POTENTIALLY FATAL MISTAKES

Why pediatric dosing errors happen & how to avoid them

By Michael Wallace, BSHS, CCPM, & Mark Meredith, MD

EMS providers often say that calls involving critically ill or injured children cause them the most anxiety.

PHOTO COURTESY MELISSA WALLACE

A 6-year-old male patient is brought to the school nurse after developing increased work of breathing while in the cafeteria. On arrival at the office, the patient is crying, and red blotchy hives are noted on his face and neck. The nurse learns he has a peanut allergy and may have ingested a cookie with peanuts. She notes that the patient's voice is becoming slightly hoarse and the hives are becoming more pronounced. Realizing the patient's condition is worsening and having no diphenhydramine or epinephrine on hand, the nurse activates 9-1-1.

EMS arrives on scene five minutes later and finds the patient anxious and pale with obvious stridor. A full set of vital signs reveals a heart rate of 140, respiratory rate of 30, blood pressure of 85/40 and oxygen saturation of 92% on room air. The urticaria is now widespread, his lips are swollen, and his capillary refill is 4–5 seconds.

The crew immediately starts high-flow oxygen. The lead paramedic measures the child using a Broselow length-based resuscitation tape and determines a weight of 20 kg, which is consistent with the school's medical chart. With the child's level of consciousness and respiratory effort rapidly deteriorating, the paramedic has his EMT partner switch to administering positive-pressure ventilations via a bag-valve mask (BVM) with 100% oxygen. The paramedic uses the Broselow resuscitation tape to determine the intramuscular (IM) dose of epinephrine 1:1,000 at 2.1 mg (2.1 mL). The injection is administered and the patient is moved to the unit for transport. Inside the ambulance, the patient is completely unresponsive and apneic. Pulseless ventricular fibrillation is apparent.

Fire personnel begin assisting with CPR as the paramedic works feverishly to place pediatric combo-pads and defibrillate according to the resuscitation tape at 40 joules (the closest monitor setting available allowed a shock at 50 joules) and CPR is immediately continued. An intraosseous (IO) device is then placed in the left tibia for rapid access, and the resuscitation tape is again consulted for the dose of epinephrine 1:10,000, which is 0.21 mg (2.1 mL). CPR is continued and, due to poor BVM compliance, the patient is intubated using a 5.5 uncuffed endotracheal tube, noting obvious laryngeal swelling and difficult insertion.

Continuous waveform capnography confirms tube placement with a CO_2 of 80.

Emergency transport to the local community hospital is immediately begun, and CPR is continued. While en route, the patient is noted to have pulseless electrical activity. A repeat dose of epinephrine 1:10,000 is given via the IO device, and the patient is found to have a strong central pulse and some respiratory effort on arrival to the emergency department. The physician immediately confirms tube placement and orders 1 mg/kg of diphenhydramine and 2 mg/kg of methylprednisolone via IV. The nursing staff can find neither on their resuscitation tape and, therefore, manually calculates the doses.

Ultimately, the nurse easily determines the correct doses in milligrams at 20 mg and 40 mg, however, the administering nurse visually estimates the amount drawn up and gives 0.5 mL and 1 mL, a fractional overdose of diphenhydramine and nearly a two-fold error of methyprednisolone.

DOSING ERRORS

In addition to the error the administering nurse made, the medic made a potentially fatal dosing error.. He had used the length-based tape dose for epinephrine 1:1,000, not realizing that it was the endotracheal tube cardiac arrest dose instead of the IM anaphylaxis dose.

In 1999 the Institutes of Medicine (IOM) published a landmark paper, "To Err is Human," that shocked the medical community with the conclusion that up to 98,000 fatal medical mistakes occur in U.S. hospitals each year, making preventable errors one of the top 10 leading causes of death. Medication errors accounted for nearly 7,000 of these events.[1] Even more disturbing research indicates mistakes that harm patients but don't cause death are conservatively estimated to be 10 times the death rate.[1,2]

Other studies have indicated that pediatric patients experience adverse events related to medication errors at a rate of 3:1 compared to adults.[3–5] In 2008, the Joint Commission emphasized the continuation of these same problems by issuing a sentinel event alert.[6] Most of these studies, including the IOM report, have focused on the "controlled" environment of the hospital, where providers have access to substantial resources and teams of clinical experts. Root cause analyses verify time and time again significant system and or environmental challenges, such as performing weight-based calculations at the point of care, resource deficits that don't provide the milliliter conversion for most medications and high stress situations impacting cognitive performance.[1,3] Several studies have now specifically assessed EMS performance and are indicating equal or greater challenges and error rates.[7–9]

