ORIGINAL ARTICLE

Opportunities for performance improvement in relation to medication administration during pediatric stabilization

N Morgan, X Luo, C Fortner, K Frush

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See end of article for authors' affiliations

Correspondence to: Dr K Frush, Duke University Medical Center, Box 3055, Durham, NC 27710, USA; frush002@mc.duke.edu

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Objectives: To identify and characterize areas for improvement in the clinical performance of nurses in relation to medication administration.

Method: Nurses participated in a simulated pediatric stabilization event which was videotaped. Their clinical performance was evaluated at each of the following steps: (1) communicating and confirming the dose of medication; (2) converting the dose; (3) selecting the correct medications; (4) properly preparing the medication formulation; and (5) measuring medication doses. The time required to convert and draw up the medications was also evaluated.

Results: A total of 150 medication orders for five medications were given by the physician. Only 55% of the orders were verbally repeated back by the nurses. Of the 120 orders in which the doses were converted from milligrams to milliliters by nurses, 17 (14.2%) were converted incorrectly and the maximum dose deviation reached 400%. Selection of the wrong medication occurred in 11 of the 150 orders. Dextrose (which requires dilution before being administered to children) was not diluted in 17% of the medication orders and in 12% it was diluted improperly. About 40% of the orders for ceftriaxone (which requires reconstitution) were not properly reconstituted. In 49 (32.7%) of the 150 medication orders that were drawn up in a syringe, the amount measured was not consistent with the stated dose. For some medications, a prolonged time was required by nurses to convert the doses and draw up the medications.

Conclusions: By observing the clinical performance of nurses in a simulated videotaped pediatric stabilization event, we have identified some important areas in need of improvement in each step of the medication administration process. These findings indicate a need for improved education, training, and use of clinical aids or adjuncts for pediatric emergency nurses.

Medication errors are among the most frequently reported errors in the pediatric emergency setting. Kozer *et al*[1] found that approximately 10% of children treated in the emergency department were subject to medication error. The risk of medication error is even more profound when children require resuscitation and emergency stabilization. This is because stabilization events are stressful and highly variable situations during which healthcare providers must make rapid decisions and react promptly to patients' needs, often with only limited information.[1] Over the past few years, several safety initiatives and clinical tools have been developed and implemented to help decrease medication errors during pediatric stabilization events. One of the most widely used tools is the Broselow-Luten Emergency Tape (Vital Signs Inc, NJ, USA). Studies have shown that this tape, which provides pre-calculated medication doses based on children's weight, is effective in reducing medication error during simulated pediatric stabilization scenarios.[2] However, this tool is not error proof, as documented by several recent studies.[3 4]

Nurses play a very important role during pediatric stabilization events and delivery of medications is one of many important tasks required of them. Medication administration is complex and consists of multiple steps including the following: (1) physicians order (prescribe) the medication and calculate the proper dose according to the weight of the child; (2) nurses then confirm the dose; (3) convert the dose from milligrams to millilitres; (4) select the appropriate medication and formulation; (5) measure and draw up the medication; and (6) deliver the medication. Errors can occur during each of the steps, potentially leading to patient harm. The Broselow tape, which provides pre-calculated doses for physicians to prescribe in milligram (mg) doses, does not provide a pre-calculated conversion (from mg to milliliters (ml)), thus leaving the nurses to perform the calculation. Safety strategies such as the designation of a ''medication nurse'' have been studied but have not been found to be effective in reducing medication error.[5] By contrast, the presence of a clinical pharmacist has been shown to be effective in reducing medication error in the acute care setting but this strategy is neither practical nor affordable in most emergency departments.[6] A feasible clinical tool which brings the dosing expertise of the clinical pharmacist into the hands of emergency nurses is therefore sorely needed.

In order to develop a clinical tool that could effectively reduce nurses' medication errors during pediatric stabilization events, it is important to first understand what types of errors are made at each step of the medication administration process. To this end, we conducted an observational study to analyze the clinical performance of nurses in the delivery of medication during a simulated pediatric stabilization event. Through this observational study we sought to identify deficiencies in performance so that targeted interventions and clinical tools can be developed to address these deficiencies.

METHODS

Study design

We conducted a prospective observational study to evaluate the clinical performance of nurses when administering medications during a simulated pediatric emergency event. Each study subject participated in a simulated pediatric stabilization scenario during which five medications were ordered and administered. The scenario was videotaped to allow for thorough evaluation and analysis.

