

# EDUCATION AND PRACTICE

## PREVENTION OF PEDIATRIC DRUG CALCULATION ERRORS BY PREHOSPITAL CARE PROVIDERS

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### ABSTRACT

**Objective.** Calculating weight-based drug doses for pediatric patients is difficult, with significant error potential. In the prehospital setting, few safeguards currently avert pediatric drug administration errors. We sought to determine whether use of a protocol-specific pediatric code card enables prehospital care providers to calculate more consistently accurate weight-based drug doses, volumes of administration, and age-appropriate endotracheal tube sizes. **Methods.** Questionnaires requiring calculations of medication doses, volumes, and endotracheal tube sizes were administered to prehospital care providers between June and November 2006 in fire department continuing education classes in the State of Maryland and the District of Columbia. Half of the participants performed the calculations with the pediatric code card as an aid, and half without. Calculations done by the two groups were compared for rate and extent of errors. We evaluated the error frequency in calculations of pediatric medication doses and endotracheal tube sizes. **Results.** Of the 523 advanced life support prehospital care providers questioned, 246 answered questions using the pediatric code card, and 277 answered questions without using the card. The mean individual percentages of correct responses were 94% for the group aided by the code card and 65% for the group unaided by the card (percentage difference, 29%; 95% confidence interval [CI], 25–31%;  $p < 0.001$ ). Ninety-eight percent of the aided group and 23% of the unaided group calculated the correct endotracheal tube size (percentage difference, 75%; 95% CI, 70–81%;  $p < 0.001$ ). **Conclusions.** The use of the pediatric code card enabled prehospital care providers to determine weight-based drug doses, volumes of administration, and endotra-

cheal tube sizes more accurately than peers without access to the code card. **Key words:** medication errors; pediatrics; pediatric code card; dose calculations

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### INTRODUCTION

Calculation of weight-based drug doses for pediatric patients is a difficult process with significant potential for human error, and in the prehospital setting there are few safeguards in place to prevent these inevitable pediatric drug administration mistakes.

The unacceptably high incidence of medical errors that occur in the hospital setting came to light in the 1999 Institute of Medicine (IOM) report *To Err Is Human: Building a Safer Medical System*.<sup>1</sup> Since that time, medical errors have become a major focus of public and regulatory scrutiny. Recent IOM reports have also highlighted specific concerns regarding pediatric care and the training of emergency medical services (EMS) providers.<sup>2,3</sup> With the understanding that human error cannot be eliminated, changes in system design for in-hospital drug calculation and administration are being aggressively pursued. In a system in which physicians order medications, pharmacists or nurses prepare doses, and nurses administer them, a significant number of mistakes occur, despite the inherent checks and balances in a system with multiple participants.

In the prehospital setting, however, a single care provider is often solely responsible for determining a patient's weight, calculating the drug dose, determining the appropriate volume of administration, and administering the medication to the patient. Although certain pediatric calculation aids exist, they are becoming obsolete as the scope of practice of prehospital care providers expands to include rapid-sequence intubation (RSI) and other skills requiring use of a variety of new medications. With these changes, the potential for error increases.

The 1999 IOM report on medical errors presented a bleak picture of the state of health care and the

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risks to which patients are exposed during hospital admissions.<sup>2</sup> According to the report, medication errors alone accounted for almost 7,400 deaths in the United States in 1993.<sup>1</sup> While the numbers of medication errors (and their resulting morbidity and mortality) in the adult patient population are discouraging, the potential for error in pediatric patients is unfortunately much greater.

Latent factors in prehospital medicine—such as time pressures, fatigue, stress, and inadequate experience—are difficult to control. These factors not only contribute to human error, but also prevent errors from being detected in a timely fashion.<sup>4,5</sup> The prevention of errors in prehospital care requires remedies designed specifically for the prehospital environment; solutions that work in hospitals may not translate well to EMS.

We tested the hypothesis that prehospital care providers using the pediatric code card (Fig. 1) would be able to calculate weight-based drug doses, volumes of drug administration, and endotracheal tube sizes more accurately than prehospital personnel who were unaided by this card. This pediatric code card was designed to be adaptable to the medical protocols of any prehospital jurisdiction and the concentrations of med-

ications utilized by its providers. At this time, we are unaware of such an aid for prehospital advanced life support (ALS) providers caring for pediatric patients.

## METHODS

### Study Design

The study was a prospective experimental investigation involving the collection of questionnaire data from prehospital care providers to assess their ability to perform common pediatric drug calculations with and without the use of the code card. This study was formally submitted to the Institutional Review Board of the University of Maryland Baltimore County and received approval via the exempt review mechanism.

