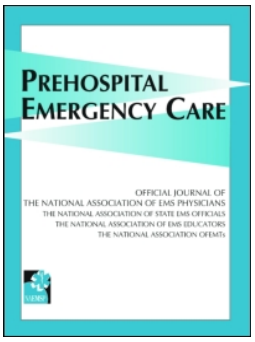

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Comparison of Errors Using Two Length-Based Tape Systems for Prehospital Care in Children

Lara D. Rappaport, MD, MPH, Lina Brou, MPH, Tim Givens, MD, Maria Mandt, MD, Ashley Balakas, RN, BSN, Kelley Roswell, MD, Jason Kotas, NREMT, Kathleen M. Adelgais, MD, MPH

Abstract

Background: The use of a length/weight-based tape (LBT) for equipment size and drug dosing for pediatric patients is recommended in a joint statement by multiple national organizations. A new system, known as Handtevy™, allows for rapid determination of critical drug doses without performing calculations. **Objective:** To compare two LBT systems for dosing errors and time to medication administration in simulated prehospital scenarios. **Methods:** This was a prospective randomized trial comparing the Broselow Pediatric Emergency Tape™ (Broselow) and Handtevy LBT™ (Handtevy). Paramedics performed 2 pediatric simulations: cardiac arrest with epinephrine administration and hypoglycemia mandating dextrose. Each scenario was repeated utilizing both systems with a 1-year-old and 5-year-old size manikin. Facilitators recorded identified errors and time points of critical actions including time to medication. **Results:** We enrolled 80 paramedics, performing 320 simulations. For Dextrose, there were significantly more errors with Broselow (63.8%) compared to Handtevy (13.8%) and time to administration was longer with the Broselow system (220 seconds vs. 173 seconds). For epinephrine, the LBTs were similar in overall error rate (Broselow 21.3% vs. Handtevy 16.3%) and time to administration (89 vs. 91 seconds). Cognitive errors were more frequent when using the Broselow compared to Handtevy, particularly with dextrose administration. The frequency of procedural errors was similar between the two LBT systems. **Conclusion:** In simulated prehospital scenarios, use of the Handtevy LBT system resulted in fewer errors for dextrose administration compared to the Broselow LBT, with similar time to administration and accuracy of epinephrine administration. **Key words:** pediatrics; medication errors; emergency medical services

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LDR, MM, TG, and KMA conceived the study, designed, obtained the necessary approvals, and supervised the conduct of the study and data collection. LDR, AB, JK, and KR assisted with recruitment of participants and data collection. LB and KMA provided the statistical analysis. LDR, LB, and KMA drafted the article and all authors contributed in the revision. LDR takes responsibility for the paper as a whole.

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Introduction

Successful resuscitation of a critically ill or injured child requires a systematic approach, a practiced skill set, and accurate medication dosing. Prehospital providers have numerous challenges that increase the risk for medication errors when caring for their pediatric patients. They infrequently encounter seriously ill or injured children resulting in both a lack of confidence in caring for children and an erosion of their medical knowledge and skills.[1–11] Furthermore, prehospital providers have fewer support mechanisms compared to hospital emergency departments, such as pharmacist cross-checking, automated drug dispensing, or computerized order entry. Given that such expertise is hard to maintain, several studies have illustrated the high frequency of medication errors in pediatric patients in the prehospital setting.[12–14]

A joint policy statement on equipment for ambulances recommends the use of a length/weight-based tape (LBT) or appropriate reference material for pediatric equipment sizing and drug dosing based on known or estimated weight in optimizing prehospital care delivery.[15] The Broselow Pediatric Emergency Tape™ (Broselow) uses pre-calculated weight-based medication doses based on patient length and matched to a color-coded system.[16] Its use by paramedics to determine patient weight has been shown to correlate well with emergency department Broselow-determined weight and actual scale weight.[17–19]

IMPORTANCE

Although the use of LBTs is recommended and widely practiced, a high rate of error persists when administering medications to children in the prehospital setting.[12,13] Initial studies demonstrated that the Broselow system has improved the frequency of certain medication errors.[20,21] However, there are challenges with its use, including difficulties with calculations under stress and medication conversion errors.[19] Recently developed by Pediatric Emergency Standards, the Handtevy™ LBT system (Handtevy) has a customized pre-printed medication guide based on the formulary specific to each agency or system.[12] This guide provides the recommended weight-based dose along with the calculated volume of medication that should be administered.

The goal of this investigation was to compare the differences in frequencies of medication errors and time to medication administration between the Handtevy and Broselow LBT systems in simulated prehospital pediatric scenarios.

