

Learning in practice

Prospective observational study on the incidence of medication errors during simulated resuscitation in a paediatric emergency department

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Abstract

Objectives To characterise the incidence and nature of medication errors during paediatric resuscitations.

Design A prospective observational study of simulated emergencies.

Setting Emergency department of a tertiary paediatric hospital.

Participants Teams that included a clinician who commonly leads "real" resuscitations, at least two assisting physicians, and two or three paediatric nurses.

Interventions The teams conducted eight mock resuscitations, including ordering medications. Exercises were videotaped and drugs ordered and administered during the resuscitation were recorded. Syringes and drugs prepared during the resuscitation were collected and analysed for concentrations and actual amounts.

Main outcome measures Number and type of drug errors.

Results Participants gave 125 orders for medications. In 21 (17%) of the orders the exact dose was not specified. Nine dosing errors occurred during the ordering phase. Of these errors, five were intercepted before the drug reached the patient. Four 10-fold errors were identified. In nine (16%) out of 58 syringes analysed, measured drug concentrations showed a deviation of at least 20% from the ordered dose. A large deviation (at least 50%) from the expected dose was found in four (7%) cases.

Conclusions Medication errors commonly occur during all stages of paediatric resuscitation. Many errors could be detected only by analysing syringe content, suggesting that such errors may be a major source of morbidity and mortality in resuscitated children.

Introduction

Medication errors are a common cause for iatrogenic adverse events.¹ In children, dosing errors are the most common type,² mostly caused by the incorrect calculation of doses.³ Resuscitation is an extremely stressful

and uncontrolled situation for medical staff and calculating drug doses under these conditions is challenging. The incidence of medication errors during paediatric resuscitation and the impact of such errors on patients' outcome are currently not known. We examined the incidence and nature of such errors in simulated resuscitation of children.

Methods

This prospective observational study was conducted in the emergency department of a tertiary paediatric hospital affiliated with a university.

From September 2001 to May 2002, fellows, residents, and nurses participated in mock resuscitations, as part of routine emergency department educational rounds. Participants knew they were taking part in a research project but not the exact nature of the study. A paediatric emergency physician experienced in conducting mock resuscitations served as a moderator for the cases. For each round a different case scenario was presented (table 1). The moderator started the scenario with a clinical description of the patient's condition and continued to provide clinical data, in response to physicians' and nurses' actions, throughout the case. To simulate real life, an age appropriate mannequin was used. A team that included a leader (a fellow in paediatric emergency medicine or a senior resident in paediatrics or emergency medicine), at least two assisting physicians (residents or fellows), and two or three paediatric nurses managed each case.

According to the team leader's decision, other physicians on the resuscitation team could also order drugs or calculate doses. Standard references such as the hospital formulary, resuscitation cards, handheld computers, and calculators were allowed. (The Broselow paediatric emergency tape and colour coded materials, which at that time were not part of the

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Table 1 Scenarios used in mock resuscitations for study of medication errors

Case No	Age	Presenting signs and symptoms
1	4 months	Non-responsive, bradypnoea, shock (see box on bmj.com for details)
2	3 weeks	Seizures, hypoglycaemia, cardiorespiratory arrest
3	6 years	Fell from bike, fracture of forearm, narrow complex tachycardia
4	2 years	Upper airway obstruction, respiratory failure
5	3 months	Wheezing, respiratory failure
6	4 years	Status epilepticus, respiratory failure
7	3 years	Respiratory distress, decreased level of consciousness, vomiting
8	13 years	Cardiopulmonary arrest

routine equipment in the department, were not used.) The nurses and the physicians prepared the drugs and administered them according to the orders. One of the nurses was assigned to prepare drugs; other nurses and the physicians also prepared drugs if and when the designated person was busy. Individual and group feedback was given immediately after the mock resuscitation.

Documentation of drug administration

Three observers from the research team recorded all orders, drugs and fluids administered. Each observer was located in a different position in the resuscitation room and focused on the actions of different team members. The scenarios were video recorded and researchers subsequently viewed the tapes to assure the accuracy of the collected data. In cases of discrepancy the tape was considered to be correct. Disagreements were resolved by consensus.