Box 1 Study scenario

A 2 year old child weighing 13 kg is brought to the emergency department by his mother with a history of sore throat and cough for past 5 days and tactile fever at home for the past 2 days. The illness began with three episodes of vomiting about a week ago, but the child has had no further vomiting. The child is not eating well and has only been drinking water or Pedialyte. His PMH is significant for a seizure disorder for which he takes phenytoin. He has not had a seizure for 2 months. He appears clinically well hydrated and is triaged as a level 4.

While waiting in triage, the child experiences a generalized tonic-clonic seizure and is rushed back to a treatment room without his mother being present. On review of the symptoms the mother reports that the child has not been given his medication (phenytoin) for about 1 week.

The nurse in the treatment room provides supplemental oxygen by mask, obtains intravascular access, and draws blood for analysis. The Dextrostik is 45 and the physician begins to order medications. After the seizure is controlled, a petechial rash is noted on the child's face and chest. The child's rectal temperature is 104°F and his blood pressure is 89/40 mm Hg. The physician is concerned about infection, including meningitis.

After initial assessment and review of the patient's clinical status, the physician began to order medications to be drawn up and administered by the nurse subject. The orders for different medications were made one at a time, with one order given after the previous order was drawn up and administered. The orders were given in mg or ml, depending upon the medication. The subject was expected to confirm the dose by repeating back the order, convert the dose from mg to ml, dilute the medication if necessary, and finally draw up the medication using equipment that was available to him/her in the emergency department setting. Each subject was directed to hand the medication to the research assistant rather than to infuse it into the IV tubing connected to the child mannequin.

Setting and study participants

Study subjects included a random sample of 30 emergency nurses with varying degrees of education and experience. The study was conducted in a tertiary academic medical center with referring hospitals in the south-east region of the US. The Institutional Review Board approved the study and all subjects gave informed consent.

Simulated scenario

The simulation was conducted in a regular treatment room for pediatric patients in the emergency department of the study medical center. A senior pediatric resident served as facilitator for the simulated scenario which was videotaped for thorough analysis. A research assistant was present during the simulation to conduct the observation and to assist the facilitator as needed. An appropriately sized anatomically and developmentally appropriate mannequin (Simulaids Inc, Woodstock, NY, USA) was used to represent a child with seizure activity awaiting treatment. The facilitator presented the same scenario to each subject, providing scripted background information and requesting identical doses of five medications. The scenario presented to the study subjects is described in box 1.

Methods of measurement and data analysis

The evaluation and analysis of each subject's performance in the simulated scenario included six steps:

(1) *Communicating and confirming the dose.* The JCAHO's National Patient Safety Goal #2a recommends that medication doses ordered by physicians should be "read back".[7] During emergency stabilizations nurses rarely have time to write down and read back the dose ordered by the physician, so we evaluated whether the subject verbally repeated back the dose. We also evaluated whether the order was repeated back correctly. We first calculated the percentage of medication orders that were repeated back and then calculated the percentage of those that were repeated back correctly.

(2) *Converting the dose.* When physicians order (prescribe) medications for children, they must perform calculations to determine the proper dose in mg according to their weight. Nurses must then convert the dose from mg to ml based on the formulation available and the desired concentration of the medication, with or without calculation aids such as calculators. We therefore evaluated whether the doses converted by nurses were correct and determined the magnitude of dosing deviation. The dosing deviation was calculated as the absolute value of the percentage of dosing deviation from the correct converted doses.[2] For each medication we calculated the percentage of orders that were not converted correctly as well as the mean, median and maximum dosing deviation. The median dosing deviation is a dosing deviation value that has half of the dosing deviation numbers greater than it and the other half less than it.

(3) *Selecting the proper medication.* For each medication we evaluated whether the correct medication vials were selected and calculated the percentage of orders in which wrong medications were selected.

(4) *Properly preparing medication formulation.* Two of the medications in this study had to be diluted or reconstituted before administration (dextrose and ceftriaxone). The formulation of dextrose that was available at the study institution was Dextrose 50% Abboject (D50), whereas national training courses such as Pediatric Advanced Life Support (PALS)[9] recommend Dextrose 25% (D25) in pediatric patients. For dextrose, we calculated the percentage of orders in which D50 was properly diluted to D25 by adding 50 ml of saline. Ceftriaxone is supplied in powder form and must be reconstituted. The proper procedure to reconstitute ceftriaxone for intravenous use involves adding an appropriate amount of IV diluents (9.6 ml to 1 g) to the powder in the vial and shaking to form a solution. We calculated the percentage of orders in which ceftriaxone was properly reconstituted.

