RESEARCH ARTICLE

The electronic Pediatric Emergency Ruler - A digital alternative to the BroselowTape

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Abstract

Study objective: The Broselow® tape (BT) is a pediatric emergency tape (PET) supporting medical teams during pediatric emergencies in estimating body weight, recommending drug dosage and medical equipment. Publications have reported the risk of incorrect use and low accuracy. A recently published digital algorithm for length-based body weight estimation showed higher accuracy for weight estimation. A prototype for an electronic Pediatric Emergency Ruler (ePER) utilizing this algorithm was developed for further testing. The aim of this study was to compare the BT with the ePER in terms of time and correctness of identifying medical information required during pediatric emergency treatment.

Methods: Voluntary participants were randomly assigned to use the BT or the ePER in a simulated low-fidelity pediatric emergency manikin scenario and instructed to identify four parameters. Outcomes were time required for identification of all parameters, correct determination of length-based weight and erroneous reading of parameters for the selected weight category. Data are mean or percent. T-test for statistical significance ($p < 0.05$) and standardized mean difference (SMD > 0.8) were calculated.

Results: Identifying medical information was significantly faster with the ePER than with the BT (24.5 vs 36.7 sec, $p<0.001$; SMD 1.53). Both devices were used correctly in 77.8% of the cases. Overall erroneous readings occurred in 1.9%.

Conclusion: The ePER represents a modern and comprehensive solution to support medical staff during pediatric emergencies. This digital solution could be considered as an alternative to the BT.

Keywords: pediatric; body weight and measures; device development; emergency treatment; resuscitation

INTRODUCTION

Background

During pediatric emergencies adequate medical treatment of the injured or critically ill child is challenging even for an experienced and skilled healthcare provider. Drug dosing and selection of medical equipment is mostly based on the patient's actual body weight. Unfortunately, this information is not always given in a pediatric emergency. Therefore, pediatric emergency tapes (PETs) such as the Broselow® tape (BT) were developed to assist medical providers. Based on the child's body length the BT estimates body weight, and drug dosing as well as sizes for medical equipment are suggested on a tape.

Importance

Main limitations of the BT are the potential for incorrect use[1-5] as well as the limited accuracy regarding body weight estimation.[6-10]

In contrast, the recently presented digital algorithm for **C**ontinuous **L**ength-based **A**lgorithm for **W**eight & **A**ge **R**ating (CLAWAR) revealed a higher accuracy than conventional PETs.[11] A prototype of an electronic PET (electronic Pediatric Emergency Ruler [ePER]) utilizing CLAWAR was developed for further clinical testing.

Goals of this investigation

The aim of the present study was to compare the BT and the ePER with regard to the usability during a simulated life-threatening pediatric emergency scenario.

MATERIALS AND METHODS

Study design

This study investigated the BT and the ePER in a simulated pediatric emergency scenario. After approval by the local ethics committee of Zurich (KEK-ZH-Nr.: Req-2017-00584) voluntary participants were included into this assessment. The trial was registered on ClinicalTrials.gov (NCT03953105) and performed in January and February 2019.

