A systems-centred approach to reducing medication error: Should prehospital providers and emergency departments dose children by age during resuscitation?

Abstract

The high-risk, high-stress and high-stakes environment of out-of-hospital or emergency department paediatric resuscitation is prone to human error, and medication errors are common. This could be contributing to the difference in survival rate of resuscitation in the out-of-hospital versus inpatient setting. Medication for children during resuscitation requires estimation of the child’s weight and calculation of the corresponding drug dose. Whilst both of these steps can lead to error, calculation errors (including tenfold errors) are much more common and harmful than weight errors. Previous solutions aim to optimise each stage of the medication dosing process. Currently, Australian guidelines suggest using the...
highly inaccurate original APLS (or EPLS) formula, weight=2x(age+4) to dose medications in these settings. This means age is converted to weight, which is then converted to dose. There is no evidence that this is causing harm to patients. Therefore, it could be suggested that age could safely be converted straight to dose according to pre-set doses. This eliminates the need for any weight estimation or dose calculation thus reducing the potential for error and harm.

Keywords resuscitation; medication errors; drug dosage calculations; paediatric emergency medicine

Introduction

The survival rates of children who experience an out-of-hospital cardiac arrest (8%) are significantly less than children who arrest in hospital (26%) (1). Many factors contribute to this significant difference, but one possible factor could be the high rate of medication error that occurs during paediatric resuscitation in the prehospital environment and the emergency department (ED) setting (2). Paediatric resuscitation in prehospital and ED settings is an unpredictable, high-risk, high-stress and high-stakes environment, making it prone to human error (3, 4). 70% of children who seek emergency care in the United States attend EDs that see fewer than 15 paediatric patients per day (5), and junior medical staff may have had limited paediatric resuscitation training (6) and are unlikely to have experienced a paediatric critical event (7-9). A recent study by Bhanji et al. (10) showed a significant difference in survival between children who arrest as an inpatient during the day compared with at night, which was preserved even after adjusting for patient-, event- and hospital-related factors. It was suggested that this difference could be due to the more junior medical staff caring for children overnight, or the higher rate of medication errors that occur overnight (10). It could be hypothesised that if the medication error rate during paediatric resuscitation in prehospital and ED settings was reduced, the survival rates for children experiencing an out-of-hospital cardiac arrest might improve.

Medication error rate during paediatric resuscitation in prehospital and ED settings

Most studies of medication error focus on admitted children (11). Measuring the exact error rate that occurs during paediatric resuscitation is difficult as the rate varies significantly depending upon the study design (analysing medication charts, safety reports, simulations or observation studies) (12). Lifshitz et al. (13) found, by looking at medication charts retrospectively, 13% of paediatric patients experienced a medication error in a mobile intensive care unit vehicle and 36% of children experienced a medication
Studies by Lammers et al. (14) and Porter et al. (15) demonstrated a 47-60% medication error rate by paramedics and 27% medication error rate by residents during simulated paediatric resuscitations. An exact medication error rate cannot be concluded due to the variation between study designs. Although studies have demonstrated that the majority of medication errors are unlikely to cause harm (11, 16, 17), during resuscitation, high-risk medications are often used, in which errors have a greater potential for harm (18).

Medication dosing during paediatric resuscitation

At present, there are five key steps to dosing medication for children during resuscitation (see Figure 1). While each stage is vulnerable to error, estimation of the child’s weight and calculation of the corresponding drug dose are those susceptible to prescriber error. Human factors, such as stress and cognitive burden, have been found to be the main contributing factors to prescriber error (3, 19).

Weight estimation

A weight estimate is often used because the child cannot be formally weighed during resuscitation efforts. Currently, Australian guidelines suggest using the outdated original APLS (or EPLS) formula, weight = 2x(age+4) (20, 21), which is highly inaccurate (22). Other ways to estimate children’s weight include alternative age-based formulae, asking the parents, tapes (including the Broselow, Mercy and PAWPER tapes), and smartphone applications (22). The only way to acquire a more accurate weight estimate beyond using age-based formulae is to input more data into the estimation method:

- For tapes, usually a height and mid-arm circumference must be measured,
- For smartphone apps an appropriate image must be obtained, or
- For parental estimation a family member must be consulted.

This makes weight estimation a time-consuming and complicated process in what is already a high-pressure environment.

Human error impacts all weight estimation techniques (23). One commonly cited study by Selbst et al. (24) examined only 33 medication errors in a paediatric ED, 9% of which were due to an incorrect weight. Hirata et al. (25) found 0.63% of all medication doses had weight-related errors and Shaw et al. (26)
found incorrectly recorded weights was a factor in 20% of all reported medication safety events. Most errors were due to incorrect documentation of the unit (pounds instead of kilograms) or other incorrect weight used, such as the patient’s temperature recorded as the weight, rather than an incorrect weight estimate (25, 26). In Hirata et al. (25), 34% of patients with erroneously recorded weights went on to have a medication-dosing error, but these did not result in serious complications. According to a systematic review by Wells et al. (22), the average error rate of the original APLS formula from the results of 11 pooled studies is approximately 20%. However, to date, no studies have investigated whether using the age-based APLS formula in Australia is causing harm to patients.