(5) *Measuring medication doses.* To evaluate the accuracy of measuring doses, we asked study subjects to state aloud the amount of medication they were measuring before it was drawn up in a syringe. We evaluated whether the actual amount of medication drawn up in the syringe (measured) was consistent with the amount the subject stated she/he was measuring. For each medication we calculated the percentage of orders in which the measured amount differed from the amount that was intended. We also calculated mean, median and maximum dose measuring deviation between the actual measure amount and the stated amount. The measuring deviation for each medication order was calculated as absolute value of the percentage difference between the actual amount and the stated amount. The median measuring deviation is a measuring deviation value that has half of the measuring deviation numbers greater than it and the other half less than it.

(6) *Time to convert and draw up the medications.* We evaluated the time required by each nurse to convert and draw up the medications. The time to convert was the time the nurse used to convert the dose from mg to ml. It was measured from the moment the drug was ordered by the physician (in mg) to the time the nurse said aloud the dose (in ml) he/she was drawing up. The time to draw up was measured from the time the nurse determined the dose in ml to the time she/he began to administer it to the patient. Mean, median and maximum times to convert and draw up the medications were calculated. The median time has half of the time points greater than it and the other half less than it.

RESULTS

Demographic data

This study included a total of 30 subjects, consisting of nurses with varying degrees of education and experience. Approximately 52% of the subjects had a BSN while the others had a nursing diploma and/or were classified as LPN or ADNs. 50% of the subjects considered the emergency department as their area of specialty, 30% specifically designated the pediatric emergency department as their field of expertise, and the other 20% were either new to the emergency department, had transferred from other departments of the hospital, or had spent a larger part of their career in another specialty. The age of the subjects ranged from 20–25 years (6.7%) to >50 years (3.3%); 80% of the participating nurses were female.

Communicating and confirming the dose

A total of 150 medication orders for five medications were given by the physician. Of these, 83 (55%) were verbally repeated back by the nurse; 95% of the 83 orders were repeated back correctly. A detailed analysis of the repeat back for each medication is shown in table 1.

Converting the dose

Except for dextrose which was ordered in ml, other medications were ordered by the physician in mg and had to be converted into ml by the nurses. There were a total of 120 medication orders in which the doses were converted from mg to ml by nurses. Of these orders, 17 (14.2%) were converted incorrectly. The mean dosing deviation was approximately 12% and the maximum dosing deviation reached 400%. Lorazepam and ceftriaxone were most often converted incorrectly (table 2). Ceftriaxone also had the greatest maximum dosing deviation, followed by lorazepam and fosphenytoin (table 2).

Selecting medications

Of the 150 medication orders, there were 11 (7.3%) in which the wrong medication was selected from the vials available. Phenobarbital had the largest percentage of orders with wrong medication being selected (13.3%), followed by lorazepam (10%), ceftriaxone (6.7%), and fosphenytoin (6.7%). Dextrose did not have any orders with wrong medication being selected.

Dilution and reconstitution

Of the 30 dextrose orders, 83.3% were diluted before administration of the drug; 88% of these were diluted properly. Of the 30 ceftriaxone orders, 60% were properly reconstituted.

Dose measuring

In 49 (32.7%) of the 150 medication orders that were drawn up in a syringe the amount measured was not consistent with the amount being stated. The mean dose measuring deviation was 8% and the maximum measuring deviation was 146%. The information on dosing deviation of each medication is shown in table 3.

Time taken to convert and draw up

The time to convert from mg to ml was analyzed for four medications as dextrose did not require such a conversion. Of the four medications, ceftriaxone was the most time consuming with a mean conversion time of 84 s, a median conversion time of 71 s, and a maximum conversion time of 202 s. The conversion time of lorazepam was shorter (mean 40 s, median 30 s, maximum 127 s). Fosphenytoin and phenobarbital required even less time (table 4).

The time taken to draw up the medication for administration was analyzed for all five medications. Dextrose required the most time with a mean of 162 s, median of 137 s, and a maximum of 5.5 minutes. Ceftriaxone followed with a mean of 100 s and a maximum of 3.5 minutes. The other medications required less time to be drawn up (table 4).