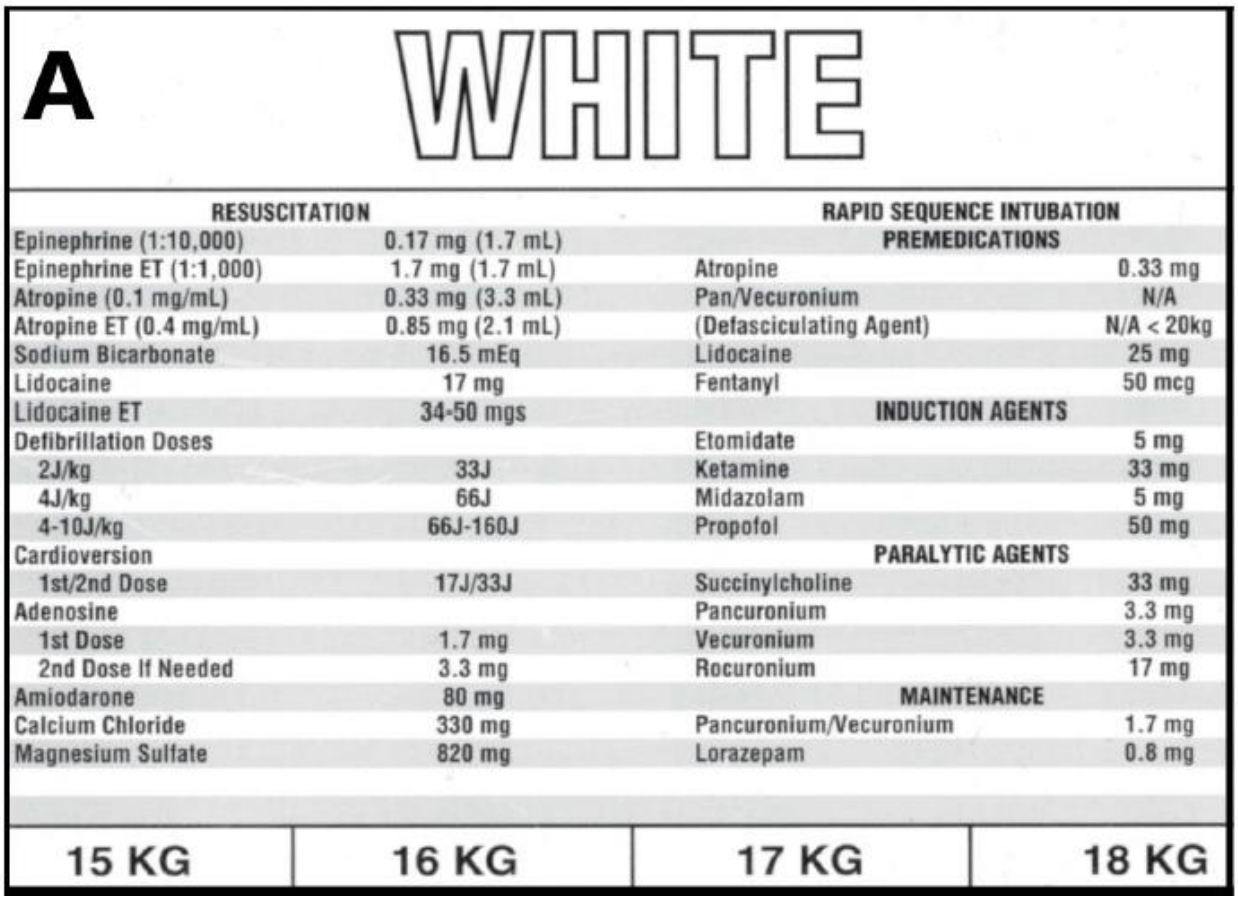
Selection of participants

In the city of Zurich, Switzerland ground-based prehospital pediatric emergency treatment is performed by "Schutz & Rettung Zürich (SRZ)". SRZ is the largest urban prehospital emergency organization in Switzerland and dispatches highly educated paramedics to about 600 pediatric emergencies annually. In the county of Bulach, Switzerland (a neighboring county to Zurich) ground-based prehospital pediatric emergency treatment is performed by a certified emergency medical service associated with the hospital of Bulach (EMS-BL). Paramedics from SRZ (n=16) and EMS-BL (n=2) who were unfamiliar with any of the two devices were asked to voluntarily participate in this study. Written informed consent was obtained from each participant.

Devices investigated

The BT (Vital Signs, Inc, Totowa, NJ) is the most frequently used and so far best investigated PET.[12-18] The BT includes 26 length-based weight categories (LWCs) for patients with a body length ranging from 47 to 144 cm. Based on these LWCs, the patient's body weight is estimated and drug

dosing as well as medical equipment suggested (figure 1). In addition, the BT advises considering the next higher color-coded zone for drug dosing if the child appears overweight. According to the user's instruction manual, the selection of medical equipment, as indicated on the back of the tape, disregards body habitus and is based on the measured body length only.