### Study Participants

The subjects included prehospital ALS providers from the District of Columbia, from Anne Arundel County, Baltimore City, Baltimore County, Howard County, and Montgomery County Fire Departments in Maryland,

## Bernius Pediatric Code Card

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### Pounds to Kilogram conversions

Pounds	Kilograms
8 lbs	3.5 kg (newborn)
11 lbs	5 kg (2-3 mo)
17.5 lbs	8 kg (6 mo)
22 lbs	10 kg (1 year)
26 lbs	12 kg (2 years)
33 lbs	15 kg (3 years)
37 lbs	17 kg (4 years)
41 lbs	18.5 kg (5 years)
44 lbs	20 kg (6 years)
55 lbs	25 kg (8 years)
66 lbs	30 kg (9 years)
77 lbs	35 kg (10 years)
88 lbs	40 kg (12 years)
100 lbs	45 kg (13 years)
110 lbs	50 kg (14 years)
132 lbs	60 kg (adult)

**\*\*Please perform all drug calculations using weight in KILOGRAMS only!\*\***

At the time this pediatric aid was created, all efforts were made to ensure that the information contained herein regarding procedures and doses were accurate. The user should refer to the literature for current standards of care.

FIGURE 1. Pediatric code card.

**Bernius Pediatric EMS Code Card**

	3.5kg	5kg	10kg	15kg	20kg	25kg	30kg	40kg	50kg	60kg
<b>Adenosine</b> (0.1mg/kg initial dose) (6mg/2mL) (0.2mg/kg second dose) <i>Rapid IV/IO push</i>	0.35mg 0.1mL 0.7mg 0.2mL	0.5mg 0.17mL 1mg 0.3mL	1mg 0.3mL 2mg 0.7mL	1.5mg 0.5mL 3mg 1mL	2mg 0.7mL 4mg 1.3mL	2.5mg 0.8mL 5mg 1.7mL	3mg 1mL 6mg 2mL	4mg 1.3mL 8mg 2.7mL	5mg 1.7mL 10mg 3.3mL	6mg 2mL 12mg 4mL
<b>Atropine</b> (0.02mg/kg IV/IO) (1mg/10mL) (0.03mg/kg ETT route) (1mg/10mL) <i>Dilute in 5mL of LR</i>	0.1mg 1mL 0.1mg 1mL	0.1mg 1mL 0.15mg 1.5mL	0.2mg 2mL 0.3mg 3mL	0.3mg 3mL 0.45mg 4.5mL	0.4mg 4mL 0.6mg 6mL	0.5mg 5mL 0.75mg 7.5mL	0.6mg 6mL 0.9mg 9mL	0.8mg 8mL 1mg 10mL	1mg 10mL 1mg 10mL	1mg 10mL 1mg 10mL
<b>Calcium Chloride</b> (0.2mL/kg IV/IO)	0.7mL	1 mL	2 mL	3mL	4 mL	5 mL	6 mL	8 mL	10 mL	10 mL
<b>Charcoal</b> (1 gram/kg PO) (50gram/240mL)			10 g 50 mL	15 g 72 mL	20 g 100 mL	25 g 120 mL	30 g 145 mL	40 g 190mL	50 g 240mL	60 g 290mL
<b>Diazepam</b> (0.1mg/kg IV/IO) (10mg/2mL) - max peds dose 1mL (0.2mg/kg rectal) -max dose 2mL	0.35mg 0.07mL 0.14mL	0.5mg 0.1mL 0.2mL	1mg 0.2mL 0.4mL	1.5mg 0.3mL 0.6mL	2mg 0.4mL 0.8mL	2.5mg 0.5mL 1mL	2.5mg 0.5mL 1mL	2.5mg 0.5mL 1mL	2.5mg 0.5mL 1mL	2.5mg 0.5mL 1mL
<b>Diphenhydramine</b> (1mg/kgIV/IO) (50mg/mL)	3.5mg 0.07mL	5mg 0.1mL	10mg 0.2mL	15mg 0.3mL	20mg 0.4mL	25mg 0.5mL	30mg 0.6mL	40mg 0.8mL	50mg 1mL	60mg 1.2mL
<b>Epinephrine: bradycardia/arrest</b> 1:1,000 (ETT) 1:10,000 (IV/IO route)	0.35mL	0.5mL	1mL	1.5mL	2mL	2.5mL	3mL	4mL	5mL	6mL
<b>Epinephrine: anaphylaxis</b> 1:1,000 (IM) 1:10,000 (IV/IO route)	0.04mL 0.35mL	0.05mL 0.5mL	0.1mL 1mL	0.15mL 1mL	0.2mL 1mL	0.25mL 1mL	0.3mL 1mL	0.4mL 1mL	0.5mL 1mL	0.6mL 1mL
<b>Lidocaine:</b> (1mg/kg IV/IO) (100mg/5mL) (2-2.5mg/kg ET)	3.5mg 0.18mL 0.45mL	5mg 0.25mL 0.5mL	10mg 0.5mL 1mL	15mg 0.75mL 1.5mL	20mg 1mL 2-2.5mL	25mg 1.25mL 2.5-3mL	30mg 1.5mL 3-3.5mL	40mg 2mL 4-5mL	50mg 2.5mL 5-6mL	60mg 3mL 6-7.5mL
<b>Morphine</b> (0.1mg/kg) (10mg/mL)	0.35mg 0.04mL	0.5mg 0.05mL	1mg 0.1mL	1.5mg 0.15mL	2mg 0.2mL	2.5mg 0.25mL	3mg 0.3mL	4mg 0.4mL	5mg 0.5mL	5mg 0.5mL
<b>Naloxone</b> (0.1mg/kg IV/IM/nasal) (0.4mg/mL) (0.2-0.25 mg/kg ETT) <i>Dilute in 5mL of LR</i>	0.35mg 0.9mL 0.35mg 0.9mL	0.5mg 1.3mL 0.5mg 1.3mL	1mg 2.5mL 2mg 5mL	1.5mg 3.8mL 3mg 7.5mL	2mg 5mL 4mg 10mL	2mg 5mL 5mg 12.5mL	2mg 5mL 5mg 12.5mL	2mg 5mL 5mg 12.5mL	2mg 5mL 5mg 12.5mL	2mg 5mL 5mg 12.5mL
<b>Sodium Bicarb</b> (1mEq/kg) (1mg/mL) <i>Dilute 1:1</i>	3.5mEq 3.5mL	5mEq 5mL	10mEq 10mL	15mEq 15mL	20mEq 20mL	25mEq 25mL	30mEq 30mL	40mEq 40mL	50mEq 50mL	50mEq 50mL
<b>Saline/LR fluid bolus</b> (20mL/kg)	70 mL	100 mL	200 mL	300mL	400mL	500mL	600mL	800mL	1 Liter	1 Liter