Even before "To Err is Human" was published, studies had repetitively proven that pediatric patients are especially vulnerable to tenfold medications errors.[10–12] As the IOM report clearly articulates, skilled clinicians are faced with faulty systems, processes and human factors that set the stage for disaster.[1]

In the case above, the paramedic was placed in a stressful situation with a rapidly deteriorating child, requiring him to make several immediate treatment decisions, manage team members, monitor interventions and find the correct epinephrine dose. His thought process took him instantly to his length-based tape because he knew it included a pre-calculated epinephrine 1:1,000 dose. However, it was an endotracheal dose for cardiac arrest.

Pediatric patients experience adverse events related to medication errors at a rate of 3:1 compared to adults.

EMS-SPECIFIC SOLUTIONS

Caring for critical pediatric patients isn't something most EMS professionals do on a daily basis. In fact, most only take care of one or two each year. In addition, pediatric patients are not just small adults, so they have different needs than their adult counterparts. A lack of routine exposure reduces competency and increases provider anxiety. These already high-stress encounters set the stage for the perfect storm. Preparing clinicians for these situations with regular training and practical tools that eliminate complex processes is the key to success.

In 2006, an important study was performed through Los Angeles County EMS that analyzed the accuracy of epinephrine administration in cardiac arrest after system-wide training and implementation of the Broselow resuscitation tape.[7] This study demonstrated a marked improvement in accuracy, but there were still notable accuracy problems. Additionally, it's worth noting that the only medication on the tape that gives you the answer in milligrams and milliliters is epinephrine because the concentrations are standard. In 2007, the American Academy of Pediatrics committee on Pediatric Emergency Medicine acknowledged similar findings in *Pediatrics*, stating, "although helpful, the Broselow tape is not ideal."[10]

In 2008, *Prehospital Emergency Care* published research on a highly effective solution that provided paramedics with pediatric code cards that pre-calculated the doses in both milligrams and milliliters on several critical intervention medications.[8] Paramedics who used the cards were 94% accurate compared to 65% for those who didn't use the cards. That same year, EMS leaders acknowledged that these high-stress situations can impair the provider's cognitive processing skills.[13] They reasoned that the only solution may be to standardize drug concentrations and develop charts for the prehospital environment.

In 2012 a large study at the University of Michigan reviewed pediatric medication errors in the prehospital environment and

TAKE-HOME POINTS

1. Get a patient weight- or length-based tape color on every pediatric patient.
2. Use a validated drug dose calculation chart to decrease errors.
3. Remember that basic supplies can simplify processes and improve safety. For example, luer-lock to luer-lock transfer connectors allow clinicians to quickly draw medications from pre-filled syringes into a more appropriate size to enhance accuracy and prevent overdose.
4. Remember that practice makes perfect. You have to practice to be able to effectively use the resources you have.
5. Talk with your partner prior to arrival at the scene so that each of you knows your role during the resuscitation.

>> CONTINUED FROM PAGE 29

RightDose guides can be used at the point of care to determine precise weight-based doses in milligrams and milliliters.

found substantial evidence of errors associated with time sensitive emergencies and incomplete resources requiring calculations.[9] He further recommended that dosing charts that eliminate the need for math be designed.

SOLUTIONS TO THE PROBLEM

Throughout the past couple decades, solutions have evolved to help increase the speed and accuracy in which providers deliver medications. Calculators, flip guides, charts, tapes, wheels and mobile applications have improved. For example, the Broselow system has been enhanced with computerization that can provide answers in milliliters, solving previous information deficits. The new online tool can be used with a variety of computer systems to precalculate the correct dose.

However, most of these resources still have significant deficiencies. They don't provide a complete answer, don't provide the correct dosing regimen for the circumstances, contain a limited number of medications or simply aren't practical to use in the emergency environment. A variety of challenges, such as multiple concentrations, varying protocols and drug shortages, seemingly oppose the mass distribution of a practical solution.