METHODS

Study Design and Setting

This was a prospective, randomized trial comparing the Broselow Pediatric Emergency Tape to the Handtevy length-based tape and system developed by Pediatric Emergency Systems (Handtevy).[22] A specifically designed Handtevy guide (Appendix A) and the Broselow LBT (2011, Edition A) were used for our study. Participants performed two low-fidelity simulation scenarios: 1) cardiac arrest with epinephrine administration and 2) altered mental status with hypoglycemia mandating dextrose administration. Participants repeated each scenario utilizing both LBT systems, alternating in size of manikin (either 1 year or 5 years of age) to prevent memorization of dose. The randomization was such that the order of the scenarios was independent for each participant. Each scenario was performed in a room equipped with a calculator, pen and paper for calculations, each LBT system, manikin, medications, needles, syringes, and a clock. Study participants performed the scenarios on an individual basis and were independently responsible for all actions necessary to administer the medication. During the simulation scenarios using standardized data collection sheets, a trained facilitator monitored each participant individually as they utilized the LBT to identify, calculate, prepare, and administer the medication. The facilitators each participated in three training sessions on how to observe and record errors and times. All facilitators were paramedic educators or pediatric emergency physicians.

Immediately prior to the simulations, the study participants were oriented to both LBT systems. The participants were instructed to use the zone color drug dose on the Broselow and the blue column precalculated mL dose corresponding to the patient's color and age in the Handtevy book based on their measurement of the manikin with the LBT. Before the scenarios, study participants completed a baseline questionnaire providing demographic information. Following the scenarios, they completed a survey reporting their perceptions on ease and efficiency of the systems.

Scenario Development and Pilot Testing

Study investigators (LDR, KMA, AB, MM) developed scenarios and predetermined expected actions. The clinical scenarios were chosen based on prior research identifying high rates of errors in medication administration for both epinephrine and dextrose.[12,13,20,23] An intravenous catheter connected to a syringe via primed tubing was attached to each manikin allowing for measurement of volume of medication administered during the scenario (Appendix B). Participants were instructed that the syringe was present to minimize leakage and were not told that the volume of medication would be measured. For the cardiac arrest scenario, two concentrations of epinephrine were available: 1:1000 and 1:10,000. For the hypoglycemia scenario, D_{50} ampules and saline were provided for dilution. Based on the size of the manikins, the expected action was the administration of 1:10,000 epinephrine or D_{25}. The scenarios were initially piloted with 4 prehospital providers in a study setting and resulted in changes to the data collection sheets for more accurate assessment of medication preparation and to standardize times measured during the scenarios. Scenario descriptions are provided in Appendix C.

Selection of Participants

Study subjects eligible for enrollment were licensed ALS paramedics employed by two local fire department agencies. These two agencies provide services to a combined population of 450,000. All participants obtained prior certification in either Pediatric Advanced Life Support (PALS)[24,25] or Pediatric Education for Prehospital Professionals (PEPP).[26] The Broselow LBT is the standard used for both agencies. The Colorado Multiple Institutional Review Board (COMIRB) approved this study.

Outcome Measures

Demographic Measurements

We utilized a survey tool to obtain demographic information and to assess the number of pediatric resuscitations in the past year, time from most recent use of the LBT, and most recent pediatric continuing education course. We assessed baseline comfort with both LBT systems using a Likert scale. After completion of the scenarios, we surveyed study participants about which LBT system they perceived as faster and more accurate.

Error Measurements

We defined an error as either the administration of doses exceeding +/− 20% of a predetermined correct dose or the administration of the wrong concentration of medication. The expected dose to be administered was based on the color zones on both the Handtevy and Broselow tapes corresponding to the length of the manikins. Each color zone has a single dose for the indicated weight range. The colors on both LBTs systems were purple (10–11 kg) and blue (19–22 kg) for the 1-year-old and 5-year-old manikins, respectively. Study investigators (KMA, TG, AB, MM) classified types of errors via a review of the data collection sheets. Errors were classified into 3 categories: cognitive, affective, or procedural.[13,27,28] Cognitive errors were defined as any inaccuracy in a mental calculation, choosing the incorrect concentration, and milligram per kilogram to milliliter conversion errors. Procedural errors included incorrect use of the tape, failure to make or dilute the medication correctly, pushing the incorrect volume of medication, and/or any accidental finger stick with the needle. Affective errors were defined as those occurring due to stress of the participant. To assess the inter-rater reliability for our method of classifying type of error, a separate study investigator (LR) reviewed 20% of the scenarios. Due to poor inter-rater reliability for affective errors, we eliminated this outcome from further analysis.

Time Measurements

Time points were measured from time 0, defined as time the participant verbally indicated the medication he or she would like to administer after hearing the scenario. We defined time to measure with the LBT as the time it took for the participant to identify and verbalize the weight, color, or age on the LBT. We defined the time to identifying the dose as the time it took for the participant to identify and verbalize the dose either on the Broselow LBT or in the accompanying page in the Handtevy LBT system booklet coordinating to the color of the manikin on the tape. We also recorded times in cases where the participant verbalized the concentration and the anticipated volume of medication. Lastly, we recorded the time to administration of the dose of medication, defined as the total time from the verbal declaration of the medication to the actual pushing of the drug. Time points were recorded and analyzed in seconds. For each scenario, participants were given a maximum of 10 minutes to administer the medication. If a participant failed to administer the medication within the 10 minutes, the scenario was stopped and it was documented that no medication was administered.