ETT size = (age + 16) ÷ 4

ETT position = 3 x normal tube size @ lip

Hypotension = SBP < 70 + (2 x age)

**Dextrose dosing:**

Neonates: 5-10 mL/kg of D<sub>10</sub>

Infants: 2-4 mL/kg of D<sub>25</sub>

Children >2yo: 1-2mL/kg of D<sub>50</sub>

Age	Weight	ETT size	Laryng blade	NG tube	Oral airway
Newborn	3.5 kg	3.5	0-1 straight	5-8 F	0
6 mo	8 kg	3.5-4.0	1 straight	5-8 F	1
1 yo	10 kg	4.0	1 straight	8-10 F	1
2 yo	12 kg	4.5	1-2 straight	10 F	2
3 yo	15 kg	4.5	2 straight	10 F	2
4 yo	17 kg	5.0	2 straight	10 F	3
6 yo	20 kg	5.5	2 curved/str	12-14 F	4
8 yo	25 kg	6.0 cuffed	2 curved/str	12-14 F	4
10-12 yo	30-40 kg	6.0-7.0 cuffed	3 curved/str	14 F	5

**Infant GCS Score:**

**Motor**

- 6-spontaneous/nl
- 5-w/d to touch
- 4-w/d to pain
- 3-abn flexion
- 2-abn extension
- 1-none

**Verbal**

- 5-coos,babbles
- 4-irritable/confused
- 3-cries to pain
- 2-moans to pain
- 1-none

**Eye opening**

- 4-spontaneous
- 3-to voice
- 2-to pain
- 1-none

FIGURE 1. Continued

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and from the Maryland State Police Aviation Division. Prince George's County Fire/EMS Department was also contacted for participation but was unable to accommodate the research activity in its classes.

The subjects were advised that participation in the study was voluntary and there would be no penalty if they elected not to participate. No providers declined participation. Because no identifying information was collected from the participants, a formal consent form was not used.