A NEW SOLUTION

To combat this problem, many EMS agencies and clinicians have developed their own dosing charts that conform to their protocols and drug concentrations. One of these solutions, the RightDose Pediatric & Adult Drug Dosing Guide, allows the clinician to enter their organization's medications, dosing protocols, specific concentrations, minimum and maximum doses, and special instructions through a Web-based portal to get the precise weight-based dose in milligrams and milliliters. Additionally, manufacturer-specific defibrillation and cardioversion dosing, fluid bolus amounts, and complex medication infusions are provided.

RightDose organizes the agency's guide into quick-reference books using categories (i.e., defibrillation, cardiac arrest, drugs alphabetical, fluids and drips, RSI and cardioversion) that are sequenced logically. The first version was piloted in early 2009, receiving accolades from field personnel, EMS officials and pediatric experts across Tennessee.

After three additional years of research and development, RightDose formalized

for national deployment and formed the RightDose Foundation, a non-profit organization that assists budget-strapped organizations with acquiring the resources necessary to help providers give the best care possible to children and adults

For another clinician-created solution, turn to "First-hand Approach," pp. 33–36.

SUMMARY

Calls involving critically ill or injured children are some of the most stressful situations EMS providers encounter. Their anxiety can be exponentially compounded with the sudden realization that precise mathematical equations must be rapidly performed "in the moment," making a challenging situation even worse at a time when there is no room for error. To help avoid these potentially devastating mistakes, all providers need to be aware of their vulnerability to pediatric dosing errors, and organizations need to support personnel with the training and resources necessary to mitigate these risks as much as possible. JEMS

Michael Wallace, BSHS, CCPM, is EMS operations manager at Williamson Medical Center in Franklin, Tenn. He is also vice president of the Board of Directors for Tennessee EMS for Children, co-founder of The RightDose Group and inventor of the RightDose Pediatric and Adult Drug Dosing guide. He can be reached at mwallace@wmed.org or found on LinkedIn.

Mark Meredith, MD, is an associate professor of pediatrics at LeBonheur Children's Hospital in Memphis. He serves on the Tennessee Committee on Pediatric Emergency Care and is active in prehospital education. He's also a member of the *JEMS* Editorial Board. He can be reached at marklm75@gmail.com.

REFERENCES

1. Kohn LT, Corrigan JM, Donaldson MS (Eds). To err is human: Building a safer health system. The National Academies Press: Washington, D.C., 2000.
2. Bond CA, Raehl CL, Franke T. Medication errors in United States hospitals. *Pharmacotherapy*. 2001;21(9):1023–1036.
3. Stucky ER, American Academy of Pediatrics Committee on Drugs, American Academy of Pediatrics Committee on Hospital Care. Prevention of medication errors in the pediatric inpatient setting. *Pediatrics*. 2003;112(2):431–436.
4. Kaushal R, Bates DW, Landrigan C, et al. Medication errors and adverse drug events in pediatric inpatients. *JAMA*. 2001;285(16):2114–2120.
5. Sullivan JE, Buchino JJ. Medication errors in pediatrics: The octopus evading defeat. *J Surg Oncol*. 2004;88(3):182–188.
6. The Joint Commission. (April 11, 2008). Sentinel event alert, Issue 39: Preventing pediatric medication errors. The Joint Commission. Retrieved from www.jointcommission.org/sentinel_event_alert_issue_39_preventing_pediatric_medication_errors/.
7. Kaji AH, Gausche-Hill M, Conrad H, et al. Emergency medical services system changes reduce pediatric epinephrine dosing errors in the prehospital setting. *Pediatrics*. 2006;118(4);1493–1500.
8. Bernius M, Thibodeau B, Jones A, et al. Prevention of pediatric drug calculation errors by prehospital care providers. *Prehosp Emerg Care*. 2008;12(4);486–494.
9. Hoyle J, Davis A, Putnam K, et al. Medication dosing errors in pediatric patients treated by emergency medical services. *Prehosp Emerg Care*. 2012;16(1):59–66.
10. Committee on Pediatric Emergency Medicine. Patient safety in the pediatric emergency care setting. *Pediatrics*. 2007;120(6):1367–1375.
11. Koren G, Haslam RH. Pediatric medication errors: Predicting and preventing tenfold disasters. *J Clin Pharmacol*. 1994;34(11):1043–1045.
12. Rowe C, Koren T, Koren G. Errors by pediatric residents in calculating drug doses. *Arc Dis Child*. 1998;79(1):56–58.
13. Limmer D, Mistovich JJ Krost WS. Beyond the basics: Pediatric assessment and management. *EMS World*. 2008;37(10):91–98.