Our primary outcome was the relative risk of an error in the administration of the dose of medication during the scenario, comparing the Handtevy LBT to the Broselow LBT. We stratified by type of scenario and medication (cardiac arrest with epinephrine and hypoglycemia with dextrose). We compared each system by type of errors (cognitive and procedural) stratified by type of scenario. We also compared the two LBT systems on all time points, again stratified by scenario type. Our secondary outcome was the time to medication administration.

Primary Data Analysis

All data were collected on standardized data collection sheets. Study data were then transcribed into REDCap (Research Electronic Data Capture), a secure web-based application designed to support data capture of research studies hosted at the University of Colorado, Denver.[29] Data were then exported into SAS (Version 9.3, SAS Institute, Cary, NC) for analysis.

We performed a sample size calculation on the basis of medication error rate. Assuming an error rate of 50%, we determined that a sample size of 78 subjects would achieve 90% power to detect a relative risk of 5 using a two-sided McNemar test with a significance level of 0.05.

For our primary outcome, we calculated the relative risk of an error in medication administration when using the Broselow tape compared to the Handtevy tape stratified by medication administered. We performed an adjusted analysis controlling for age of patient in each scenario and whether it was the participant's first or second attempt at the scenario as these factors may contribute to the likelihood of an error. We also analyzed the likelihood of an error based on whether that first or second attempt was utilizing the Broselow or the Handtevy LBT. We calculated relative risk to identify the likelihood of the type of error by LBT and type of medication. We also analyzed the effect of manikin size on the type of error.

For time data, we calculated medians with interquartile ranges. We compared times by medication administered, age of patient in scenario, and LBT using Wilcoxon rank sum test due to the non-parametric distribution of time. We performed a sensitivity analysis

TABLE 1. Characteristics of study participants*

Characteristics ($n = 80$)	n (%)
Male	71 (90)
Race	
White	74 (92)
Full Time	80 (100)
Last Pediatric Refresher Course	
Within the last year	59 (74)
1–5 years ago	17 (21)
> 5 years ago	5 (4)
Last time length-based tape was used	
Within the last year	54 (68)
1–5 years ago	21 (27)
> 5 years ago	4 (5)
Comfort with Broselow Tape	
Not At All	5 (6)
Somewhat Uncomfortable	11 (13)
Comfortable	58 (73)
Very Comfortable	6 (8)
Comfort with Handtevy System	
Not At All	74 (92)
Somewhat Uncomfortable	2 (2)
Comfortable	3 (5)
Very Comfortable	1 (1)

*Response rate: 100%.

to measure the impact of error on time of medication administration.

RESULTS

Characteristics of Study Subjects

Eighty subjects participated in 320 simulation sessions over a 6-month period. Demographic characteristics and survey responses are listed in Table 1. Prior to participation in the study, on a scale of 1 to 4, the median comfort level reported with the Broselow Pediatric Emergency Tape was 3 (Comfortable) compared to the baseline comfort level reported with the Handtevy System of 1 (Not at All Comfortable).

Frequency of Errors

Overall, there were 28.4% of scenarios with an error resulting in the administration of an incorrect dose of medication. The frequency and risk of errors stratified by LBT type and medication are shown in Table 2. The use of Broselow LBT resulted in significantly more errors during dextrose administration (63.8%) when compared to Handtevy (13.8%)(RR 4.7 95% CI 2.7, 8.4). This difference was not found with epinephrine; however, there was a 21.3% error rate with Broselow and 16.3% with Handtevy (RR 1.2, 95% CI 0.7, 2.4). When adjusting for age of the manikin and whether it was a first or second attempt at the scenario, the overall risk of an error was relatively unchanged, specifically for an epinephrine error (aRR 2.9, 95% CI 1.2, 7.4) and for a dextrose error (aRR 4.5, CI 95% 2.5, 8.1).

TABLE 2. Adjusted analysis relative risk in medication dose with length base tape as exposure, Handtevy as reference group

	Error N (%)	RR (95% CI)	aRR* (95% CI)
Broselow ($n = 160$)	68 (42.5)	2.8	3.0
Handtevy ($n = 160$)	24 (15.0)	(1.8, 4.2)	(2.0, 4.6)
Stratified by medication	Error N (%)	RR (95% CI)	aRR¶ (95% CI)
Epinephrine			
Broselow ($n = 80$)	17 (21.3)	1.2	2.9
Handtevy ($n = 80$)	13 (16.3)	(0.7, 2.4)	(1.2, 7.4)
Dextrose			
Broselow ($n = 80$)	51 (63.8)	4.7	4.5
Handtevy ($n = 80$)	11 (13.8)	(2.7, 8.4)	(2.5, 8.1)

*Adjusted for medication, attempt and age, ref: Handtevy.
¶Adjusted for attempt and age, ref: Handtevy.
RR = Relative Risk; aRR = Adjusted Relative Risk.