The total numbers of prehospital personnel in the State of Maryland at each ALS certification level were ascertained from the 2006 annual report of the Maryland Institute for Emergency Medical Services Systems (MIEMSS).<sup>6</sup> These totals included current, extended, military status, and inactive providers. They also included providers from the larger urban and suburban jurisdictions sampled in the study, and from the rural EMS agencies with a large volunteer component.

Data were not available from MIEMSS on the number of ALS providers at the various certification levels by each jurisdiction, but because of the substantial number of participants in the study, our numbers are likely representative of the current trends within these large jurisdictions.

Only EMS providers certified at an ALS level, and therefore able to administer medications in the field, were included in the study. Cardiac Rescue Technician (CRT) is an older ALS designation roughly equivalent to the current EMI-I status. The State of Maryland has a pilot program for RSI. Providers certified to perform RSI were questioned on the medications utilized in that protocol.

Information was collected from the participants on their level of training, the length of their EMS careers, their current certification level, and their use of standard pediatric aids in the field.

## Study Setting

The investigators attended the mandatory continuing education classes offered in each of the participating jurisdictions between June and November 2006 in order to administer the questionnaires. This setting was selected because it allowed capture of the greatest number of participants in the fewest seatings. The questionnaire was administered prior to each class.

## Study Protocol

The questionnaire consisted of eight general medication calculation questions and two questions on determination of appropriate endotracheal tube size. Six additional calculation questions on RSI medications were addressed to providers certified to perform RSI (Table 1).

The milligram-per-kilogram doses and vial concentrations used in the questions were consistent with state

protocols and stock vials. For external validation, the sample drug calculations in the questionnaires were reviewed by five board-certified emergency physicians active in EMS. They approved the sample calculations as typical of those required of prehospital care providers.

In order to randomize the questionnaires, an alternate questionnaire was used for each consecutive continuing education class attended. No providers were present for more than one class. Questionnaires A and B consisted of the same questions, while questionnaire B also included the pediatric code card. Recipients of questionnaire A were instructed to calculate the answers through mathematical calculations done either mentally or on paper. Recipients of questionnaire B were instructed to answer the questions using the code card, rather than attempting the mathematical calculations. The investigators read standard written instructions on use of the code card in an attempt to normalize the context of the questionnaire administration for all classes.

## Data Analysis

### Medication Calculations

Individual responses to the questionnaires were evaluated for calculation errors. The error rate was calculated as a percentage of the total number of questions answered, pooling answers from all respondents from each group. We compared error rates between groups using a chi-square test. We compared times to complete the test using a t-test.

In the responses from the unaided group, doses based on reasonable mathematical rounding were not considered errors, even if the answer was not as precise as the response provided by the code card. Ranges for correct responses, allowing for mathematical rounding, were defined in advance. Calculation errors considered particularly severe were defined as responses less than or greater than the appropriate dose for a child weighing 5 kilograms less or more than the child in question. This generous range was chosen to standardize the evaluation of calculation skills for each question. Errors that were 10-fold and 100-fold less than or greater than the correct dose were identified. The clinical significance of "severe" errors would vary with the medication.

Errors in the group aided by the code card were categorized as follows: calculation error; response provided from an adjacent row or column; response given in the incorrect unit of measure; dose given via an alternate route of administration; and blank. If the type of error could not be identified as one of the above, it was listed as "other." Calculation errors were identified by examining the questionnaires for obvious evidence that respondents performed their own calculations.

TABLE 1. Pediatric Drug Calculation Study Questionnaire

## Pediatric Drug Calculation Questionnaire

1. The intravenous dose of 1:10,000 epinephrine for a child with bradycardia is 0.1 mL/kg. For a 15-kg child, what would be the appropriate dose (in mL) of 1:10,000 epinephrine for intravenous administration?
2. The dose of diazepam for seizures lasting greater than 10 minutes per Maryland protocol is 0.2 mg/kg rectal (with a maximum dose of 10 mg). For a 5-kg child, what would be the appropriate dose (in mg) of diazepam?
3. Diazepam comes in a 10-mg/2-mL vial. What is the appropriate volume of administration (in mL) for a dose of 3 mg?
4. The endotracheal dose of naloxone for opioid overdose in the pediatric patient per Maryland protocol is 0.25 mg/kg. For a 15-kg child, what would be the appropriate dose (in mg) of naloxone?
5. Naloxone comes in a 0.4-mg/mL vial. What is the appropriate volume of administration (in mL) for a dose of 2.5 mg?
6. The dose of atropine for pediatric bradycardia per Maryland protocol is 0.02 mg/kg IV/IO. For a 20-kg child, what would be the appropriate dose (in mg) of atropine?
7. Atropine comes in a 1-mg/10-mL vial. What is the appropriate volume of administration (in mL) for a dose of 0.5 mg?
8. The multidose vial of atropine is 8 mg/20 mL. What is the appropriate volume of administration (in mL) for a dose of 0.5 mg?
9. What is the formula to calculate appropriate endotracheal tube size based on age?
10. What is the appropriate endotracheal tube size for a 6-year-old child?

