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# Patient Safety Tip of the Week

# May 4, 2021

# More 10x Dose Errors in Pediatrics

Ten-fold medication errors are a concern for patients of any age. Several of our previous columns (see our Patient Safety Tips of the Week for March 12, 2007 "10x Overdoses", September 9, 2008 "Less is More….and Do You Really Need that Decimal?", and January 18, 2011 "More on Medication Errors in Long-Term Care") provided examples of how 10-fold overdoses occur in a variety of settings.

But, for a variety of reasons, 10-fold errors are more common in children. Our April 17, 2012 Patient Safety Tip of the Week "10x Dose Errors in Pediatrics" highlighted that issue.

A recent bulletin on weight-based medication errors in children from the Healthcare Safety Investigation Branch (HSIB) of UK's National Health Service brought the issue to our attention again (HSIB 2021). The bulletin was issued after analysis of an incident related to a weight-based medication error involving a child who received ten times the intended dose of dalteparin on five occasions over a period of three days. This occurred following prescribing by a junior doctor, using the Trust's electronic prescribing and medicines administration (ePMA) system.

A 4-year-old child was hospitalized following complications for a complex cardiac procedure. She developed a DVT. A multidisciplinary team agreed that the child should be prescribed dalteparin 100 units/kg twice daily (a recommendation in accordance with the British National Formulary for Children). The drug was prescribed by an approved prescriber using the Trust's electronic prescribing and medicines administration system. The child's weight at the time of the prescription was 15.2kg so the dose for administration should have been 15.2 x 100 = 1520 units twice daily rounded down to 1500 units twice daily. The child was inadvertently prescribed 15,000 units of dalteparin twice daily. The approval, dispensing, checking and administration steps did not identify the incorrect prescription meaning the child received 15,000units (10 times the dose intended) of dalteparin on five occasions over three days.

The report notes 5 important factors that may make pediatric medication errors more common:

- Individualized dosing and calculations

- Drug formulations
- Inexperience working with children
- Communication with children
- Off-license prescribing

As opposed to adults, prescribing in children is individualized, typically based on weight, age, or body surface area. So, doses need to be calculated, incorporating one or more of those variables. Such calculations are often manually undertaken in pediatrics as some electronic prescribing systems do not have automated calculation, and some systems with automated calculation are not used.

Units used in such calculations can sometimes contribute to errors. For example, there are many examples where pounds and kilograms get mixed up. That is why we always recommend that weights be input in one standard: kilograms.

Varying concentrations of liquid formulations are also problematic. Facilities need to consider whether they really need multiple different concentrations of medications. Often, standardization on one concentration makes a lot of sense.

The HSIB report notes that many electronic prescribing and medicines administration (ePMA) systems used by hospitals in the UK are configured locally. These local configurations may mean that some systems designed for adult patients are then modified for pediatric patients. The investigation has also seen that even in pediatric-only facilities, the age and weight ranges of patients may mean adult equivalent doses of medicines are sometimes needed. The report notes it would be beneficial for facilities that have adult and pediatric prescribing supported through the same system to ensure they have adequately risk assessed the way in which the system supports the calculation of doses to ensure that adult doses do not require manipulation for pediatric patients.

Our April 17, 2012 Patient Safety Tip of the Week "10x Dose Errors in Pediatrics" highlighted a study from the Hospital for Sick Children in Toronto, Ontario (Doherty 2012) that reported on 252 10-fold medication errors over a 5-year period. That translated to a mean reporting rate of 0.062 per 100 total patient days. Since this was a retrospective review taken from voluntary incident reporting the authors acknowledge that the true incidence may be higher. Morphine was the most frequently reported medication, and opioids were the most frequently reported drug class, followed by antimicrobials and anticoagulants. Patient harm was described in 22 of the reported cases. Contributing factors included intravenous formulations, paper ordering, drug-delivery pumps, errors of dose calculation, documentation of decimal points, and confusion with zeroes. They note that the errors occurred in all phases of the medication process (prescribing, transcribing, dispensing, administering, and monitoring), though the prescribing and administration phases were overrepresented. Of the errors, 123 ten-fold medication errors were intercepted before reaching the patient, most often by pharmacists or nurses but occasionally by physicians or patients or their families.

It also raises an issue we've previously ignored: 10x dosing errors are not always overdoses! They note that almost 30% of the 10-fold dosing errors they found would have resulted in significant **underdosing** with resultant loss of efficacy. That was especially true for antimicrobials.