Table 3 demonstrates the frequency of making a particular type of medication error stratified by LBT system. Overall, the LBT was used incorrectly in approximately 9% of scenarios with no difference between Handtevy and Broselow. Procedural errors and cognitive errors associated with dextrose administration were higher when using the Broselow LBT compared to the Handtevy LBT. Specifically, we found errors with dilution, during mental calculation, and when choosing the appropriate concentration. There were no differences in the type of errors (cognitive or procedural) for epinephrine administration between the two LBTs. Pushing the incorrect volume was the most common procedural error with no difference between Broselow and Handtevy.

We found that in 6.3% of scenarios with epinephrine administration, the manikin received between 5 and 10 times the recommended dose. For under- or overdosing of epinephrine, there was no significant difference between Broselow (10.0%) and Handtevy (6.3%). In contrast, we found in the majority of scenarios with dextrose administration, there was an under-dose and that these were almost exclusively in cases where the Broselow LBT was used (42/50 scenarios, 84%). Among all the scenarios, we did have 4 cases (1.2%) in which no medication was given due to the participant's stress and anxiety during the scenario. There were no missed doses due to going over the allotted time for the scenario.

Time Analysis

A comparison of time points to expected actions recorded by the facilitators during the scenarios is shown in Table 4. There was no difference in time to measurement with the LBT and time to verbalizing the concentration of medication. For both

TABLE 3. Frequency of types of errors between medications stratified by length based tape type

Error Type*	Epinephrine n (%) Handtevy N = 80	Epinephrine n (%) Broselow N = 80	Epinephrine n (%) Total N = 160	Dextrose N (%) Handtevy N = 80	Dextrose N (%) Broselow N = 80	Dextrose N (%) Total N = 160
Procedural	21 (26.3)	23 (28.8)	44 (27.5)	15 (18.7)	31 (38.6)	46 (28.8)
Incorrect use of Tape	7 (8.7)	13 (16.3)	20 (12.5)	4 (5.0)	5 (6.3)	9 (5.6)
Failure to dilute correctly	0 (0)	1 (1.3)	1 (0.6)	6 (7.5)	12 (15.0)	18 (11.3)
Pushed wrong dose even though calculated correctly	15 (18.8)	12 (15.0)	27 (16.9)	9 (11.3)	14 (17.5)	23 (14.4)
Cognitive	8 (10)	6 (7.5)	14 (8.8)	13 (16.3)	57 (71.3)	79 (43.8)
Faulty recall of dose	0 (0)	0 (0)	0 (0)	0 (0)	16 (20.0)	16 (10.0)
Unaided calculation	0 (0)	0 (0)	0 (0.0)	6 (7.5)	32 (40.0)	38 (23.8)
Faulty recall of dose	0 (0)	0 (0)	0 (0)	0 (0)	16 (20.0)	16 (10.1)
Wrong mg/kg dose for route	0 (0)	1 (1.3)	1 (0.6)	0 (0)	0 (0)	0 (0)
Mg/kg to mg calculation error	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.3)	1 (0.6)
Mg to ml conversion error	3 (3.8)	1 (1.3)	4 (0.3)	2 (2.5)	17 (21.3)	19 (11.8)
Confusing mg with mL on syringe	0 (0)	0 (0)	0 (0)	5 (6.3)	4 (5.0)	9 (5.6)
Chose wrong concentration	5 (6.3)	3 (3.8)	8 (5.0)	2 (2.6)	25 (31.3)	27 (16.9)

*Kappa Values with 95% Confidence Interval: Procedural error K = 0.45 (0.23–0.67); Cognitive Error K = 0.65, (0.46–0.83); CI = Confidence Interval; mL = milliliters; mg = miligrams; kg = kilograms.

medications, time to identify the recommended dose was different; however, there was no clear pattern between LBT systems or medications. In addition, there was no difference in time to medication administration for epinephrine. However, we did find a difference in time to medication administration between the two LBT systems in scenarios where dextrose was administered (Figure 1).

Finally, we examined the time differences between correct and incorrect doses (Table 5). We found that for epinephrine, it took less time to administer a correct dose compared to an incorrect dose. This was true with both LBT systems. In contrast, we found that it took longer to administer a correct dose of dextrose compared to an incorrect dose independent of LBT system used.

Provider Satisfaction

In a post-participation survey, the majority of study participants (91%) indicated that they preferred the Handtevy to the Broselow system. The majority also perceived the Handtevy LBT system as easier (98%), faster (91%), and more accurate (88.2%).

DISCUSSION

Recent Institute of Medicine Reports concerning the care of pediatric patients and the training of emergency medical service providers identified significant gaps in the care of children in the prehospital environment, particularly in the area of safety.[4,30,31] Few prehospital studies have examined medication errors in pediatric patients; however, although the numbers of medication errors in the adult population are discouraging, the potential for error in the pediatric prehospital patients is much greater.