## Additional Questions on Rapid-Sequence Intubation

11. The dose of midazolam for rapid-sequence intubation per Maryland protocol is 0.05 mg/kg IVP over 1–2 minutes. For a 20-kg child, what would be the appropriate dose (in mg) of midazolam?
12. Midazolam comes in a 10-mg/2-mL vial. What is the appropriate volume of administration (in mL) for a dose of 0.5 mg?
13. The dose of etomidate for rapid-sequence intubation per Maryland protocol is 0.3 mg/kg IVP over 30–60 seconds. For a 15-kg child, what would be the appropriate dose (in mg) of etomidate?
14. Etomidate comes in a 2-mg/mL vial. What is the appropriate volume of administration (in mL) for a dose of 6 mg?
15. The dose of succinylcholine for rapid-sequence intubation per Maryland protocol is 1.5 mg/kg rapid IV push. For a 15-kg child, what would be the appropriate dose (in mg) of succinylcholine?
16. Succinylcholine comes in a 200-mg/10-mL vial. What is the appropriate volume of administration (in mL) for a dose of 30 mg?

IO = intraosseous; IV = intravenous; IVP = intravenous push.

## Endotracheal Tube Size Calculations

To determine the correct endotracheal tube (ETT) size for a child whose age is known, ALS providers in the State of Maryland and the District of Columbia are taught to use the formula  $(age + 16) \div 4$ . If the child's age is unknown, the care providers can use an alternative method to identify the proper ETT size: with a length-based aid (such as the Broselow tape) or based on the size of the child's naris or pinky finger.

Participants who wrote the correct formula without indicating that the *sum* of the age and 16 is to be divided by 4 (i.e.,  $age + 16 \div 4$ ) were given credit for having the correct answer, even though performing the calculation as written would yield an incorrect response (e.g., an ETT size of 10 for a 6-year old child). Providers were not questioned on the alternative means of determining ETT size because such estimations are considered backup methods when age is unknown and, in our question, the child's age was given.

The correct response to the question was that a 5.5-mm internal diameter ETT is the appropriate size for a 6-year old child. Responses less than 5.0 or greater than 6.0 were considered significant errors.

## Completion Time

The time for each individual to complete the questionnaire was recorded by the investigators.

## RESULTS

## Participants

Between June and November 2006, the investigators attended 24 ALS continuing education classes in the

participating jurisdictions. The number of participants in the unaided group totaled 277, and the number in the aided group totaled 246. These percentages of providers trained at the various ALS levels were compared with the total number of ALS-level providers in the state in 2006 based on available MIEMSS data. We believe the difference between the state percentages and those of the study group reflects a trend in the participating major metropolitan fire and EMS departments to dual train personnel in fire suppression and EMS (with most providers being trained to the ALS Emergency Medical Technician–Intermediate [EMT-I] level, as distinct from career paramedics, who are more likely to pursue Emergency Medical Technician–Paramedic [EMT-P] licensure) (Table 2).

The mean lengths of time providers had been certified at their current level of training were 7.7 years in the unaided group and 7 years in the aided group. Providers from the unaided group had spent a mean of 13.1 years as emergency responders, whereas those in the aided group had been emergency responders for a mean of 13.4 years.

Thirty of the responders in the unaided group (10.8%) and 23 in the aided group (9.3%) were RSI-certified.

## Medication Calculations

Medication calculation errors were evaluated for each individual provider and as a percentage of the total question pool (Table 3). The mean individual percentages correct were 65% in the unaided group and 94% in the aided group. Mean percentages correct in the various certification groups are presented in Table 4. The

TABLE 2. Number of Participants Based on EMS Provider Certification Levels

Provider Level	Unaided Group	Aided Group	Overall Study Group	State of Maryland 2006
CRT	7 (2.5%)	8 (3.3%)	15 (2.9%)	277 (9%)
EMT-I	92 (33.2%)	89 (36.2%)	181 (34.6%)	505 (17%)
EMT-P	178 (64.3%)	149 (60.6%)	327 (62.5%)	2,200 (74%)
TOTAL	277	246	523	2,982

CRT = Cardiac Rescue Technician; EMT-I = Emergency Medical Technician–Intermediate; EMT-P = Emergency Medical Technician–Paramedic; EMS = emergency medical services.

percentage of incorrect responses for each question is reported by group in Figure 2.