The authors do a very good job identifying both sources for the errors and contributing factors. Dosage calculation errors and incorrect programming of delivery devices were the top sources for the errors. But they note that paper-based ordering was frequently an enabling factor. On the other hand, CPOE failed to block almost as many 10-fold errors. In addition, overriding of alerts on delivery devices was also a frequent enabler. Simultaneous programming of multiple intravenous pumps was another mechanism. And, as could be anticipated, urgent clinical scenarios were more prone to errors.

Where we had previously talked about sticking keys or keys that don't work on infusion pumps, they noted that the keyboard layout on many pumps may lead to errors. They point out that the "zero", "decimal point", and "confirm" or "enter" keys are often in close proximity on many keyboards, making it too easy to hit more than one key at the same time.

The authors put together many excellent recommendations to minimize the risk of 10-fold errors. Solutions to address dose calculation errors would include mandatory use of dose calculators, increased on-ward clinical pharmacists, and a system for prescribing high-risk medications that requires no calculations by the prescribing physician, such as use of fixed-dose order sets or CPOE that automatically calculates drug dose based on patient weight. Of course, that assumes the correct weight has been input into the EMR. If that weight is incorrect, it would make all such calculations incorrect.

Having decision support systems (tied to CPOE, barcoding systems, and automated dispensing machines) that flag doses of medications falling outside conventional dose ranges is another good way of helping avoid 10-fold medication errors. But beware that computer systems in their study were often enablers since they allowed many 10-fold errors to pass through the system.

Tse and Tuthill (Tse 2020) evaluated 10-fold or greater or a tenth or less medication errors in children aged <16 years in Wales. They found 50 cases over a 3-year period, 43 being overdoses and 7 underdoses. 33 of these incidents occurred in children <5 years of age. The incidents occurred across multiple different healthcare settings. Enteral medications were involved in 31 cases and liquid preparations were often used. Overall, 37 different medications were involved. Five children suffered temporary harm but all fully recovered.

Though they note the overall risk was low, calculating a minimum annual incidence of 1 per 3797 admissions, or 4.6/100 000 children, they recommend improvements can be made to further reduce the risk.

They note that, similar to other studies, errors occurred mainly in the very young and with small volumes of liquid medication.

They reiterate particular issues in pediatrics which make errors more likely:

- doses are individualized for weight
- missing or erroneously adding weight dose adjustments
- many drugs are off license
- multiple concentrations exist
- liquid preparations are often specially manufactured
- incorrect conversions for different concentrations
- unit mix-ups
- decimal point misplacements

Recognizing that liquid preparations are often problematic, Tse and Tuthill recommend switching to tablets whenever possible. They also recommend involving pediatric pharmacists.

Tse and Tuthill also recognized communication issues contributing to these medication errors. They recommend that, to avoid mistakes, advice given over the telephone for infrequently used medicines should be supported by both employing verbal communication tools such as SBAR (Situation, Background, Assessment, Recommendation) and written confirmation of the dose.

One recommendation in most studies has been to incorporate calculations into CPOE or ePrescribing systems and populate the equations with a weight from the electronic medical record (EMR). Of course, that assumes the correct weight has been input into the EMR. If that weight is incorrect, it would make all such calculations incorrect. And standardization of how those weights are input is critical. The error of mixing up pounds and kilograms is critical. Weights should always be input in kilograms. A good system will always force the clinician to input the wight in kilograms (or ask the clinician if the input weight is in kilograms or pounds and convert the latter to kilograms).

Mixing up mg, g, µg can also give rise to 10-fold (or more) errors. Therefore, it is critical to **avoid dangerous abbreviations**. ISMP recommends using "mcg" for micrograms rather than µg (ISMP 2021).

In addition to mixing up pounds and kilograms, another common error is mixing up milligrams and milliliters. Many medication formulations are in mg/mL. If the order was for 10 mg of a medication and one inadvertently drew up 10 mL from a vial where the concentration was 10 mg/mL, you'd have a 10-fold overdose. See also our April 2015 What's New in the Patient Safety World column "Pediatric Dosing Unit Recommendations", which cited the AAP (American Academy of Pediatrics) policy statement "Metric Units and the Preferred Dosing of Orally Administered Liquid Medications" (AAP 2015). The latter includes a reminder that an important facet of avoiding pediatric medication errors is providing appropriate education to the **parents** at the time of prescribing (and dispensing). Health literacy and numeracy are factors

important in contributing to medication errors (see our prior columns for June 2012 "Parents' Math Ability Matters", November 2014 "Out-of-Hospital Pediatric Medication Errors", and January 13, 2015 "More on Numeracy"). Therefore, the AAP statement includes attention to use of tools and techniques such as teach-back, show-back, dose demonstration, pictures and drawings when educating the parents about the medication.