DISCUSSION

This prospective observational study provides a comprehensive analysis of the clinical performance of emergency nurses in relation to medication administration during a simulated pediatric emergency event. Previous studies have described the clinical performance of pediatric emergency physicians in prescribing (ordering) doses of medications and several studies have documented important deficiencies in these steps.[1 2] In contrast, observational studies that evaluate the clinical performance of nurses in relation to medication administration are limited in number, with ever fewer focusing on emergency nurses.[9] The current study provides a valuable addition to the literature in this important area.

Through observation we identified some important opportunities for improvement in each step of the medication administration process. Firstly, the JCAHO's patient safety goal 2a recommends that "for verbal or telephone orders or for telephonic reporting of critical test results, verify the

Table 1 Analysis of nurses' communication and confirmation of the doses ordered by doctors

	Repeated back		Repeated back correctly	
	Total	No (%) repeated back	No repeated back	No (%) repeated back correctly
Dextrose	30	20 (66.7%)	20	19 (95.0%)
Lorazepam	30	18 (60%)	18	17 (94.4%)
Fosphenytoin	30	17 (56.7%)	17	17 (100%)
Phenobarbitol	30	12 (40%)	12	11 (91.7%)
Ceftriaxone	30	16 (53.3%)	16	15 (93.7%)
Total	150	83 (55.3%)	83	79 (95.2%)

Table 2 Analysis of nurses' dosing conversion

	N	No (%) calculated incorrectly	Mean dosing deviation	Median dosing deviation	Maximum dosing deviation
Lorazepam	30	8 (26.7%)	22.9%	0	100%
Fosphenytoin	30	3 (10%)	2.7%	0	61.5%
Phenobarbitol	30	0 (0)	0	0	0
Ceftriaxone	30	6 (20%)	21.5%	0	400%
Total	120	17 (14.2%)	11.7%	0	400%

complete order or test result by having the person receiving the order or test result 'read back' the complete order or test result''.[7] In this study we found that approximately 45% of the medication orders were not repeated back to the physician who gave the verbal order. While orders are often not written down to be ''read back'' during an emergency, it is important that the orders are at least repeated back to double check them and to avoid an error in communication. According to the JCAHO, ''ineffective'' communication is one of the major root causes of sentinel events whereas effective communication which is ''timely, accurate, complete, unambiguous, and understood by the recipient'' can reduce error and improve the safety of all of those involved.[7]

A second concern we observed in the nurses' clinical performance was in their ability to convert doses in mg (stated by the physician) to doses in ml. For medications such as lorazepam and ceftriaxone, more than 20% of the orders were converted incorrectly. One possible reason for incorrect conversions is that the nurses did not have a clinical tool which provides the pre-calculated conversion. In fact, this type of tool is not currently available to nurses in most emergency departments. Many dose conversions require complex calculations—for example, when the physician orders 1.3 mg of lorazepam, the nurse must calculate the number of ml to be drawn up from a vial of lorazepam which contains 2 mg/ml. In an emergency setting the healthcare team must act quickly and nurses are forced to perform such calculations mentally or without a ''second check''. If the nurse could be provided with a conversion chart, this would eliminate the need to perform mathematical calculations and conversions—a step that has been shown to lead to frequent errors.[10]

A third opportunity for improvement in performance was that of selecting incorrect medications. Of the 150 medication orders, the wrong medication was selected in 11. Although infrequent, this is a serious problem, especially during emergency stabilizations when patients who require prompt interventions might receive unintended pharmaceutical treatments. A bigger concern is that the use of incorrect medications could result in adverse drug reactions, potentially leading to severe harm to the patient. As we carefully analyzed the videotaped simulations, we found that one reason a nurse might select an incorrect medication is the similarity between the different medication vials. If a nurse did not read the label carefully, he/she could easily pick up the wrong vial. Under the stress of an emergency situation, human factors such as these can often lead to medical errors. It is critically important not only to educate nurses about the importance of reading medication labels but also to improve the design of the vial labels by manufacturers so that problems associated with medication selection can be minimized.

Another deficiency which became readily apparent on review of the videotaped simulation is the improper dilution or reconstitution of medications by some nurses. D50, which requires dilution before being administered to children, was not diluted in 17% of the medication orders and in another 12% it was not diluted properly. In several cases nurses said that they were unfamiliar with D25 dilutions because they usually work in the adult emergency department and are rarely assigned to the pediatric emergency department. Although one solution may be to assign pediatric trained nurses to the pediatric emergency department, this is not always possible due to staff constraints. Another solution may be to supply D25 as a stock item, although the infrequent use of D25 compared with D50 and higher expenses associated with D25 might also be issues. Focused education and a clinical tool providing clear instructions about proper dilution may be helpful.