Need for significant dose calculation and manipulation under pressure

Significant error can occur whilst performing quick dosage calculations in the high-stress environment of paediatric resuscitation. They occur in 22% of prescriptions in critical care settings (27), are much more common than weight errors (27), and have been shown to lead to patient harm (26, 28, 29). A common type of calculation error in paediatrics that can lead to significant harm is a tenfold error, where a decimal point is moved leading to a child receiving ten times the amount of drug (29). Kozer et al. (30) found in eight simulated paediatric resuscitation scenarios, four tenfold errors occurred. Hansen et al. (31) performed a retrospective analysis of 35 paediatric out-of-hospital cardiac arrests, which found 20% of patients were given a ten-fold overdose of adrenaline. Although a number of resuscitation aids with pre-calculated doses are available, even with the use of aids, calculation errors remain common (32, 33).

Current approaches

Possible solutions to human error challenges may be divided into either person-centred approaches or systems-centred approaches (34). In a person-centred approach, the focus is on reducing errors made by an individual such as improving a person’s knowledge, experience, or ability (34); whereas a systems-centred approach assumes all humans are fallible, and instead shifts the focus onto reducing structural factors that create the foundation for individual errors (34). Most strategies to reduce medication error during paediatric resuscitation in prehospital and ED settings currently aim to optimise each stage of medication dosing to reduce the total cumulative risk to the patient (see Figure 2). These are predominantly person-centred approaches such as providing training, tools, and feedback to individual healthcare providers and teams (5). An example of this approach was studied by Leach et al. (35), where
‘prescribing champions’ were given a number of workshops and ongoing weekly feedback using a ‘star chart game’ to try and reduce the high medication error rate in the PICU and paediatric wards. This led to an initial improvement; however, this was not sustained (35). Other strategies include aids which provide pre-calculated doses or algorithms that help with management, however studies show that using the correct tool or remembering the right algorithm is another source of significant error (14, 32). Overall, given the multifactorial causes of medication errors, addressing a singular aspect will have a limited benefit in reducing the error rate (36, 37).

Possible approach

Instead of optimizing each stage of the medication dosing process, another way to approach the problem could be to try and reduce the number of steps required, and thus the cognitive load during paediatric resuscitation (see Figure 3). Australian prehospital and ED guidelines currently convert age to weight (using the age-based formula), then weight to dose (20, 21). Instead, age could be converted straight to dose according to pre-set doses by age-group. This eliminates the need for dose calculation, which carries the largest potential for error and harm with tenfold errors (38).

Another minor advantage of the proposed model is that overweight and obese children would be dosed closer to ideal body weight rather than total body weight. Recent research suggests that dosing obese children according to total body weight carries significant risk of overdose (39). All weight estimation strategies are highly inaccurate at the extremes of body weight (40). With rising rates of childhood obesity, dosing protocols based on total body weight estimates might carry additional risks, and thus dosing based on age might be safer.

The trade-off for reducing the rate of calculation and tenfold errors is that a margin of error would need to be accepted when determining set doses for age groups. Currently used weight estimation strategies, such as the original APLS formula, employ a significant margin of error (22) and there is limited evidence to suggest these strategies result in significant harm to patients. However, there is substantial evidence to suggest that tenfold errors are common and result in significant harm to patients (26, 28, 29). Significant research would be required to determine the width of age brackets used and acceptable standardised doses for common resuscitation medications.
If the emergency care community supports the idea that we should transition towards dosing children by age during paediatric resuscitation in prehospital and ED setting, we would need to first find supporting evidence that shows dosing by age reduces the rate of medication errors. Should this evidence support our hypothesis, we would then need expert opinion to come to a consensus on the breadth of age group categories that we could use safely and determine appropriate doses for each of the common medications used during paediatric resuscitation. After we have acceptable doses and age ranges, simple reference tools or pre-filled syringe kits could be developed to help healthcare professionals implement these new guidelines.

Conclusion

The management of paediatric cardiac arrest is high-stress, error-prone, and has a much lower survival rate than inpatient cardiac arrest. Weight estimation methods currently used in Australia are extremely inaccurate. Having to perform timely calculations to calculate dose in a high-stress situation often leads to tenfold errors, which are associated with significant morbidity and mortality. While current strategies to combat medication error during paediatric resuscitation focus on person-centred approaches, an alternative systems-centred approach could reduce the number of steps in the process by dosing by age instead of by weight. This eliminates the need for any weight estimation or dose calculation thus reducing the potential for error and harm. To transition towards dosing children by age during paediatric resuscitation in prehospital and ED setting, further discussion, research and evaluation is required.

References


Ascertain child age

Weight estimation [weight = 2x(age+4)]

Calculate dose of desired drug for child (from unit/kg)

Preparation of medication

Administration of medication

JPC_14626_Figure 1.png
Ascertained child age

Weight estimation
[weight = 2x(age+4)]

Calculate dose of desired drug for child (from unit/kg)

Preparation of medication

Administration of medication

JPC_14626_Figure 3.png