A WHITE

RESUSCITATION	
Epinephrine (1:10,000)	0.17 mg (1.7 mL)
Epinephrine ET (1:1,000)	1.7 mg (1.7 mL)
Atropine (0.1 mg/mL)	0.33 mg (3.3 mL)
Atropine ET (0.4 mg/mL)	0.85 mg (2.1 mL)
Sodium Bicarbonate	16.5 mEq
Lidocaine	17 mg
Lidocaine ET	34-50 mgs
Defibrillation Doses	
2J/kg	33J
4J/kg	66J
4-10J/kg	66J-160J
Cardioversion	
1st/2nd Dose	17J/33J
Adenosine	
1st Dose	1.7 mg
2nd Dose If Needed	3.3 mg
Amiodarone	80 mg
Calcium Chloride	330 mg
Magnesium Sulfate	820 mg

RAPID SEQUENCE INTUBATION	
PREMEDICATIONS	
Atropine	0.33 mg
Pan/Vecuronium	N/A
(Defasciculating Agent)	N/A < 20kg
Lidocaine	25 mg
Fentanyl	50 mcg
INDUCTION AGENTS	
Etomidate	5 mg
Ketamine	33 mg
Midazolam	5 mg
Propofol	50 mg
PARALYTIC AGENTS	
Succinylcholine	33 mg
Pancuronium	3.3 mg
Vecuronium	3.3 mg
Rocuronium	17 mg
MAINTENANCE	
Pancuronium/Vecuronium	1.7 mg
Lorazepam	0.8 mg

15 KG	16 KG	17 KG	18 KG

B

WHITE

PEDIATRIC ADVANCED LIFE SUPPORT	
Chest Compressions	100-120/min. Compress/vent 15:2 (2 rescuers), 30:2 (1)
Defibrillation First Shock	33J
Defibrillation Second Shock	66J
Defibrillation Subsequent Shocks	66J-160J
Cardioversion First Synchronized Shock	17J
Cardioversion Second Synchronized Shock	33J
Epinephrine (1:10,000)	0.17 mg (1.7 mL)
Amiodarone	80 mg
Adenosine First Dose	1.7 mg
Adenosine Second dose	3.3 mg
Atropine (0.1 mg/mL)	0.33 mg (3.3 mL)
Calcium Gluconate	1650 mg
Magnesium Sulfate	820 mg
RESUSCITATION EQUIPMENT	
Endotracheal Tube	5.0 Uncuffed
ETT Insertion Length	14-15 cm
Suction Catheter	10 French
Laryngoscope	2 Straight
Bag-Valve-Mask	Child
Oral Airway	60 mm
Nasopharyngeal Airway	22 French
Laryngeal Mask Airway	2
Bag-valve Mask	Child
Oxygen Mask	Pediatric Nonrebreather Mask
End-tidal CO_2 Detector	Adult
Urinary Catheter	10-12 French
Chest Tube	20-24 French
IV Catheter	18-22 gauge
Intraosseous Catheter	15 gauge
Blood Pressure Cuff	Child

15 kg	16 kg	17 kg	18 kg

Figure 1: Photos by the author from the Broselow® tape. Top (A): length-weight category for 15-18 kg body weight. Displayed are total amount of drug in mg to administer and in addition total mL to apply for epinephrine. Bottom (B): sizes for medical equipment are provided on the other side, necessitating turning the tape.

A prototype of the ePER (figure 2) was developed by the Department of Anesthesia, University Children's Hospital, Zurich and the University of Zurich, Switzerland. The ePER uses an electronic measuring ruler for length determination communicating with a tablet PC utilizing an application (APP) based on CLAWAR (CLAWAR APP. Version 1.0, University of Zurich, Switzerland). This APP allows for length-based and habitus adapted weight estimation, drug dosing and size selection of medical equipment for a body length from 42 to 160 cm. The algorithm of CLAWAR is described in detail in a previously published study.[11]