In children, medication-dosing errors are linked to accurate estimation of weight. Several studies have shown that weight estimation based upon parental report or an experienced provider is highly inaccurate.[32–34] The American Heart Association (AHA) recommended in 2010 that providers use a length-based tape with pre-calculated drug doses if the child's weight is unknown and it is recommended on the joint statement *Equipment List for Ambulances*.[15,25] The Broselow Pediatric Emergency Tape™ has been widely used and accepted in both the hospital and prehospital arenas.[16] Early studies demonstrated that the system drastically reduced

TABLE 4. Comparison of time to expected actions by length-based tape stratified by medication administered

Time to Action	Dextrose Handtevy n = 80	Dextrose Broselow n = 80	Dextrose Wilcoxon p-value	Epinephrine Handtevy n = 80	Epinephrine Broselow n = 80	Epinephrine Wilcoxon p-value
Measures with LBT median seconds (95%CI)	13 (11, 16)	15 (12, 17)	0.13	12 (11, 14)	13 (12, 15)	0.56
Determines Dose median seconds (95%CI)	37 (31, 42)	45 (40, 55)	0.02	33 (30, 40)	29 (26, 33)	0.04
Verbalizes Concentration median seconds (95%CI)	25 (21, 30)	52 (28, 62)	<0.001	24 (20, 25)	20 (15, 24)	0.10
Administer Dose median seconds (95%CI)	173 (160, 185)	220 (205, 243)	<0.001	89 (78, 100)	91 (81, 100)	0.65

LBT = Length Based Tape.

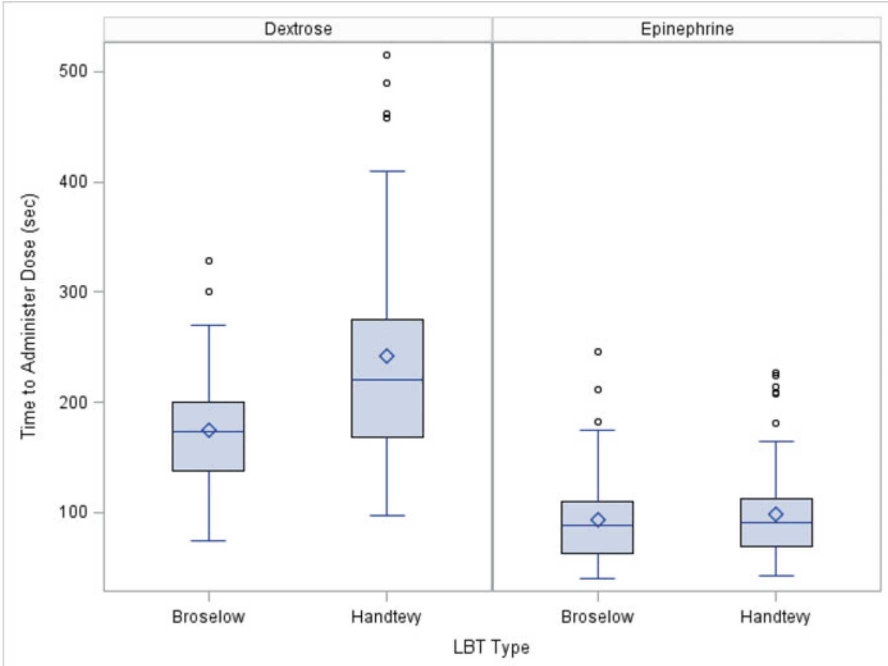

FIGURE 1. Time to dose administration by LBT type and medication type. LBT = Length-based tape; sec = seconds. Median-central line of the box, Mean-diamond, 25th percentile-bottom edge of box, 75th percentile-top edge of box, 1.5(IQR)-whiskers, Outliers-small squares.

errors.[20] Other studies have noted difficulties with its use, such as performing calculations under stress and conversion of milligram per kilogram to milliliters.[12] The Handtevy system is another system that offers pre-calculated drug dosing and volume based upon patient length. In our randomized trial comparing the Broselow and Handtevy LBT systems for errors and time to medication delivery, we found a significant decrease in errors when using the Handtevy system for administration of dextrose while preserving time and accuracy for epinephrine administration.

Providers face known challenges when using LBTs. One report examining use of the Broselow LBT describes multiple errors including incorrect (e.g., upside down) or inadequate (tape placed correctly on bed next to patient then not used to obtain dose information) use of the tape.[35] Their conclusion was that this was due to inconsistent use of the tape and inadequate training on the tape. Lammers et al.[13] found that among EMS crews who used the LBT in their simulation scenarios; 5.7% used it incorrectly. In their study, an additional 13% did not even attempt to use the tape. Follow-up focus groups identified that infrequent use was one reason providers did not think to use it when in their simulation scenario.[13] In our study all participants were instructed to use the tape, and we found a slightly higher frequency of measuring with the tape incorrectly (overall 8.7%), with no real difference between the Broselow and Handtevy systems. Because our participants performed repeated scenarios, we adjusted for whether it was their first or second attempt at the scenario during our analyses to ensure no confounding. Ultimately, we did not find any significant improvement in accuracy related to the order of their simulation participation.