All syringes and drugs prepared during the resuscitation were collected and marked. The actual drug content and drug concentration in the syringes were analysed in the laboratory to compare them with the presumed drugs and concentrations ordered.

Definition of drug error

We considered the following as medication errors²: a medication that was ordered but not given (unless the order was cancelled), a medication that was given but not ordered, a drug given in a dose different by at least 20% from the recommended dose, administration of a drug by an incorrect route, and a drug ordered that is not indicated for the patient's condition. The references for correct practice and drug doses were the hospital resuscitation card and formulary. We did not consider the failure to order a drug that was necessary for the patient's condition as a medication error.

Results

We conducted eight mock resuscitations in which 20 physicians and 15 nurses took part. Participants initiated 125 orders for drugs. In 24 cases the same order was repeated more than once. In 17 cases we were unable to determine whether or not the drug was given. In 12 cases the ordered drug was not administered. Seventy two drugs were given, and 58 syringes were analysed for content. We identified medication errors in seven of the eight mock resuscitations.

Incomplete orders and dosing errors

In 21 (17%) of the orders the exact dose was not specified. In only 52 orders (41%) was the route of administration specified.

Nine dosing errors occurred during the ordering phase (table 2). In four cases the dose ordered was higher than the recommended dose and in five cases it was lower. We did not identify any error in the doses of resuscitating fluids. Identifiable causes of errors included ordering of a total daily dose of vancomycin as a single dose and ordering the wrong concentration of dextrose. Of these errors, five were intercepted before the drug reached the patient.

We identified a total of four 10-fold errors: three at the ordering phase and one at the administration phase. All these errors were intercepted before the drug reached the patient.

Errors in preparation and administration

One nurse prepared a 10-fold higher dose of midazolam. The charge nurse identified the error before the drug was given. One drug was given via the wrong route—that is, oral paracetamol suspension was administered rectally. In one case racemic adrenaline was ordered but L-adrenaline was given via a nebuliser. The dose, however, was not specified when the drug was ordered and we could not verify the dose that was given.

Expected v actual syringe content

Seventy two drugs were given, and the laboratory analysed 58 syringes. In nine syringes (16%) the laboratory identified a deviation of at least 20% from the expected dose. In four cases (7%) the deviation from the expected dose was at least 50%. These included a two-fold higher dose of midazolam, a threefold higher dose of lorazepam, a 25-fold lower dose of hydrocortisone, and a twofold lower dose of atropine.

Table 2 Dosing errors during ordering phase in mock resuscitations

Case No	Weight (kg)*	Drug	Correct dose†(dose per kg)	Ordered dose (dose per kg)
1	7	Succinylcholine (suxamethonium)	7-14 mg (1-2 mg)	1.4 mg (0.2 mg)
1	7	Mannitol	3.5-7.0 g (0.5-1.0 g)	0.40 g (0.06 g)
4	12	Atropine	0.12-0.24 mg (0.01-0.02 mg)	0.010 mg (0.001 mg)
5	5	Adrenaline (epinephine)	0.05 mg (0.01 mg)	0.16 mg (0.03 mg)
4	12	Midazolam	0.6-2.4 mg (0.05-0.20 mg)	0.50 mg (0.04 mg)
4	12	Vancomycin	180 mg (15 mg)	600 mg (50 mg)
2	4	Dextrose 50%‡	20-40 ml dextrose 10% (0.5-1.0 g)	4 ml (1 ml)
5	5	Salbutamol§	0.30 ml (0.03 ml)	0.15 ml (0.03 ml)
4	12	Atropine	0.12-0.24 mg (0.01-0.02 mg)	0.400 mg (0.033 mg)

*Weight was provided by moderator at beginning of mock resuscitation.

†See text for the definition of correct doses.

‡Use of 50% dextrose in neonate was considered an error.