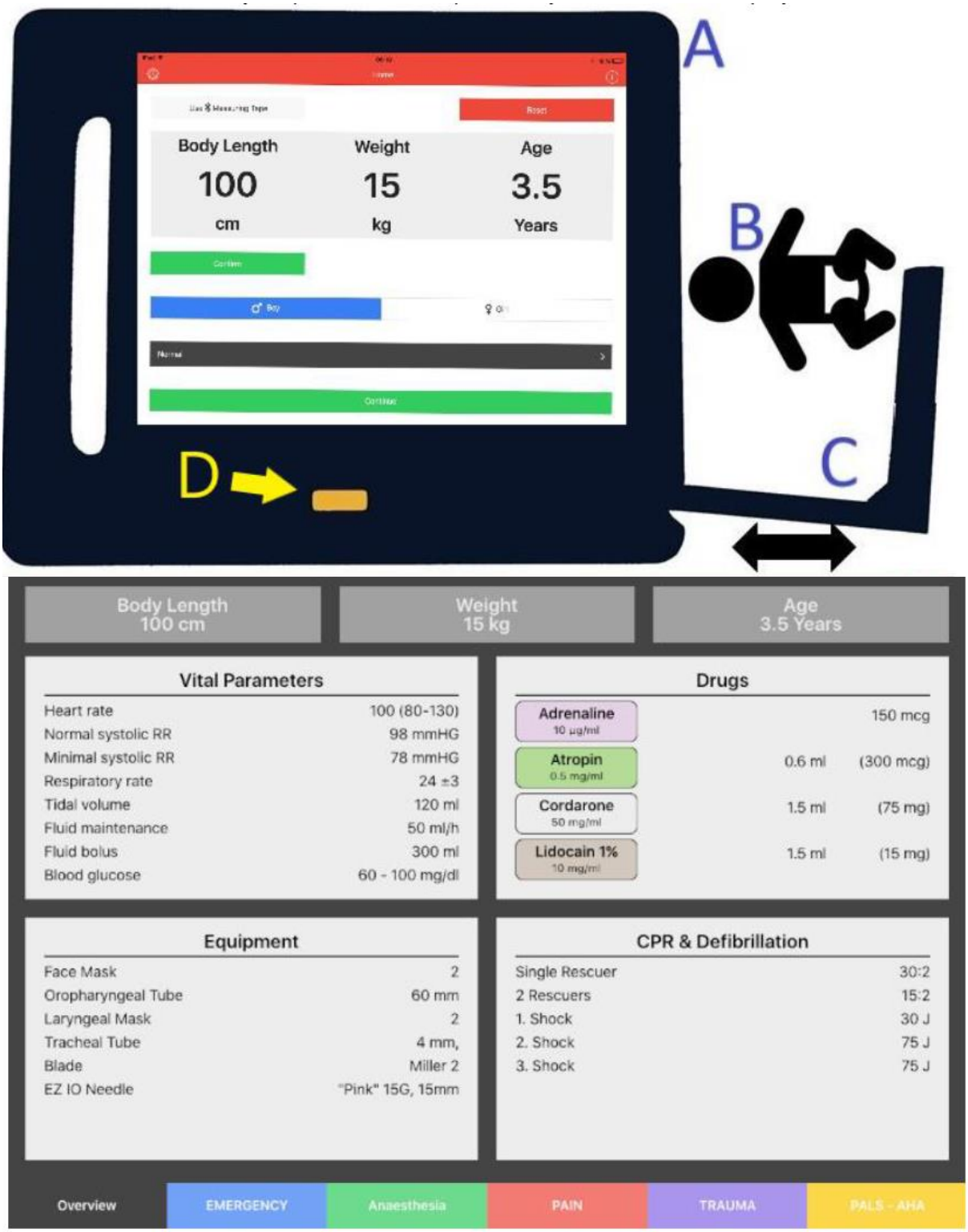


Figure 2: Top: (A) The Electronic Pediatric Emergency Ruler (ePER) is placed next to the patient´s head (B), the measuring tape (C) is pulled to the patient´s feet and the length is electronically measured by activating the yellow button (D). Patient's age and body weight are calculated from measured length based on the CLAWAR algorithm.[11] Bottom: after confirmation of the initial demographic calculations first line information mandatory for pediatric cardio-pulmonary resuscitation is displayed.

Setting

Each paramedic received individual standardized instruction by the study investigator (C.B.) on how to use the BT and the ePER. The paramedics received hands-on time with each of the two devices. Using the Laerdal SIM Baby (Laerdal/Dräger Medical Switzerland AG, Liebefeld, Switzerland) they were able to practice until they felt comfortable using both devices.

Randomization of the device was conducted by the paramedics drawing a sealed envelope containing a card with the name of one of the two devices. Each paramedic was evaluated one at a time, without other paramedics be present. This setup prevented any bias or teaching effects among participants.

A cardiac arrest was chosen as the simulated low-fidelity pediatric emergency scenario and the Ambu® junior (Ambu® GmbH, Bad Nauheim, Germany) was used as a manikin for assessment of the devices during the simulation. In this study habitus or gender adaptation was not included for both devices since the Ambu® junior's gender is undefined and the body habitus is normal. Prior to initiation of each paramedic's evaluation, the paramedic stood aside from the Ambu® junior with the randomized PET in his hand. After a start signal the study investigator asked the paramedic to identify the following set of information from the PET:

I. Estimated body weight
II. Joule (first dose) suggested for defibrillation
III. Recommended intravenous epinephrine dose
IV. Suggested cuffed/uncuffed endotracheal tube size (ETT)

This setup was identical for both, the BT and the ePER group. In each scenario, the time required to identify the information and the answers given were recorded using an iPhone 8 (Apple Inc, Cupertino, USA) in the audio tracking mode. Analysis of time to identification and correctness were performed afterwards from the audio tracking file.