We observed another problem in the preparation of medications. In approximately 40% of the orders for ceftriaxone, this medication was not properly reconstituted. Nurses' lack of experience in conducting reconstitution may be a major contributing factor to these problems. These skills are taught in school but may not be reviewed on a regular basis. While more training and ongoing education are needed in this area, we also recognize that the proper reconstitution of ceftriaxone, including adding a precise amount of diluent to the vial (for example, 9.6 ml for 1 g) is not a trivial task, especially during an emergency situation. Moreover, ceftriaxone is provided by the manufacturer (and often stocked in emergency departments) in different vials containing different dosages; each vial requires a different amount of diluent for reconstitution. If a nurse does not read the label carefully, he/she might easily add an inaccurate amount of diluent. This example shows how the complex process of medication administration sets up opportunities for human errors and underscores the importance of the development of more simplified processes. For example, it

Table 3 Analysis of nurses' dose measuring

	No (%) measured incorrectly	Mean measuring deviation	Median measuring deviation	Maximum measuring deviation
Dextrose (N = 30)	9 (30%)	1.5%	0	23.1%
Lorazepam (N = 30)	15 (50%)	22.4%	1.5%	146%
Fosphenytoin (N = 30)	10 (33.3%)	3.4%	0	61.5%
Phenobarbitol (N = 30)	9 (30%)	4.7%	0	60%
Ceftriaxone (N = 30)	6 (20%)	7.2%	0	80%
Total (N = 150)	49 (32.7%)	8.0%	0	146%

Table 4 Analysis of time taken by nurses to determine and convert dose

	Time to convert dose (s)				Time to draw dose (s)			
	N	Mean	Median	Maximum	N	Mean	Median	Maximum
Dextrose					28	162	137	330
Lorazepam	20	40	30	127	27	34	28	125
Fosphenytoin	20	32	34	63	25	52	43	175
Phenobarbitol	18	17	7	125	26	25	26	55
Ceftriaxone	18	84	71	202	25	100	89	210

might be helpful to supply each vial of ceftriaxone concurrently with a bottle containing the precise amount of diluent. Standardizing and limiting the number of drug dosage vials available in the organization might also be helpful to prevent some of the confusion and to eliminate the medical errors associated with these complex tasks.

We observed that, for 35% of the medication orders, the measured dose of medication (ml drawn up in a syringe) was not equivalent to the intended dose (as stated by the nurse). In one instance the amount of medication drawn up in the syringe was nearly 150% of the intended dose. The factors contributing to these errors ranged from misreading the syringe lines to picking up the wrong size syringe. In these cases, a person acting as a second check would be useful.

By reviewing the videotaped simulation scenarios, we found delays in converting the doses from mg to ml. It took, on average, more than 1 minute to convert the dose for some medications. We also found that some nurses required a prolonged time to prepare medications for delivery to patients. The delays in the dose conversion were most commonly caused by the need to calculate complex equations, whereas the delays in medication delivery were most often due to the need to reconstitute and dilute medications. Because rapid treatment is critical in emergency situation, the delays in each step of patient care—including dose conversion and medication administration—must be minimized to avoid a negative impact on patient outcomes.

This study is subject to several limitations. Firstly, we enrolled only 30 emergency nurses in our study. We stopped after evaluating 30 subjects because we felt that sufficient information had been gathered to identify the deficiencies. Secondly, our study subjects were limited to one teaching hospital. The results could not be generalized to other teaching hospitals or community hospitals. Finally, our study was conducted in a simulated environment and not a ''real world'' setting. We chose to use a simulated scenario because the study process could be better controlled and each step of medication administration could be carefully recorded and analyzed without interrupting the delivery of clinical care.

Nurses play an essential role in the process of medication administration. Through careful observation of the clinical performances of nurses in relation to medication administration in a simulated pediatric stabilization event, we have identified some important deficiencies in each step of this complex process. While these deficiencies indicate a great need for improved education and training among pediatric emergency nurses, we also recognize the need to simplify the process. The complexities of the process set up many opportunities for nurses to make errors. Future investigations should examine how to simplify the whole process and standardize many of the steps.

Authors' affiliations

N Morgan, School of Nursing, Duke University, Durham, NC, USA
X Luo, K Frush, Center for Patient Safety and Clinical Quality, Duke University Health System, Durham, NC, USA
C Fortner, K Frush, Department of Pediatrics, Duke University Medical Center, Durham, NC, USA

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