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The Effect of Detection Approaches on the Reported Incidence of Tenfold Errors

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Abstract

Background: Tenfold errors in calculation of paediatric drug doses are often life threatening. The magnitude and characteristics of this phenomenon have not been fully described.

Objectives: The objective of this study was to describe the incidence and nature of paediatric tenfold errors and to describe the effect of different detection approaches on the detection of such errors.

Methods: To evaluate the incidence of tenfold errors, data were collected from three different studies on medication errors all conducted at a large tertiary care paediatric hospital: (i) a study investigating medication event reports to the hospital's Medication Incident Committee; (ii) a study auditing the charts of 1532 patients in the emergency department (ED) and; (iii) a prospective study of medication errors occurring during mock code resuscitations in the ED.

Results: In the first study, 20 tenfold errors were reported during the surveyed period. Almost all errors were prescribing errors. The calculated incidence was 1 per 22 500 doses prescribed. In chart auditing study in the ED, two tenfold errors where found in 1678 orders. In the prospective study, four tenfold errors were identified in eight mock resuscitations (125 orders for drugs).

Conclusion: The incidence of tenfold errors in paediatrics varies dramatically when different detection approaches are used. The rate of tenfold errors may be especially high in resuscitation situations and is underestimated by spontaneous reporting.

Background

Medication errors are a major source of morbidity and mortality in both children and adults.[1-3] Such errors can occur at any stage of the decision path from prescription to administration, and may reflect human and/or system errors.[4,5] Dosing errors are a common type of mishap[6] and erroneous use of medication dosage equations may account for a large proportion of dosing errors.[7] Tenfold errors are a particularly concerning subset of mishap as they typically involve a calculation (in the majority of cases) or transcription errors, and have the potential to be fatal.

Several studies have shown that tenfold errors can be reproduced when health professionals are

tested for their computational skills.[8,9] In infants and young children, there is a higher chance of such errors reaching the patient because even a tenfold higher amount of stock solution may appear to be an apparently small volume of drug.

Among paediatric faculty, residents and nurses there is a subgroup prone to commit calculation errors.[8,9] This subgroup is probably at a higher risk for committing a tenfold error. Typically, tenfold errors are published as case reports or case series, and generally highlight the success of toxicological treatment.[8,10,11]

One previous study has shown that tenfold errors represent 15% of all medication prescribing errors involving the use of dosage equations in paediatric patients.[7] However, the characteristics of drugs involved in such errors were not reported in the study. We previously reported on the incidence of tenfold medication errors in a paediatric hospital.[12] The incidence of all types of medication errors has been found to vary substantially by detection approach and the same may be the case for tenfold errors.

The objective of the present study was to estimate the incidence of tenfold medication errors detected by different methodologies in a tertiary paediatric hospital. The study also aimed to identify characteristics of these errors that may help suggest prevention strategies.

Patients and Methods

To evaluate the incidence of tenfold errors we collated data from three different studies[12-14] on medication errors that were all conducted at the Hospital for Sick Children, a large tertiary care facility in Toronto, Canada. These studies were: (i) an investigation into voluntary reports of medication events to the Medication Incident Committee;[12] (ii) a review of patients' charts in the hospital's emergency department (ED);[13] and (iii) a prospective study of medication errors occurring during mock code resuscitations in the ED.[14] In all three studies tenfold errors were defined as a dose that was ten times higher or lower than the recommended dose. The incidence of tenfold errors was calculated with 95% confidence intervals.

Reports to the Medication Incident Committee

We reviewed, in detail, all forms of medication incidents submitted to the Pharmacy Department by all in-patient units and the ED at the Hospital for Sick Children between 1 April and 1 November 2000, to identify any reports of tenfold errors. The Hospital has a central dispensing pharmacy with a satellite pharmacy for the Pediatric Intensive Care Unit. Most drugs are dispensed as a patient unit-dose with a mean of 8.7 medication doses per patient day (range 3–18). In several areas of the hospital, namely the operating rooms, paediatric and neonatal intensive cares, and the ED, drugs may be prepared by the nurses or physicians from ward stock.