Outcomes Measures

To investigate the usability and the clearness of the interface for each PET, the primary outcome was defined as the time required to identify the four parameters listed above. Secondary outcomes were correct use of the PET (defined as determination of the manikin's appropriate length-based weight) as well as erroneous reading of Joule amount, epinephrine dose and ETT size for the related length-based weight and age respectively.

Primary Data Analysis

Sample size calculation was performed a priori for comparison of two independent means estimating a clinically significant difference for the primary outcome of 10 sec (±5 sec). For an α of 0.05 and a power of 0.8 the suggested sample size was 4.

The collected data were compiled in Microsoft Excel 2013 (Microsoft Corporation, Redmond, WA, USA) and processed using SPSS (IBM SPSS Statistics 22.0). Shapiro-Wilk was used to test for normal distribution. Data are given as mean ± standard deviation (95% confidence interval) or as count (percent). A t-test was performed for statistical significance and a $p < 0.05$ was considered to be statistically significant. In addition, standardized mean difference (SMD) was calculated for

evaluation of clinical significance, defining a SMD > 0.8 as significant.

RESULTS

A total of 18 paramedics (7 female and 11 male) were included in this study. One (5.5%) paramedic was in training, three (16.7%) had less than 5 years of experience, five (27.8%) 6-10 years of experience, two (11.1%) 11-15 years of experience and seven (38.9%) more than 15 years of experience as a paramedic. Demographic data for the two groups is displayed in table 1. The Shapiro-Wilk test showed a normal distribution for the primary outcome in both groups (BT and ePER).

Table 1: Demographic data distribution for the participants between the two groups.

	BT group	ePER group
gender		
male	4 (22.2%)	7 (38.9%)
female	5 (27.8%)	2 (11.1%)
Experience		
in training	1 (5.6%)	0
1-5 years	3 (16.6%)	0
6-10 years	1 (5.6%)	4 (22.2%)
11-15 years	1 (5.6%)	1 (5.6%)
>15 years	3 (16.6%)	4 (22.2%)

BT: Broselow® tape ; ePER: electronic Pediatric Emergency Tape

The time until all four requested parameters were identified using the BT was 36.7 ± 4.9 sec (33.1 – 40.6) and 24.5 ± 5.5 sec (20.3 – 28.7) with the ePER ($p<0.001$; SMD 1.53). Detailed data are presented in table 2.

Correct use of the BT and ePER were equal, the weight was identified correctly in seven cases (77.8%) using the BT and in seven cases (77.8%) with the ePER. Overall erroneous readings of joule amount, epinephrine dose or ETT size from the devices occurred in only one of 54 (1.9%) assessments (for ETT size using the BT).

Table 2: Time until of identification of each and all requested parameters.

time for (sec)	BT				ePER				p	SMD
ETT size	8,3	±3,4	(5,7	- 10,9)	5,3	±1,8	(3,9	- 6,6)	0.031	1.0
weight identification	12,0	±4,9	(8,2	- 15,7)	8,2	±2,5	(6,3	- 10,1)	0.054	0.9
joule amount	10,1	±2,4	(8,3	- 12,0)	5,4	±1,9	(3,9	- 6,9)	<0.001	1.5
epinephrine dose	6,4	±1,2	(5,5	- 7,4)	5,6	±2,9	(3,4	- 7,8)	0.424	0.4
all parameters	36,9	±4,9	(33,1	- 40,6)	24,5	±5,5	(20,3	- 28,7)	<0.001	1.5

BT: Broselow® tape; ePER: electronic Pediatric Emergency Ruler; ETT: endotracheal tube. Displayed are mean ± standard deviation (95% confidence interval [minimum – maximum]).

LIMITATIONS

First, this study used a manikin simulation and not clinical testing. In an in-vivo setting the results might be different, since the real-life stress level of the caregivers during pediatric resuscitation is missing. Second, the work was performed in a single-center study and the healthcare providers were highly motivated to participate in the study. It is likely, that the results could be different in a large population of subjects.

