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Reducing Pediatric Medication Errors

Children are especially at risk for medication errors.

Of all the ways that pediatric patients can be harmed during treatment, medication errors are the most common¹ and the most preventable.² When medication errors occur, pediatric patients have a much higher risk of death than do adults.³ Evidence suggests that for each medication error that harms an adult patient, there are 100 undetected errors. Approximately one in every 100 medication errors results in what is known as an adverse drug event, in which a patient is harmed or dies as a result.² Considering how many inpatient medication orders and outpatient medication prescriptions are written each day, the number of pediatric medication errors is likely to be staggering.

As research results emerge, we are beginning to understand the impact of medication errors on children. Several studies of pediatric inpatients found rates of medication error ranging from 4.5 to 5.7 errors per 100 medication orders,⁴ rates similar to those found in studies of adult inpatients.⁵ Horen and colleagues found that pediatric outpatients had three times the risk of an adverse drug reaction, compared with adult outpatients, especially when the medication was used for an “off-label” indication—a

common practice in pediatrics.⁶ While this study found significant error rates, the frequency of pediatric medication errors in ambulatory settings may be greater, because there are fewer checks and balances in place to prevent them. According to Miller and colleagues, “Pediatric patient safety in ambulatory care settings should be a high research and policy priority given the unique vulnerabilities of children, the glaring lack of current knowledge, and the disproportionate reliance on ambulatory care as compared to inpatient care.”⁷

Medication errors take many forms, but they don’t all result in injury or death. Medication errors are defined as the preventable, inappropriate use of medications that may occur at any stage of the medication process, including ordering, transcribing orders, dispensing, administering, and monitoring. In some instances, medication errors result in an adverse drug event. Adverse drug events can also occur at any step in the medication process.^{5,8,9}

TYPES OF MEDICATION ERRORS

Bates and colleagues, among others, have demonstrated the phases of the care process in which medication errors are most likely to occur.¹⁰ In pediatrics, the prescribing or ordering phase is associated with the most errors—usually dosing errors—followed by the administering phase.¹¹ According to research recently published in *AJN*, “When respondents to [a] staff patient-safety survey were

asked to identify which profession has primary responsibility for ensuring patient safety, 96% of nurses and more than 90% of physicians, administrators, and pharmacists assigned primary responsibility to nurses,” regardless of the factors that contributed to the error (see “An Error by Any Other Name,” June 2004).¹² Therefore, nurses involved in the care of children must be well informed about their patients and the medications ordered.

Contrary to earlier research,^{13,14} nurses play a significant role (specifically in medication administration) in pediatric medication errors.⁵ Even though many errors are caught before a drug is administered,¹⁵ medication errors not caught or intercepted by nurses can result in an adverse event. Because nurses are the ones who predominantly administer medications to patients, they are often the last potential barrier between a medication error (such as the wrong medication given at the wrong time) and serious harm. Nurses have a responsibility to ensure that patients receive the right medication at the right time, and to monitor patients after they’re given or have taken the medication to observe possible adverse events.

THE UNIQUE NATURE OF MEDICATIONS FOR CHILDREN

Children and adolescents are at greater risk than adults for medication errors because they have an immature physiology as well as developmental limitations that

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affect their ability to communicate and self-administer medications. Another important factor is that the great majority of medications are developed in concentrations appropriate for adults; therefore, pediatric indications and dosage guidelines often aren't included with a medication, necessitating weight-based dosing or dilution.¹⁶ That is, in order for many drugs to be used in children, safe dosages—which are fractions of those normally given to adults—must be calculated. Determining pediatric dosages can be complicated because of the need to calculate them according to the child's weight; therefore, those children who take such medications are at greater risk for medication error than others who take medications that don't require such calculations. If no calculation is required, the risk of an error decreases significantly.