Overall, we found no difference in frequency or type of errors with epinephrine administration when comparing Handtevy to Broselow. Hoyle et al. found medication dosing errors in 34.7% of pediatric drug administrations.[12] Specifically, the investigators found high rates of error in epinephrine administration; 60% overall among which 80% were overdoses.[12] Kaji et al. found that even after a cognitive educational intervention and practice change mandating prehospi-

TABLE 5. Comparison of time to medication by correct versus incorrect

	Handtevy			Broselow		
LBT Medication	Correct	Incorrect	Difference	Correct	Incorrect	Difference
Epinephrine median, sec (95% CI)	84 (74, 95)	104 (77, 123)	−20	86 (77, 94)	95 (84, 143)	–9
Dextrose median, sec (95% CI)	177 (160, 185)	143 (121, 200)	34	225 (203, 300)	217 (197, 247)	8

sec = seconds; CI = Confidence Interval; LBT = length based tape.

tal use of the Broselow tape and reporting the corresponding color-coded zone to the base station, correct epinephrine dosing improved to only 57% in cases of pediatric cardiopulmonary arrest.[20] In a setting similar to our study, Lammers et al. found that only 31% of paramedics gave the correct volume of epinephrine when performing a simulation-based assessment of pediatric skills.[3,31] Hubble et al. found that due to suboptimal education and infrequent practice, paramedics often were unable to correctly convert milligram doses to milliliter volume of the appropriate concentration of epinephrine for administration.[36] Our reported errors are overall much lower than those previously reported. The Broselow LBT does state the dose and concentration for epinephrine in milligrams and milliliters, thereby eliminating the need for calculations. Of note, the majority of study participants also partook in a pediatric resuscitation refresher course that focused on administration of epinephrine in pediatric cardiac arrest.

Our study emphasized dextrose administration by paramedics to younger children. Since we had simulation scenarios for 1- and 5-year-old patients, the expected actions were not only to choose the correct concentration of dextrose, but also to accurately dilute D_{50} to make D_{25} and give the correct volume of medication for the estimated weight. In fact, the *Equipment for Ground Ambulances* list includes D_{50} for the ALS portion with the recommendation for sterile dilutent to make D_{25} for pediatric patients.[15] The Broselow LBT version used in our study provides instructions for diluting D_{25} at the tip of the tape; however, it does not indicate the appropriate concentration based on estimated age or weight. Additionally, the dosage is stated in grams, requiring the provider to recall the correct concentration and perform additional calculations prior to administering the dose. As a result, we found that errors were significantly more frequent when using the Broselow LBT compared to the Handtevy LBT. Only two prior studies examined errors associated with dextrose administration. Hoyle's study identified a 50% error rate with dextrose administration, but there were only 4 total doses given.[12] Lammers et al. found that 94% of prehospital providers gave an incorrect dose of D_{25}.[13] Of note, we found in our study that the majority of significant errors resulted in under-dosing of dextrose. For patients with symptomatic hypoglycemia, this would have more significant clinical implications than overdosing.

We attempted to classify the error type as a way to explore potential causes of the medication error. With this information, we may be able to examine some of the reasons for differences in error frequency between the two systems. A better understanding of the type of errors that occur also provides essential information to EMS educators for training and competency assessment. We used similar methods for error classification as done in prior studies of simulations with prehospital providers.[3,13,27,28] The most commonly reported error types in pediatric medication administration are cognitive errors.[37–41] These errors include mistakes with decimal point placement, division errors, and weight-based errors where weight in pounds is substituted for weight in kilograms.[36,42] Our study showed the scenarios with dextrose had the highest numbers of cognitive and procedural errors. In the studies by Lammers, there were many errors associated with stress including difficulty performing calculations and administering the wrong volume of medication.[14,23] Although we did see some suggestions of errors due to stress (participants walking out of the room in frustration and accidental needlesticks), we did not have a reliable way to measure this type of error and, therefore, future study is needed to examine the effect of stress on errors.

We did find some differences in time to medication between the two LBT systems. Fineberg et al. showed that a standardized volume/weight-based dose reformulation tool reduced time to medication delivery by greater than 50% in clinical scenarios.[43] This study was too small to draw any conclusions about dosing error rate. In contrast, our study had the statistical power to evaluate time and error differences.[43] Our study found no difference in time to medication administration between the two LBT systems for epinephrine. We found that when participants used either the Broselow or Handtevy for dextrose, an incorrect dose was given more quickly than a correct dose. This was likely secondary to the increased complexity and time-consuming nature of diluting and administering a correct dose of dextrose.