§Salbutamol 5 mg/ml solution for inhalation. Minimum recommended dose for acute bronchospasm is 0.3 ml.

Discussion

In a model of simulated paediatric resuscitation, we identified frequent and potentially serious medication errors. These errors occurred at all stages of resuscitation. Both physicians and nurses made errors. Some errors, including potentially lethal errors, were intercepted by a team member and several errors could be detected only when the content of the syringe was analysed.

Full cardiopulmonary arrest in children is associated with high mortality and morbidity.⁴ If one assumes that drugs given during resuscitation have beneficial effects on outcome, then preventing errors will improve rates of full recovery. Maybe even more serious is that major drug errors may be missed if the child dies because it is not suspected that the drugs actually caused or contributed to the morbidity and mortality.

Shah and colleagues also used simulated resuscitation to study medication errors.⁵ Participants were randomised to a standard dosing system (Broselow tape) or traditional dosing references. The Broselow paediatric emergency tape and colour coded materials was associated with lower deviation from the recommended dose range. The design of our study, which used simulated resuscitations, represented the closest possible alternative to real resuscitations. In the study by Shah et al the researchers studied only the ordering stage of giving drugs, did not specify how errors were detected and did not verify the contents of the syringes.⁵

Specific errors

In our study physicians often gave incomplete orders (for example, no specific route of administration), though none of these resulted in a drug given by the wrong route, probably because well trained members of the resuscitation team interpreted such orders correctly. It is not clear whether such orders would be interpreted correctly by less well trained members. When an incomplete order did not specify the exact dose it caused delay which could have detrimental effects during resuscitation, when every second counts.

We identified four 10-fold errors in 125 orders for medication. This incidence was substantially higher than previously reported, in studies based on incidence reports⁶ and retrospective chart reviews^{7, 2} and in simulated resuscitation.⁵ We previously audited more than 1500 charts in the emergency department and detected only two 10-fold errors.² Hence, during resuscitation the rate of 10-fold errors is in the order of 24-fold higher. Errors of this magnitude may occur more commonly in children because the dose per kilogram for some of the drugs is extremely small, which results in a low total dose.⁸

Detection and prevention of medication errors

Improved communication within the team could reduce medication errors.⁹ Many of the important errors in our study were intercepted by a team member. We suggest that every paediatric emergency department should have regular team training of physicians and nurses.

The results from studies on medication errors vary depending on methods and the definition of errors. Studies of medication errors using an observer¹⁰ may detect some errors that would not be detected by

What is already known on this topic

Medication errors are common in paediatric emergency departments

The incidence of medication errors during paediatric resuscitation has not been fully investigated

What this study adds

Frequent and potentially serious medication errors occur at all stages of paediatric resuscitation

Many errors could be detected only by analysis of syringe content, suggesting that the incidence of medication errors during resuscitations is substantially higher than previously estimated

voluntary reporting or chart review. Analysis of syringe contents may reveal errors that could not be detected in other ways. Parshuram et al analysed morphine infusions in the paediatric and neonatal intensive care units of a tertiary paediatric centre.¹¹ They found discrepancies of at least 10% between ordered and measured concentrations in over two thirds of infusions. Our finding of 15% of cases with considerable discrepancy between the expected and actual content of the syringes suggests that the incidence of medication errors in sick children might be substantially higher than previously estimated.

Various strategies have been suggested to reduce drug errors. A standard dosing system (Broselow tape) is practical during resuscitation and can significantly reduce errors during the ordering phase,⁵ and the use of such systems should be encouraged.

Limitations

It is not clear whether one can extrapolate the data from our model to real patients. Yet, this experimental model gave us the opportunity to analyse the actual syringe contents of the drugs given and to detect discrepancies that could not be detected in real resuscitations. Because observers were located in different positions in the resuscitation room we did not try to assess interobserver reliability or the differences between the data collected by the observers and the data seen on the videotape.

Our model could not adequately simulate the emotional stress and other factors such as fatigue, which may occur during real resuscitation. Moreover, because the scenarios were videotaped participants may have tried harder to perform their best. The rate of drug errors identified by us could be lower than the actual incidence during real life resuscitations.