Research has identified some of the children most vulnerable to medication errors, including those

- who are younger than two years.¹⁷
- who are in ICUs, especially neonatal ICUs.^{4, 18, 19}
- who are in EDs, especially if seriously ill, between the hours of 4 AM and 8 AM or on weekends.²⁰
- who are receiving chemotherapy.²¹
- who are receiving IV medication.^{21, 22}
- whose weight hasn't been documented.²³

Many of the medications of benefit to children in emergency situations and in the treatment of certain diseases have been approved by the Food and Drug Administration (FDA) only for use in adults.²⁴ Testing of these medications in children has been thwarted by several barriers

inherent to research in children (for example, ethical concerns about using children as clinical trial subjects, the necessity of obtaining parental consent, and the difficulty of enrolling a sufficient number of children).

However, the majority of medications used in neonates^{25, 26} and children who need chemotherapy²⁰ are off-label (sometimes called *unlicensed*) medications, because the majority of medications FDA approved for children don't offer many of the therapeutic benefits of off-label medications. It's safe to use an off-label medication in a child only when its use is fully understood by all clinicians who treat the patient.²⁴ Because most medications don't carry information on child-related dosing guidelines, adverse effects, or safety and efficacy information, using medications in off-label applications—that is, without FDA approval for children—puts children at significant risk for error.^{24, 27}

WHAT'S THE RIGHT DOSE FOR A CHILD?

Giving an adult dose to a child without considering the child's weight, age, and clinical condition can cause an overdose and may result in toxicity and death. The most commonly used methods for calculating pediatric doses involve determining a fraction of an adult dose. Such calculations have been used by pediatricians nationwide for more than 50 years and may be used in children 12 years of age and younger and in those weighing less than 40 kg.²⁸ (While the calculations are necessary to convert adult doses to safe pediatric doses, it's important to note that the calculated fraction of the adult dose may not be safe for a particular child, given his health condition, status, and physiology.)

- **Weight-based method.** The following equation can be used to calculate a pediatric dose based on the child's weight in kilograms:

$$\frac{\text{child's weight in kg}}{50 \text{ kg}} \times \frac{\text{adult dose}}{\text{in mg}} = \text{pediatric dose in mg}$$

The FDA also includes weight-based dosing recommendations for specific medications at www.fda.gov/cder/pediatric/labelchange.htm.

- **Body-surface area (BSA).** A nomogram is used to determine dosage based on the actual size of the child, using the child's height in centimeters and weight in kilograms. A straight line drawn across the nomogram from the child's height (in the left column) to the child's weight (in the right column) will intersect the BSA column (center) at a point indicating the child's approximate BSA in square meters (m²). Then use the following equation to calculate the pediatric dose:

$$\frac{\text{child's BSA}}{\text{in m}^2} \times \frac{\text{adult dose}}{\text{in mg}} = \text{pediatric dose in mg}$$

This method assumes that the glomerular filtration rate is proportional to BSA. The glomerular filtration rate (which is an indication of how well the kidneys are able to excrete the medication) can be used as an index of filter integrity in patients three years of age and older.^{29, 30} This kind of dosage calculation is often used with medications that have a low therapeutic-toxic ratio, in which the rate of excretion is



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important in achieving the correct therapeutic effect, as in chemotherapy.

- **Status of prematurity.** When calculating dosages of medications to be given to premature newborns (infants born at less than 30 weeks' gestation), special consideration is given to their unique physiologic characteristics, including low gastrointestinal motility, high levels of extra-cellular body water, low total body fat composition, and decreased plasma protein binding. Essentially, this results in much smaller doses for premature infants than would be given to other infants.
- **Dilution.** Dilution is used when adult doses of liquid preparations of medication are available, from which a pediatric dose must be prepared. The general rule is to divide the desired amount of medication by the amount of medication in the available liquid preparation, and then multiply the result by the available amount of liquid preparation. For example, suppose you're given an order for a child to receive 120 mg of penicillin, and the liquid preparation that's available contains 200 mg of penicillin in 5 mL of liquid. How many milliliters should be given? Cross-multiply the following:

$$\frac{200 \text{ mg}}{5 \text{ mL}} :: \frac{120 \text{ mg}}{x \text{ mL}}$$

This yields the following proportion:

$$200x = 600$$

Then solve for x by dividing both sides of the equation by 200:

$$\frac{200x}{200} = \frac{600}{200}$$

Therefore, $x = 3$; the pediatric dose is 3 mL.