The HSIB case was also an example of how many systems of double checking are weak (see our prior columns on double checking listed below). Though we've noted that many reported 10-fold medication errors have not been prevented by double checks, that does not mean double checks should be scrapped. Particularly for high-alert medications, double checks can be important. But they must be truly **independent** double checks.

And we have long lamented the apparent death of the "**mental double check**". In the past, nurses would typically look at a dose they are about to administer and ask themselves if that dose makes sense. Unfortunately, in the computer era all too much confidence is put on CPOE and barcoding and the "mental double check" seems to have become a thing of the past.

Clinical decision support systems (CDSS) are important in reducing the risk of significant medication overdoses. For many drugs, a typical therapeutic dose range can be programmed in and if an order for a medication includes a dose that exceeds the upper limit, a "hard" stop can be initiated. But, unfortunately, that may not work for all medications. For example, insulin doses can range from a few units to over 100 units. And the CDSS tools would need to distinguish between adult and pediatric patients.

Missing **decimal points** are a big reason for 10x overdoses and decimal points very frequently appear when dosages must be calculated, as they are in pediatrics. Our September 9, 2008 Patient Safety Tip of the Week "Less is More….and Do You Really Need that Decimal?" we raised the issue of decimal points leading to excessive doses and whether you really need decimal points at all. When do you really need them? You all know you should never use a "trailing zero", i.e. a zero following a decimal point, because if the decimal point is not seen there is a risk of a 10-fold (or higher) overdose. But what about other numbers following a decimal point? They are important in certain circumstances (eg. a dose of 0.3 mg or 2.7 mg). However, at higher doses they become much less relevant. For example, let's say you performed a calculation and the result was a recommended dose of a drug is 72.2 mg. Is there really a difference if the patient gets 72 mg or 72.2 mg of most drugs? Yet ordering the latter dosage increases the risk that the decimal point may not be seen or not input into a computer or missed in a faxed order and the patient gets a 10x overdose. So, we strongly recommend that in writing medication orders one specifically decides whether such fractional doses are important or merely place the patient at increased risk of an error. In our September 2011 What's New in the Patient Safety World column "Dose Rounding in Pediatrics" we discussed when dose rounding is appropriate and when it is not. To avoid decimal point errors, we need to heed ISMP's long-standing recommendations (ISMP 2021):

- Use a leading zero before a decimal point when the dose is less than one measurement unit

- Do not use trailing zeros for doses expressed in whole numbers

Lastly, don't forget that **faxes** can have a role in promoting 10-fold medication errors. A smudge on the fax can obscure a decimal point, resulting in a 10-fold overdose. And a small dot on a fax can be mistaken for a decimal point, resulting in a 10-fold underdose. While most healthcare facilities no longer accept faxed orders, a clinician might be referring to faxed medical records as he/she enters orders via CPOE or an ePrescribing system. See our May 2021 What's New in the Patient Safety World column "Axe the Fax" for more comments on why we need to get rid of the fax in healthcare.

**Update 5/11/2021**: Here's another unusual cause of 10-fold medication errors that just came to our attention after last week's column. After a Windows computer system upgrade, the computer system in several Australian hospitals began to duplicate the last digit of medication doses (Keane 2021). For example, if a medication dose was supposed to be 17 mg, the computer would record it as 177 mg. This is another reminder that system upgrades are a time of vulnerability to many of our patient safety tools. Close scrutiny for unwanted consequences are indicated any time your system undergoes an upgrade.

Keane D. Health boss unsure how many patients impacted by dosage bungle blamed on Windows upgrade. ABC News 2021; May 7, 2021
https://www.abc.net.au/news/2021-05-07/sa-health-unsure-of-patient-impact-of-medication-dosage-bungle/100122958