In the overall pool of questions, 33% of the responses were incorrect in the unaided group, whereas 6.6% of the responses were incorrect in the aided group. Predefined “severe” errors made up 20.9% of the total responses in the unaided group and 4.9% in the aided group. Tenfold errors were committed in 6.2% of the answers in the unaided group, and 0.8% in the aided group. There were ten 100-fold errors in the unaided group (0.4%) and one (0.05%) in the aided group.

A total of 138 questions were missed in the aided group. They are distributed as follows (Table 5):

- Sixteen (11.6%) of the incorrect responses appeared to be a dose listed in an adjacent column.
- Fifty-one (37%) appeared to be calculation errors, based on evidence on the questionnaires’ suggesting that respondents performed their own mathematical calculations.
- Certain questions required respondents to answer either in milligram doses based on a child’s weight or milliliter volumes based on milligram doses. Of the

incorrect responses in the aided group, 33 (27.5%) were answers given in the incorrect unit or incorrect route of administration (e.g., the intravenous [IV] route was indicated when the rectal dose was requested).

- Twenty (14.5%) responses were simply left blank.
- If the type of error could not be identified as one of the above, it was listed as “other.”

### Endotracheal Tube Size Calculations

Respondents were asked two questions on calculation of appropriate ETT size: one about the formula to calculate the appropriate size and the other about a scenario in which the size needed to be calculated.

Of the 523 respondents in the study, 141 (27%) knew the correct formula for calculation of pediatric ETT size. Of the 69 respondents in the unaided group who knew the correct formula, 20 (29%) calculated an incorrect ETT size for a 6-year-old child.

In the aided group, 241 (98%) indicated the correct (5.5 mm) tube size; two more were correct within 0.5 mm; one respondent answered 4.0; and two left the question blank (Table 6). In the unaided group, there

TABLE 3. Individual Scores and Error Results

Measure	Unaided Group	Aided Group	Difference (95% CI, p-Value)
Mean percentage correct	65%	94%	Percentage difference, 28% 95% CI, 25–31 p < 0.001
% Total question errors	775/2,350 (33%)	138/2,106 (6.6%)	Percentage difference, 26.4% 95% CI, 24.2–28.7 p < 0.001
Severe errors	491/2,350 (20.9%)	104/2,106 (4.9%)	Percentage difference, 16% 95% CI, 14–17.9 p < 0.001
Tenfold errors	146/2,350 (6.2%)	16/2,106 (0.76%)	Percentage difference, 5.4% 95% CI, 4.4–6.5 p < 0.001
Hundredfold errors	10/2,350 (0.4%)	1/2,106 (0.05%)	Percentage difference, 0.38% 95% CI, 0.05–0.7 p = 0.025
Correct endotracheal tube calculation	63/277 (23%)	241/246 (98%)	Percentage difference, 75% 95% CI, 69.6–80.9 p < 0.001
Time for completion of questionnaire	11.4 min	7.1 min	Mean difference, 4.3 min 95% CI, 3.7–4.9 p < 0.001

CI = confidence interval.

TABLE 4. Mean Percentage Correct by Provider Type and RSI Certification

Provider Type/Certification	Unaided Group: Percentage Correct	Aided Group: Percentage Correct
CRT	41%	86%
EMT-I	62%	95%
EMT-P	68%	94%
RSI-certified	78%	96%
Non-RSI-certified	64%	94%

CRT = Cardiac Rescue Technician; EMT-I = Emergency Medical Technician-Intermediate; EMT-P = Emergency Medical Technician-Paramedic; RSI = rapid-sequence intubation.

was a wide range of responses. Sixty-three participants (23%) gave the precise 5.5 mm ETT response, and a total of 133 (48%) were within the clinically acceptable range of 5.0 to 6.0 mm.

### Completion Time

The mean times required to complete the questionnaire were 11.4 minutes in the unaided group and 7.1 minutes in the aided group (mean difference, 4.3 minutes; 95% CI, 3.7-4.9).

## DISCUSSION

### Medication Calculations

While the results of this study are encouraging from the perspective of the utility of the code card, the magnitude of calculation errors committed by participants is extremely troublesome. Each provider answered ten to 15 calculation questions; therefore, statistically, the most reliable means of evaluating the results is to look at individual provider scores.