Formulas such as these shown above are especially useful when a child weighs less than 40 kg. Pediatric dose calculations employing units such as milligrams per kilogram of body weight or milligrams per square meter of BSA require an accurate weight in kilograms, not pounds. As children gain or lose weight and as their bodies mature, pharmacokinetics change; dosing must reflect these changes. It's critical to monitor and document weight changes and the child's age, as well as responsiveness to the drug therapy.

Several important exceptions or caveats apply to any conversion formulas used. For example, standing orders for ibuprofen (Advil and others) or acetaminophen (Tylenol and others) to reduce fever assume that the correct dose for a particular patient will be determined by the patient's weight in kilograms multiplied by the suggested amount of the medication in milligrams per kilogram. Unfortunately, errors can be made when a clinician calculates dosages for patients weighing 40 kg or more, the threshold at which an adult dosage can be considered, and the standard pediatric-dose conversion formulas become less useful. Clinicians should adjust the dosage according to the patient's illness and overall medical condition, such as the presence of diseases affecting metabolism of the drug.³¹

A system of checks and balances should be instituted in every facility, but that has not been the case. The Institute for Safe Medication Practices reported on a survey of health care workers it conducted in 2000.³² Only about half of all respondents said that

a pharmacist always recalculates a drug dose before filling an order or that the child's weight in kilograms has been entered into the pharmacy computer before the drug is given out.

Technologic advances, such as computerized physician order entry with clinical decision support and bar coding, can decrease, if not eliminate, errors.^{16, 33} (Clinical decision support software provides clinicians with comprehensive reference information on medications, such as dosing parameters and recommendations, potential drug interactions, and known side effects.) Computerized physician order entry can help prescribers determine the therapeutic medication dose using weight-based calculations, thereby eliminating human miscalculations and providing a warning if the attempted dose is too large or small, or if there's a potentially harmful medication interaction or allergy.^{10, 34}

MATHEMATICAL MISCALCULATIONS

As noted above, almost all pediatric medications require the clinician to perform a mathematical calculation, one that may be complex. The most common calculations involve fractions, percentages, decimals, and ratios. In mathematical tests, new interns and nurses have been found to have poor mathematical skills—nurses more so than physicians—and pharmacists have demonstrated the best computational skills.³⁵⁻³⁷ The inability to calculate the correct therapeutic volume of a drug dose accounts for the majority of pediatric medication errors.³⁸ Research has found that the major problems behind many of these miscalculations are associated with

- an inability to conceptualize the right mathematical calcu-



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lation to be performed³⁹ and understand the mathematical process leading to the solution.⁴⁰ For example, to be able to give doses listed as “mg per kg,” a nurse would need to first calculate the dose and then the volume to be given, based on the concentration available in stock. Using amoxicillin (Amoxil and others) as an example, if the order reads “Administer 20 mg per kg of amoxicillin every 12 hours” for a child who weighs 15 kg, the nurse would multiply 20 mg by 15 (kg) to arrive at a dose of 300 mg. The medication is supplied in a suspension of 250 mg per 5 mL. The nurse would then have to make a further calculation to know how many mL of medication to give the patient (6 mL).

- a lack of math skills needed to solve the problem,⁴¹ specifically, the use of fractions, percentages, decimals, and ratios.⁴²
- infrequent use of calculation conventions in practice^{36,37} and inexperience in applying these calculations in the clinical setting^{18,19}—both common among those who haven’t used these calculations since school. While these studies involved physicians, nurses must be able to perform the same calculations. If they can’t, they shouldn’t administer the medication.

Misplacement of the decimal point is a common dosing error that can lead to a tenfold error in overdosing or underdosing.⁴³ The consequences of such errors include transient renal failure, tachycardia, respiratory failure, and cardiac arrest.³⁵ Because dosage calculations for small children are dependent upon the use of a decimal point for accuracy, tenfold medication errors are more likely to occur.¹⁹ It’s

important to note that some research has found that those who make tenfold calculation errors are also more likely to cause other medication errors.⁴⁴ Some errors of this type have been linked to performance on calculation tests because those who perform poorly on such tests are more likely to make a mistake in practice, especially when fatigued or distracted.⁴⁵

PREVENTING PEDIATRIC MEDICATION ERRORS

There are several practical steps that nurses should take to improve pediatric medication safety. While any of the following would be a good way to start, a multifaceted approach that includes all of these actions is recommended.