**Some of our other columns on pediatric medication errors**:

| | |
|---|---|
| November 2007 | "1000-fold Overdoses by Transposing mg for micrograms" |
| December 2007 | "1000-fold Heparin Overdoses Back in the News Again" |
| September 9, 2008 | "Less is More and Do You Really Need that Decimal?" |
| July 2009 | "NPSA Review of Patient Safety for Children and Young People" |
| June 28, 2011 | "Long-Acting and Extended-Release Opioid Dangers" |
| September 13, 2011 | "Do You Use Fentanyl Transdermal Patches Safely?" |
| September 2011 | "Dose Rounding in Pediatrics" |
| April 17, 2012 | "10x Dose Errors in Pediatrics" |
| May 2012 | "Another Fentanyl Patch Warning from FDA" |
| June 2012 | "Parents' Math Ability Matters" |
| September 2012 | "FDA Warning on Codeine Use in Children Following Tonsillectomy" |
| May 7, 2013 | "Drug Errors in the Home" |
| May 2014 | "Pediatric Codeine Prescriptions in the ER" |
| November 2014 | "Out-of-Hospital Pediatric Medication Errors" |
| January 13, 2015 | "More on Numeracy" |
| April 2015 | "Pediatric Dosing Unit Recommendations" |

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| September 2015 | "Alert: Use Only Medication Dosing Cups with mL Measurements" |
| November 2015 | "FDA Safety Communication on Tramadol in Children" |
| October 2016 | "Another Codeine Warning for Children" |
| January 31, 2017 | "More Issues in Pediatric Safety" |
| May 2017 | "FDA Finally Restricts Codeine in Kids; Tramadol, Too" |
| August 2017 | "Medication Errors Outside of Healthcare Facilities" |
| August 2017 | "More on Pediatric Dosing Errors" |
| September 2017 | "Weight-Based Dosing in Children" |
| February 19, 2019 | "Focus on Pediatric Patient Safety" |
| June 2020 | "EMR and Medication Safety: Better But Not Yet There" |
| December 2020 | "Guidelines for Opioid Prescribing in Children and Adolescents After Surgery" |

**Some of our other columns on double checks**:

| | |
|---|---|
| January 2010 | "ISMP Article on Double Checks" |
| October 26, 2010 | "Confirming Medications During Anesthesia" |
| October 16, 2012 | "What is the Evidence on Double Checks?" |
| December 9, 2014 | "More Trouble with NMBA's" |
| April 19, 2016 | "Independent Double Checks and Oral Chemotherapy" |
| December 11, 2018 | "Another NMBA Accident" |
| January 1, 2019 | "More on Automated Dispensing Cabinet (ADC) Safety" |
| March 5, 2019 | "Infusion Pump Problems" |
| August 27, 2019 | "Double Check on Double Checks" |
| November 19, 2019 | "An Astonishing Gap in Medication Safety" |
| April 14, 2020 | "Patient Safety Tidbits for the COVID-19 Pandemic" |
| March 2020 | "ISMP Smart Infusion Pump Guidelines" |
| August 4, 2020 | "Intravenous Issues" |
| August 18, 2020 | "More Caution on Double Checks" |

**Some of our previous columns on the impact of abbreviations in healthcare:**

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|---|---|
| March 12, 2007 | "10x Overdoses" |
| June 12, 2007 | "Medication-Related Issues in Ambulatory Surgery" |
| September 2007 | "The Impact of Abbreviations on Patient Safety" |
| July 14, 2009 | "Is Your "Do Not Use" Abbreviations List Adequate?" |
| April 2015 | "Pediatric Dosing Unit Recommendations" |
| December 22, 2015 | "The Alberta Abbreviation Safety Toolkit" |
| May 14, 2019 | "Wrong-Site Surgery and Difficult-to-Mark Sites" |

**References**:

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https://www.hsib.org.uk/documents/295/HSIB_Bulletin_Weight-based_medication_errors_in_children_v04.pdf

Doherty C, McDonnell C. Tenfold Medication Errors: 5 Years' Experience at a University-Affiliated Pediatric Hospital. Pediatrics 2012; 129 (5): 916-924 Published online April 2, 2012
https://pediatrics.aappublications.org/content/129/5/916

Tse Y, Tuthill D. Incidence of paediatric 10-fold medication errors in Wales. Archives of Disease in Childhood 2020; Published Online First: 27 October 2020
https://adc.bmj.com/content/early/2020/10/26/archdischild-2020-319130

ISMP (Institute for Safe Medication Practices). List of Error-Prone Abbreviations. ISMP 2021; February 5, 2021
https://www.ismp.org/recommendations/error-prone-abbreviations-list

AAP (American Academy of Pediatrics). Committee on Drugs. Policy Statement. Metric Units and the Preferred Dosing of Orally Administered Liquid Medications. Pediatrics 2015; 135(4): 784-787; originally published online March 30, 2015
http://pediatrics.aappublications.org/content/early/2015/03/25/peds.2015-0072.full.pdf


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