on their child's medications, including adverse effects.
- Notifying their child's health care professionals if he/she appears to be having any adverse effects.
- Providing their child's school with a list of current medications and allergies.
- Using an appropriate measuring device at home for all oral liquids.

Health care providers should identify educational needs with each encounter. Medication education is often best provided with a combination of verbal and written instructions. All parents should learn about safe medication use, including dose preparation. While the use of oral measuring devices is recommended in both the Joint Commission and the USP statements, many parents may not be able to accurately use measuring devices without instruction. In a study of 96 adult volunteers, only 67% were able to correctly measure a liquid dose with an oral syringe.[22] Even fewer (15%) were able to measure a correct dose using a dosing cup.

Summary

The previous decade has seen tremendous growth in the development and implementation of tools to improve medication safety. While many of these tools and guidelines have provided significant benefit, there are often consequences that must be addressed. In order to comply with the SEA, health care providers must assess their current medication management process and implement those ideas and new products which are most likely to improve patient safety.

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Editor's Note

In the October issue, we included information on an extemporaneous liquid formulation for levothyroxine. This formulation may not produce a uniform suspension and is **not** recommended by the UVA pediatric endocrinologists. Levothyroxine tablets may be crushed and mixed with water, milk, breastmilk, or formula.

Formulary Update

The following actions were taken by the Pharmacy and Therapeutics Committee at their meeting on 11/19/08:

1. Regadenoson (Lexiscan™) was added to the Inpatient Formulary for radionuclide myocardial perfusion imaging.
2. Agalsidase (Fabrazyme®) was added for the treatment of patients with Fabry disease.
3. DTaP-IPV/Hib vaccine (Pentacel®) was added to the Inpatient and Outpatient Formularies.
4. Dalteparin (Fragmin®), a low molecular weight heparin, was added to the Inpatient and Outpatient Formularies. Enoxaparin is now restricted to Cardiology and Pediatrics.
5. Flecainide was added to the Inpatient Formulary, and nadolol was added to both Inpatient and Outpatient Formularies.
6. Mesalamine suppositories (Canasa®), insulin aspart (Novolog®), and tamsulosin (Flomax®) were also added to the Outpatient Formulary.

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