Report medication errors.

Understanding how errors or “near misses” occur provides important information on preventing medication errors.^{5,38} Unfortunately, formal incident reports are not indicative of the total number of medication errors. Nurses underreport them if they fear reprisal or if they are uncertain of the definition of an error.⁴⁶ Managers are responsible for ensuring that nurses and other providers are not punished for mistakes, that error reporting is encouraged, and that hiding mistakes is discouraged.⁴⁷

Know the medication before administering it. You must have adequate knowledge of any medication you are about to administer to a child, specifically: why the medication is being used, whether it is appropriate for a child, what the acceptable or recommended therapeutic dose range is, and how patients may respond (including possible adverse reactions). If you are unsure or concerned about the dosage, remember that asking

questions and gaining more information is always in the patient’s and your best interests. Lack of drug knowledge has been found to account for 15% of medication administration errors among nurses,⁹ who should take advantage of pharmacists’ knowledge when preparing, administering, and monitoring drug therapy.

When a medication is prescribed for an off-label use in a child, double-check the suggested dosage and duration of treatment with a pharmacist, in an appropriate reference such as a current edition of *Physician’s Desk Reference* or in a computerized drug order entry system. If a medication is prescribed for an off-label use, finding the correct dose may be more difficult. The FDA publishes a list of off-label pediatric uses for approved drugs at www.fda.gov/cder/pediatric/labelchange.htm.

As our knowledge of medications improves and the variety of available medications increases, nurses must continue to develop their knowledge and understanding to ensure medication safety. Some medications, known as high-alert medications, have been associated with higher rates of medication errors, and nurses should be particularly cautious when administering them and double-check any orders for them (see Table 1, page TK).

Confirm patient information before administering medications. Every child, especially those weighing less than 40 kg, must be weighed and the weight documented in the medical record prior to administering any medication. The weight should be recorded in kilograms, not pounds. Don’t give any medication until the current weight is recorded. Also, make sure that the most recent weight was used in the calculation of the dose. It’s



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Table 1. High-Alert Pediatric Drugs Associated with Medication Errors by Setting

Drug Class	Hospitals ^{4, 43, 48, 49}	EDs ^{18, 19}
Adrenals, corticosteroids	X	
Analgesics		
• Acetaminophen		X
Antiinfectives, antibiotics	X	X
Antihistamines	X	X
Antineoplastics		X
Asthma medications	X	
Bronchodilators	X	X
Cardiac drugs	X	X
Electrolytes, minerals, and vitamins	X	
Insulin	X	
Opioids (such as morphine)	X	
Sedatives (such as opioids, benzodiazepines, chloral hydrate [Aquachloral Suppettes and others], barbiturates)	X	

Table 2. What to Do Before Giving Any Medication to a Child

Type of Medication	What to Check
Common medications (such as antibiotics and antipyretics)	<input type="checkbox"/> name and purpose of medication <input type="checkbox"/> name of child to receive the medication <input type="checkbox"/> weight of the child (in kilograms) and appropriate dosing <input type="checkbox"/> any drug allergies or sensitivities <input type="checkbox"/> any contraindications to using with other medications being taken <input type="checkbox"/> that policies and procedures for safe medication administration are followed
Off-label medications (such as immunosuppressants, antineoplastics, and cardiac medications)	<input type="checkbox"/> verify with the prescriber: the medication, its dosage, and duration of administration <input type="checkbox"/> double-check dosage <input type="checkbox"/> discuss with team, including pharmacist, possible drug–drug interactions or adverse reactions to be vigilant for while monitoring the child

Sources: Conklin D, et al. *AARN News Lett* 1990;46(1):8-9; Stucky ER, et al. *Pediatrics* 2003;112(2):431-6.

also important to document known allergies and previous medication use.

Double-check orders and collaborate with other clinicians to verify information.

Handwritten orders can be misinterpreted and verbal orders confused and miscommuni-

cated, leading to errors and, potentially, fatal overdoses.³ To avoid errors,

- get clarification from the prescriber on incomplete and illegible orders and discrepancies, such as those between protocols or standardized regimens and the patient's

order and between recommended dosing and the patient's order.