The Hospital for Sick Children has a voluntary reporting system for adverse drug events. Nurses, physicians and pharmacists fill in an incidence report whenever an adverse event involving a drug occurs and when a administration error is identified. Although health professionals are encouraged to fill in the reports, this is a voluntary, non-punitive system. The Pharmacy and Therapeutic Committee, and the Medication Incident Committee reviews all the reports. Details of drug errors that are collected include: the drug involved, the erring professional, the circumstances of the incident, and whether the error was intercepted before reaching the patient and by whom. The distribution of the drugs involved in tenfold errors was compared with the most commonly prescribed drugs in our institution.

Chart Auditing in the Emergency Department

We calculated the incidence of tenfold errors through chart auditing in the ED. All charts from 12 randomly selected days during the summer of 2000 were reviewed for medication errors. The review process has been described in detail elsewhere.[13] Briefly, all charts were first screened by research workers who marked possible deviations from the recommended dose for a drug. In a second phase, two emergency paediatricians separately decided whether or not a tenfold error had occurred.

Mock Resuscitations in the Emergency Department

Eight mock resuscitations were conducted as part of the educational rounds in the ED.[14] A team that included a leader (a fellow in paediatric emergency, or senior resident in paediatrics or emergency medicine), at least two assistant physicians (residents or fellows) and two or three paediatric nurses managed each case. The responsible physician conducted a full resuscitation including ordering medications. Cases were inspected by three observers and videotaped. Drugs ordered and administered during the resuscitation were recorded by the researchers. All syringes and drugs prepared during the resuscitation were collected and analysed in the laboratory to ascertain the actual content of the syringes. Two emergency pediatricians and a pharmacist reviewed all the orders and syringes content to determine if a tenfold error had occurred.

Statistical Methods

The rates of tenfold medication errors were compared among the three detection methods (mock resuscitation, audit and spontaneous reporting) by means of the Chi-squared test and Yates correction. The odds ratio (OR) and 95% confidence interval were calculated. No formal sample size calculation was performed, as we used three existing studies with their defined sample sizes.

Results

Twenty tenfold medication errors were reported to the Medication Incident Committee during the 7 months that were audited (table I). During this time period, there were 51 000 patient days with a mean of 8.7 doses per patient day, which totalled 449 834 doses. The incidence of reported tenfold errors was therefore 1 per 22 500 doses.

Two tenfold errors were found in the auditing of 1532 charts (1678 orders for drugs) from the ED (0.12%). The two errors found during chart auditing were not reported through the incident reporting system.

In eight mock resuscitations (125 orders for drugs) we identified four tenfold errors (3.2%). Three of these errors occurred at the ordering phase and one in the administration phase.

The incidence of tenfold errors in the mock resuscitation study was higher than in the chart auditing study (OR 27.7, 95% CI 5.8, 130.5), and the incidence in the chart auditing study was higher than with spontaneous reporting (OR 26.8, 95% CI 7.0, 103.5).

Of the 20 tenfold errors reported to the Medication Incident Committee, 5 reached the children and 15 were intercepted: by pharmacists (n = 12), nurses (n = 2) or physicians (n = 1). All four tenfold errors that occurred during mock resuscitations were intercepted (two by a physician and two by a nurse) before reaching the mock patient. We were unable to determine whether or not the tenfold errors found through chart auditing reached the patients.

The tenfold errors identified through incident reports commonly occurred with pharmacologically potent drugs and with drugs that were not among the top 20 medications commonly used in our hospital. Those found in chart review included morphine and amoxicillin – both commonly used in the ED. The four tenfold errors identified during mock resuscitations involved potent drugs that are not commonly used.