DISCUSSION

This study compared the BT and the ePER in a simulated pediatric emergency scenario in terms of time and correctness, assessing four important parameters required for pediatric cardiopulmonary resuscitation. The main findings were that with the ePER the parameters studied were identified significantly faster, however there was no difference with regard to correct use of the device or erroneous readings.

The requirement of less time to identify information using a digital device is in accordance with the findings of Jung et al showing that a digital device allows for faster availability of important data compared to a conventional PET.[19] Their digital device consisted of an electronic ruler wirelessly connected to a personal computer with length-based body weight and drug calculation. The authors reported that the mean time interval from the start of each body length measurement to ordering an adrenaline dose, an endotracheal tube size and the defibrillation dose was significantly shorter for the digital device compared with the PET (digital device: 26 sec vs PET: 36 sec, $p<0.001$). These results are almost exactly the same compared to the findings of the present study (ePER: 24.5 vs BT: 36.9, $p<0.001$). One reason for this might be a non-easy-to-use interface of the PET. We assume the layout and total quantity of medical information given to the user might be the reason why the parameters were identified

more quickly with the ePER than with the BT (compare figure 1 vs figure 2). The information given on the interface of the ePER is limited. Only the information essentially needed during a resuscitation is displayed on the initial page and one defined clear dosing recommendation is given. The ePER delivers further information after selecting defined registers at the bottom of the page (e.g. PAIN, ANESTHESIA, and PALS ALGORITHM). Time is crucial in a pediatric emergency situation and taking more time to identify important information may increase stress on medical staff, thus enhancing the risk of errors.

The incorrect use of a PET is a known problem reported in prior publications. Heyming et al investigated the accuracy of the BT by comparing the length-based BT category selected by paramedics in a prehospital setting with the length-based BT category assessed in the emergency department and found that from 384 assessments a total of 115 (30%) were not identical.[1] The results of the present study showed a lower incidence of 22.2% for incorrect use in both devices. Concerns for erroneous reading with the ePER or BT could not be found in this study. In only one of 54 cases (1.9%) a parameter (ETT size using the BT) was read incorrectly for the selected length-based weight. This is in contrast to data published from other studies. Larose et al analyzed data from an experimental trial using simulated scenarios in which residents were asked to estimate the weight of a manikin using BT.[2] Although most residents reported having experience with the BT, 40% of them made erroneous readings from the BT. Incorrect selection of the length-appropriate weight category for drug dosing on the BT can lead to relevant under- or over-dosing of drugs. If the BT is imprecisely placed next to the patient a drug dosing weight of 13.0 kg (yellow category, 84.5 – 97.5 cm) might be selected instead of the actually correct category of 17.0 kg (white category, 97.5 – 110.0 cm). The ePER uses a continuous length-based algorithm for body weight estimation. This algorithm results in a lower impact of imprecisely measured body length on the body weight estimation. For example, a patient with a body length of 102cm instead of 100cm will have an estimated bodyweight of 15.5 kg instead of 15.0 kg.

The ePER is a digital device and therefore, there are other advantages that should be mentioned. Firstly, the possibility of easy updating or adaptation of given information. The user can be notified by a push-notification that an update is available. This is important if new guidelines or recommendations are published. Paper-based products don't easily allow for this option. They require reprinting and re-distribution, leading to higher costs for the consumer. Secondly, a software can be individually programmed, for example with regards to language, drug names or concentrations, medical equipment and local medical algorithms. Thirdly, the CLAWAR application on the ePER uses a growth chart for length-based weight estimation. Growth charts differ between ethnicities. With a digital solution, the growth chart used for estimation could be modified depending on the country (ethnical area) in which the ePER is used.

In conclusion, using the ePER to identify important information for cardio-pulmonary resuscitation was faster than using the BT.

There was no difference with regard to correct use or erroneous readings between the two devices. The ePER is a modern digital technology representing an interesting comprehensive approach in supporting medical staff during in- and out-of-hospital pediatric emergencies by length-based estimation of weight, drug doses and size selection of medical equipment.

Acknowledgment:
We would like to thank the paramedics of the emergency medical service Bulach (Dr. K. Homburg and J. Mezghini) and from the prehospital emergency organization Schutz & Rettung Zurich for participating in this study.

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