- make sure everything is double-checked by you and either a pharmacist, coworker, or computerized drug order entry system before any drug is administered.^{11, 34, 50-52}
- if an order is given verbally, write it down and repeat it back to the prescriber for confirmation.
- be aware that rules, routines, and policies concerning medication errors are meant to assist nurses and other providers and to decrease the likelihood of error^{53, 54}; however, they can also give a false sense of security if followed in lieu of active involvement in the problem-solving often needed to determine what therapeutic dose will be effective and safe.⁵⁵

Certain critical information—standardized dosing and infusion rates and administration times—should be distributed and displayed. Many medication errors have been made because of an overreliance on memory.^{9, 45} Work collaboratively with an interdisciplinary team to establish maximum and subtherapeutic dose ranges and maximum single dose amounts for each pediatric medication, based on a child's age and weight (when applicable). For some medications given frequently, establish standardized doses and standardized dosing times, to prevent problems with missed doses or the administration of drugs at the wrong time. This should include standardized protocol checklists (see Table 2, at left) and safety reminders for nonstandardized doses and high-alert medications.

Minimize distractions during medication administration.

Distractions interfere with the

ability to concentrate and may lead to errors during the process of administration.^{56,57} Being inattentive or allowing yourself to rush through tasks or from patient to patient while administering medications should be avoided.⁵⁸

Communicate with parents and families and involve them in patient care. Pediatric patient care inherently involves the family. Nevertheless, depending on the age and developmental stage of the child, family members may not always be aware of the treatment plan. This can be complicated because families are focused on the well-being of their child. It's important to communicate with parents and families from admission to discharge. For example, upon admission the nurse may have to ask the family some probing questions about medications that are being taken at home. Parents may forget that the child has been taking an antibiotic or antipyretic at home. While it may take a few extra minutes to obtain an accurate history from the family, they are still a vital source of information.

The Agency for Healthcare Research and Quality states that the single most important thing families can do to prevent medical errors is to actively participate in the child's health care.⁵⁹ Nurses can involve the family whenever administering a medication and inform worried parents by taking the time to state the name of the medication, discuss why the medication is being administered and explain the dose, frequency, and purpose of the medication. This can even have the bonus result of providing an important safety check for potential errors. For example, a study of medical errors on the neonatal intensive care unit reported that, even when families

contributed to the cause of errors, they also assisted in the discovery of them.⁵⁸

Improve communication among clinicians during transitioning and handoffs. When the patient is in transition from one clinician to another or from one setting to another, patient safety can be jeopardized. These are times when medication errors and patient treatment protocol errors are most likely to occur.⁷ Clarity is required whenever one communicates with another clinician, and especially when handing off a patient to the next shift or to another clinician. One study showed a 17% reduction in medical errors as a result of improved communication among health care staff.¹¹

Provide child-centered care to patients and their parents and families. The transition home—whether from hospital, ED, or physician's office—is a time when education and clear communication is needed among patients, their families, and all clinicians involved. The route of medication administration is likely to change, and parents and family members will have to assume responsibility for dispensing and administering medications. In addition, as a child is discharged home, the family may be least receptive to new information because of anxiety about their ability to manage their child's care. During these transitions, nurses can educate the family on the plan of care and assess the family's readiness to receive new information.

Simple steps that nurses can incorporate into discussions about discharge include confirming the type of medication to be administered and the route of administration. Parents, family members, and patients will need to know what the medication

looks like, exactly how and when to give—or take—the medication, how to use the correct administration devices (droppers, oral dosing syringes, medication cups), the importance of using the correct administration device to avoid over- or underdosing, what to do if a dose is missed or if the child spits out the medication or can't or won't take the solid form, and what to look for that would warrant a call to the pediatrician. If injections are necessary, ask parents to demonstrate their ability to administer them; research has demonstrated that this can improve the accuracy of and compliance with a treatment regimen.⁶⁰ Nurses should also encourage families to seek out information on their child's care, read package labels carefully, and ask questions about their medications. ▼

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