The Handtevy system does have some inherent limitations. The booklet is customized and therefore, if an agency makes changes to its formulary, then a revised version must be obtained from the manufacturer at some financial cost. Given the need for some turnaround time, agencies will also need to anticipate these changes to ensure they have updated booklets available to their providers.

Our study has certain limitations. First, it was simulation-based and our results may not be indicative of the true out-of-hospital performance of paramedics. We enrolled participants as individuals and not as members of teams, which does not reflect real-life circumstances. We were also unable to account for possible benefits of teamwork such as the ability to verify decisions made by team members. We did find some instances in which there was an attempt at self-correction by a participant but this was relatively rare (1% of scenarios). In addition, both EMS systems used the Broselow LBT prior to the initiation of the study and the majority of study participants also partook in a pediatric resuscitation refresher course 6 months prior the study that focused on administration of epinephrine in pediatric cardiac arrest. We do not know if this familiarly with the Broselow system and with epinephrine biased the study.

We did not videotape the simulation exercises, but instead relied on recording of paramedic actions and times by study facilitators when assessing performance. We did assess inter-rater reliability in reviewing the data collection forms to classify types of error to mitigate against possible misclassification. We found good inter-rater reliability for cognitive errors and fair inter-rater reliability for procedural errors (Table 3). In 4 scenarios, no medication was given due to participant anxiety; however, a true assessment of errors due to stress could not be examined given poor inter-rater reliability for this measurement. The assessment of error type in this study was exploratory and further study is needed to better examine the nature of how these types of errors contribute overall to medication administration errors in the prehospital setting. Although there was a statistical difference in time to administration of the medications, we acknowledge that these times are not clinically relevant.

CONCLUSION

In summary, our study demonstrates that the Handtevy LBT system, a standard volume-weight system, is superior to the Broselow LBT in terms of error rate and time to achieving the correct dose for dextrose in prehospital simulation scenarios. We found no difference between the performance of prehospital providers in using the Handtevy and Broselow systems in terms of time to and error rate of epinephrine administration. Post-scenario surveys of study participants identified a strong preference for the Handtevy system over the Broselow tape, despite their initial relative unfamiliarity with the Handtevy system.

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APPENDIX A.

Example of Handtevy Guide Correlating to 4 KG (Newborn) Year Old or Grey Length on Tape

Option 1 -USE ACTUAL AGE (IF STANDARD SIZED CHILD)
Option 2 -ESTIMATE AGE USING HANDTEVY LENGTH BASED TAPE (HEAD TO HEEL)

NB

PINELLAS COUNTY EMS — 4 KG IDEAL WEIGHT

DRUG	CONC	VOL	RT	DOSE/KG	AMOUNT
Adenosine [1st]	6 mg/2 mL	0.13 mL	IV	0.1 mg/kg	0.4 mg
Adenosine [2nd]	6 mg/2 mL	0.27 mL	IV	0.2 mg/kg	0.8 mg
Albuterol	2.5 mg/3 mL	1.5 mL	NEB	Dose =	1.25 mg
Amiodarone	150 mg/3 mL	0.4 mL	IV	5 mg/kg	20 mg
Atropine	1 mg/10 mL	1 mL	IV	Dose =	0.1 mg
Bicarb 4.2%	(Dilute 8.4% 1:1 NS)	8 mL	IV	1 mEq/kg	4 mEq
Calcium Chloride	1 g/10 mL	0.8 mL	IV	20 mg/kg	80 mg
Dextrose 10% in Water	25 g/250 mL	20 mL	IV	0.5 g/kg	2 g
Diazepam IV	10 mg/2 mL	0.08 mL	IV	0.1 mg/kg	0.4 mg
Diazepam PR	10 mg/2 mL	0.4 mL	PR	0.5 mg/kg	2 mg
Diphenhydramine	50 mg/mL	0.08 mL	IV/IM	1 mg/kg	4 mg
Dopamine	400 mg/250 mL	1 gtt/min	IV	Titrate to BP: Max 4 gtt/min	
Epinephrine 1:1,000 IM	1 mg/mL	0.04 mL	IM	0.01 mg/kg	0.04 mg
Epinephrine 1:10,000 IV	1 mg/10 mL	0.4 mL	IV	0.01 mg/kg	0.04 mg
Fentanyl Intranasal	250 mcg/5 mL	0.18 mL	IN	1 mcg/kg	4 mcg
Fentanyl IV	250 mcg/5 mL	0.04 mL	IV	0.5 mcg/kg	2 mcg
Glucagon	1 mg/mL	0.5 mL	IV/IM	Dose =	0.5 mg
Glucose (oral)	15 g/pouch	N/A	PO	Not Indicated	
Ipratropium Bromide	0.5 mg/2.5 mL	1.25 mL	NEB	Dose =	0.25 mg
Magnesium Sulfate	1 g/2 mL	0.4 mL	IV	50 mg/kg	200 mg
Methylprednisolone	125 mg/2 mL	0.13 mL	IV	2 mg/kg	8 mg
Midazolam Intranasal	10 mg/2 mL	0.26 mL	IN	0.2 mg/kg	0.8 mg
Midazolam IV/IM	10 mg/2 mL	0.08 mL	IV/IM	0.1 mg/kg	0.4 mg
Morphine	10 mg/mL	0.04 mL	IV	0.1 mg/kg	0.4 mg
Morphine	4 mg/mL	0.1 mL	IV	0.1 mg/kg	0.4 mg
Naloxone	2 mg/2 mL	0.4 mL	IV/IM	0.1 mg/kg	0.4 mg
Naloxone Intranasal	2 mg/2 mL	1 mL	IN	Dose =	1 mg
Normal Saline Bolus	0.9%	40 mL	IV	10 mL/kg	40 mL
Ondansetron IV	4 mg/2 mL	1 mL	IV	Dose =	2 mg
Ondansetron ODT	4 mg/tab	N/A	PO	Not Indicated	