Study participants who did not have access to the code card as an aid were able to answer only 65% of the questions correctly. Even more worrisome is the fact that each question required only a single calculation. In practice, determination of a pediatric medication dose requires a two-step calculation to determine, first, the appropriate dose in milligrams and, second, the appropriate volume of administration in milliliters. An

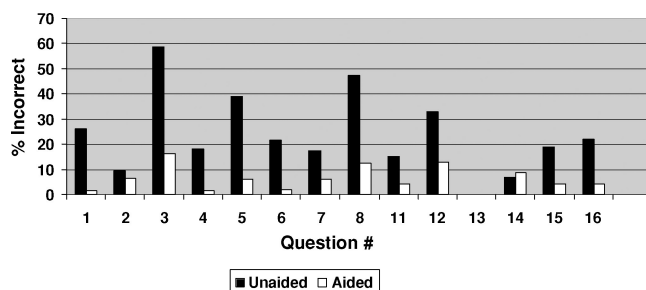


FIGURE 2. Percentage error by question.

TABLE 5. Evaluation of Errors in the Aided Group

Error Type	Number (%)
Calculation	51 (37%)
Wrong route of administration or unit of measure	33 (27.5%)
No response given	20 (14.5%)
Other	18 (13%)
Adjacent column	16 (11.6%)
TOTAL	138

additional calculation may be required to determine a child's weight in kilograms. There is no reliable way to extrapolate our findings to estimate the rate of errors that could be expected in such two- or three-step calculations, but the error rate would likely be compounded in both number and severity. Of potential interest in comparing the results of the unaided group with those of the aided group is the fact that determination of a pediatric dose using the code card involves only a one-step process.

The providers who answered the questions using the code card had a mean score of 94%. Any score less than 100% is arguably unacceptable, despite the fact that this score was significantly better than the score in the unaided group. Of the incorrect responses in the aided group, 11.6% were answers from an adjacent column. As a result of these findings, and in order to reduce visual errors, the code card has been redesigned to have alternate shading of columns.

A few studies have looked at pediatric medication errors in the prehospital setting. Kaji et al. reviewed rates of medication errors in administration of epinephrine prior to and after implementation of a program that required paramedics to use a Broselow tape and report color zone categories to a base station contact before administering medications.<sup>7</sup> Prior to the change in protocol, only 29 of 104 patients (28%) received a correct

TABLE 6. Response to ETT Size Question

ETT Size	Aided Group		Unaided Group	
	Number of Respondents	Frequency	Number of Respondents	Frequency
2.0 mm	0	0	2	0.007
2.5 mm	0	0	1	0.003
3 mm	0	0	15	0.054
3.5 mm	0	0	3	0.010
4.0 mm	1	0.004	30	0.108
4.5 mm	0	0	5	0.018
5.0 mm	1	0.004	55	0.198
5.5 mm	241	0.979	63	0.227
5.75 mm*	0	0	1	0.003
6.0 mm	1	0.004	15	0.054
6.5 mm	0	0	3	0.010
7.0 mm	0	0	2	0.007
8.0 mm	0	0	1	0.003
9.0 mm	0	0	1	0.003
No response	2	0.008	80	0.288

\*This response does not represent an available ETT size. <ETT = endotracheal tube.

epinephrine dose, and only 46 of 104 (44%) received a first dose within 20% of the correct dose. In the same prehospital system, Gausche et al.<sup>8</sup> found a 62% error rate in the pediatric dosing of epinephrine, which is consistent with our findings.

Hubble et al. evaluated the medication calculation skills of practicing paramedics.<sup>9</sup> They found that, similar to other health professionals, practicing paramedics had poor medication calculation skills. Conceptual errors in setting up the problems were more prevalent than mathematical, weight conversion, or unit conversion errors.

The instructions given to providers directed them not to perform any mathematical calculations and to extract all answers from the code card. Analysis of the questionnaires revealed that 37% of the errors in the aided group occurred when providers attempted to perform their own mathematical calculations despite the instructions. Training in the use of the code card (which would certainly be more extensive than the 2-minute introduction used in the study setting), and a change in practice culture compelling providers to use such an aid for every administered medication, would presumably lessen the number of calculation errors observed in the aided group. However, such errors would be extremely difficult to eliminate completely in clinical practice, especially for calculations that the provider perceives to be simple.