Since the completion of the study the Broselow tape and resuscitation carts are now used during resuscitations. Drugs are given from the cart on the basis of the estimated weight of the child, with a colour coded system. We also increased the number of mock codes to give trainees more opportunities to practise resuscitation and developed and implemented a formal teaching programme on the use of sedation and intubation drugs for staff and trainees.

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Women in medicine: the changing pattern over the past 50 years

The attitude to women in medicine has radically changed over the years. I qualified in the mid 1950s, having previously gained state registration in nursing.

While a schoolgirl, I had seen so many sixth form girls being rejected for medical training, so I decided to take up nursing. After qualification, still dreaming about medicine, I sought an interview with matron to say that I had decided to apply for a place at medical school. Anger was expressed. She gave no support. Luckily I was offered an interview at a London teaching hospital. The candidates were mainly men.

During my interview, the basic contents of matron's reference were revealed. They were damning. Eventually the dean asked where I would live during training. I replied that, for financial reasons, I would remain in my parent's suburb home; I was told that rail travel would limit the time I could spend on studying. I was questioned about my marital status, whether I was still unattached. I was at the time.

Finally I left and sat miserably in the peaceful hospital grounds, realising that women were still not welcome in medicine. Suddenly a tall figure approached and looked down at me. I recognised the dean. I still remember his angry words: "I cannot, I will not abide autocratic females. Keep this confidential." Firmly he marched away.

Unbelievably, some weeks later I received a letter of acceptance. Immediately I wrote a letter of thanks to matron, letting her know that her reference had undoubtedly secured me a place in medical college. She did not reply.

Later, I formed a firm attachment to a Cambridge medical student. We decided we wanted to train together. I went to the newly appointed dean to explain that we were soon to be married and to ask whether we could train together. The dean smiled and rose from his seat, saying, "Tell him to write, letting me know he wishes to accept a place." Puzzled, I stuttered that he had not yet been interviewed. Ushering me out from his room, the dean's final words were "A place has been allocated."

However, when I informed my local authority, from which I received a grant, about my marriage I was told that marriage made me ineligible and that my grant was therefore cancelled. Fortunately my husband had served in the Royal Air Force, and so a grant was offered.

While I was in training, one disapproving professor refused to accept my new surname. However, I survived, enjoying in particular the clinical elements, and, encouraged by my husband, even entered some of

the hospital scholarships. I benefited enormously from training in the same hospital as my husband. Each of us learnt from the other. Also I was able to act as his chaperone during examinations of patients, thus avoiding the loss of nursing time.

One memory remains particularly vivid. We all dreaded the clinical finals for the MBBS, particularly those in surgery. The examining consultant surgeon was deemed hostile to women. Always unsmiling, he seemed so hard to please. In my finals I was sent to examine a male patient. As I nervously approached him, my small handbag slipped from my shoulder, scattering the contents widely—lipsticks rolled, a shattered compact scattered powder. Acutely embarrassed, I went down on my knees to clear the mess. Suddenly my head cracked against another. Facing me on his knees was that surgeon, smiling and clutching a lace handkerchief.

Happily, I achieved examination success and, surprisingly, had done reasonably well, especially in surgery. Entrance for those hospital scholarships had been a good practice. Hopefully I applied for a house post. "Mrs Edwards, go and have a baby," was the reply from one consultant. These days, I suppose that would be termed sex discrimination. Eventually I was offered a post by a consultant physician to serve as his junior houseman in another of his hospitals.

I look back upon those years with wonder. I owed everything to my matron's reference, and, of course, to that dean's response. Nearly 50 years have elapsed since my qualification. The numbers of women students accepted for training slowly increased over the years, and this September's *BMA News* told me that about 60% of medical students are now women. It seems unbelievable. In these days, would anyone dare to advise a newly qualified married woman applying for a house post to "Go and have a baby"?

Vivian Edwards *retired medical officer, Fort Rise, Newhaven Harbour, East Sussex*

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