PHILIPS MRx	JOULES/KG	1ST	2ND	3RD	4TH
Defibrillation	2 → 4 → 6 → 10	8	15	20	50
Cardioversion	0.5 → 1 → 2 → 2	2	4	8	8

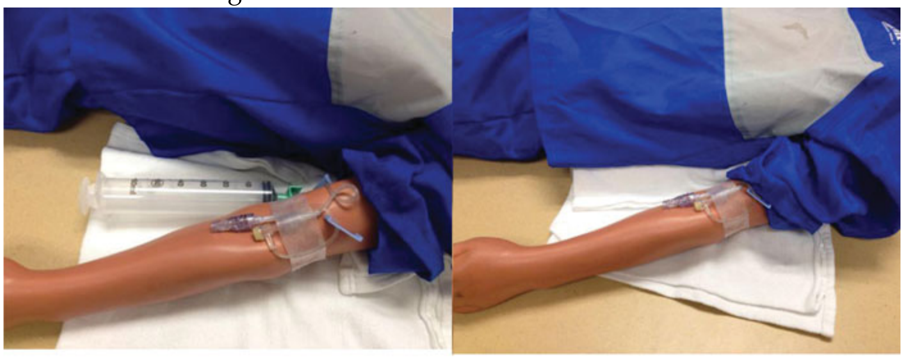
ET TUBE	DISTANCE AT LIP
2.5 Uncuffed / 3.0 Cuffed	3 KG: 9-9.5 cm 4 KG: 9.5-10 cm 5 KG: 10-10.5 cm

VITALS	SBP	60 - 100	HR	100 - 160	RR	30 - 60

DRAFT

APPENDIX B

Syringe Placement on Manikin during Scenarios



Syringe primed with fluid along tubing

Hidden from view during scenario

APPENDIX C

Cardiac Arrest and Altered Mental Status Scenarios with Expected Actions and Measurements

Scenario Description	Expected Actions	Outcome Measurements (seconds, accuracy)
"You are dispatched to a single family home where a *X*-year old male has been found down and unresponsive. Police and another one of your units are on scene and have declared the scene safe. The mother of the child is being questioned in another room and members of your team have already initiated resuscitation efforts. One of your partner's has established a secure airway and is bagging the patient with 100% oxygen. Another partner is performing quality chest compressions and has established a patent IV. The patient is on a cardiac monitor and during the last rhythm check, asystole was noted. What medication do you want to give?"	Measure with LBT	Red to head 1-year-old: color Purple 5-year-old: color Blue
	Determine dose on LBT (Broselow) or in guide (Handtevy)	1-year-old: 1 mg epinephrine 5-year-old: 2 mg epinephrine
	Choose correct concentration of Epinephrine	1:10,000 Epinephrine
	Draw up appropriate dose in syringe and administer	1-year-old: 0.8-1.2 mL 5-year-old: 1.6-2.4 mL
"You are dispatched to a local daycare. The daycare director brings you to the back room where a *X*-year old boy is lying on the ground. The patient's teacher reports that the child was acting strange and became lethargic during story time. The patient is awake but appears listless. He has a patent airway and when you obtain IV access, he does not respond much. Your partner obtains a set of vitals: HR 100, BP 100/68, RR 20, Pulse Ox 98% on 2 L NC and tells you his BGL is 30. What medication do you want to give?"	Measure with LBT	Red to head 1-year-old: color Purple 5-year-old: color Blue
	Determine dose on LBT (Broselow) or in guide (Handtevy)	1-year-old: 5 g Dextrose 5-year-old: 10 g Dextrose
	Identify correct concentration of Dextrose	D_{25}
	Prepare correct concentration of Dextrose	Dilution of D_{50} 1:1 with NS to make D_{25}
	Draw up appropriate dose in syringe and administer	1-year-old: 16–24 mL 5-year-old: 36–48 mL