In studies of pediatric medication errors, incorrect dosing is the most commonly reported error.<sup>10–15</sup> The most common calculation errors include errors in decimal point placement (including leading and trailing zeros); division errors; tenfold errors, in which either ten times or one-tenth of the appropriate dose is administered; multiplication errors; and weight-based errors, in which patient weight in pounds is mistakenly substituted for weight in kilograms.<sup>12</sup> Miscalculations have been blamed for nearly 55% of all prescribing errors in pediatric patients.<sup>4,16</sup> Perlstein et al.<sup>17</sup> reported that 8% of drug calculations performed by neonatal intensive care unit (NICU) staff were incorrect by a factor of 10. Obviously, when medications with a narrow therapeutic window are administered, the potential for an adverse outcome with calculation errors of this magnitude is much higher.

Of the total responses in our unaided group, 6.2% were tenfold errors, versus 0.8% in the aided group. These results are more difficult to correlate with clinical scenarios because recognition of such significant errors should be more likely in the clinical setting than in the classroom. The potential for errors inherent in pediatric dosing is exacerbated by the fact that drug vials manufactured for adult doses are frequently used.<sup>12,18,19</sup> When these medication vials are used for smaller pediatric patients, what is really an enormous ten- or 100-fold calculation error may appear as a very small volume.<sup>12,18,20,21</sup> Potential adverse drug events have

been identified eight times more often in NICU than in adult inpatients, and the use of off-the-shelf preparations is believed to be a major factor in drug administration errors.<sup>20,21</sup> Chappell and Newman found that nearly one-third of IV medication orders in a neonatal unit required dosing of less than one-tenth of a single drug vial, and several required doses of less than one-hundredth of a vial.<sup>18</sup> In the Maryland Medical Protocols for Emergency Medical Services Providers, proper dosing of midazolam in a newborn would require a dose of one-fiftieth of a vial, whereas proper dosing of atropine in a newborn would require one-hundredth of a multidose vial.<sup>22</sup>

## Endotracheal Tube Size Calculations

The percentage of respondents who knew the correct formula for ETT size calculation was lower than anticipated. However, evaluation of calculation errors by prehospital care providers disclosed that even for those who did know the correct formula to determine ETT size by a child's age, 29% still calculated the incorrect ETT size when they did not have the code card as an aid.

## Completion Time

The time necessary to complete the questionnaire was significantly longer in the unaided group (11.4 minutes) than in the aided group (7.1 minutes). The code card is not intended to be a time-saving device. Obviously, a setting involving a sick or injured child in need of medication is a time-pressured environment. This type of environment is one of the critical factors in the frequency of medication errors in emergency departments.<sup>15,23</sup> The fact that the code card seems to enable providers to determine appropriate medication doses with fewer errors and in a shorter period of time indicates its value as a tool for EMS providers.

## Broselow Tape Use

Although the policy of the Maryland jurisdictions is that each medic unit is to be equipped with a Broselow tape, in practice this stipulation has been difficult to achieve consistently because of cost limitations. The Broselow tape has also become another source of potential medication errors, because it is not specific to the medications or drug vial concentrations used in a particular hospital or prehospital system.<sup>24,25</sup> For example, midazolam is not dosed on the Broselow tape in accordance with Maryland State protocols, which has led to administration errors.

## Limitations and Future Research

The main limitation of this study is that it was performed in a classroom setting. Future research would

help to evaluate the effectiveness of the code card in clinical practice, and determine the best method to implement its use, measure its effect, and perhaps evaluate additional venues for its use.

The clinical significance of pediatric dosing errors for each of the medications used in prehospital care also requires further investigation.

## CONCLUSIONS

With the use of the pediatric code card, prehospital care providers were better able to determine accurate weight-based drug doses, volumes of administration, and ETT sizes than were EMS personnel who did not have access to such an aid. Maryland's version of the pediatric aid provides dosage information based specifically on Maryland ALS protocols and drug vial concentrations, enabling care providers to administer appropriate doses without performing any calculations.

The characteristics of the code card that are considered critical to addressing and minimizing pediatric drug calculation errors in the prehospital setting include its ease of use, small size, affordability, accessibility, and adaptability to any jurisdiction's protocols.

The findings of this study support the use of the pediatric code card as a significant way to minimize pediatric drug administration errors made by prehospital care providers. The data supporting that conclusion are powerful, but the most effective integration of the code card into prehospital systems will likely require changes in practice culture. Medical directors and EMS administrators should stop treating error as a moral issue. They should recognize that while human error is inevitable, it is often latent system flaws that lead to patient harm, not individual errors. When the philosophical changes that now drive patient care improvements in the hospital setting are validated for the world of prehospital medicine, valuable tools such as the pediatric code card will be readily accepted, and emergent treatment of children will benefit.

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