Discussion

We found very large discrepancies in the incidence of tenfold errors among studies in different settings, with different detection approaches. The incidence of tenfold errors was highest in the study looking at mock resuscitations,[14] followed by the study using chart auditing,[13] and was lowest in the analysis of voluntary incident reports.[12]

Although it is not surprising that by using different detection approaches we found different incidences of tenfold errors, such discrepancies must be acknowledged and accounted for.[15,16] In the study of mock resuscitations, physicians and nurses were continuously observed and their actions were videotaped. The four tenfold errors that we identified in that study were all intercepted. It is possible though that these errors would not have been identified if we had used a different methodology, such as chart auditing. The incidence of errors tends to be higher in seriously ill patients.[13] Therefore, different patient selection may account for the much higher rate of tenfold errors during mock resuscitations.

Table I. Characteristics of the tenfold errors identified

Drug order (patient's weight)	Incident and comment	Patient outcome (none, mild, moderate)	Erring health professional	If intercepted, by whom?
Milrinone 8 mg/50mL IV (NA)	Improperly mixed, given as 0.8 mg/50mL	None	Physician	No
Pancuronium 2.5mg (2.7kg)	Patient received 1 mg/kg instead of 0.1 mg/kg	None	Physician	No
PCA pethidine (meperidine) 10 mg/mL total dose limit (NA)	Dose should have been 1 mg/mL Was given for 20h	None	Physician Pharmacy	No
Ciclosporin 8mg PO q12h (NA)	Patient should have received 0.08mL, not 0.8mL stock solution	Moderate Ciclosporin concentration the next day = 956 ng/L	Physician Pharmacy	No
Epinephrine 30mg in 50mL NS 1 mL/min 0.01μg/kg/min at 1 mL/hr (NA)	Should have been 1 mL/h = 1μg/kg/min	None	Physician Pharmacy	No
Clonidine 0.01mg PO (50kg)	Dose should have been 1mg	None	Physician	Yes Pharmacist
Digoxin 2 μg/day (54.5kg)	Dose should have been 20 μg/day	None	Physician	Yes Pharmacist
Amphotericin B 175mg IV q24h (NA)	Dose of 5mg/kg ordered, should have been 0.5 mg/kg	None	Physician	Yes Pharmacy
Diazoxide 4mg PO tid (NA)	4mg = 0.08 mL, pharmacist prepared 0.8mL	None	Pharmacy	Yes Pharmacy
Morphine 7.5mg IV q4h prn (9.22kg)	Order written based on 1 mg/kg/dose, should have been 0.1 mg/kg/dose	None	Physician	Yes Pharmacy
Heparin 1000 U/100mL at 14.4mL/h	Dose should have been 10 000 U/dL	None	Physician	Yes Another physician
Indomethacin 0.7mg IV (NA)	Dose should have been 0.07mg	None	Physician	Yes Pharmacy
Salbutamol inhalation solution (5mg/mL) 1.2mL (NA)	Tenfold higher than recommended	None	Physician	Yes Nurse
Ampicillin 40mg IV q6h × 4 days (NA)	Dose should have been 400mg	None	Physician	Yes Pharmacy
Captopril 7mg (NA)	0.7mg was given of 7mL	None	Physician	Yes Nurse
Penicillin 17 000U (NA)	Dose should have been 170 000U	None	Physician	Yes Pharmacy
Heparin 1000U (NA)	Received 0.1mL (100U) instead of 1mL	None	Pharmacist	Yes Pharmacy
Cefuroxime 50mg IV (NA)	Dose should have been 500mg	None	Physician	Yes Pharmacy
Cefazolin 3300mg (NA)	Physician aimed to give 330mg	None	Physician	Yes Pharmacy
Gentamicin 9mg (NA)	Dose should have been 90mg	None	Physician	Yes Pharmacy

IV = intravenous; **NA** = data not available; **NS =** normal saline; **PCA** = patient-controlled analgesia; **PO** = oral; **prn** = on an as needed basis; **qxh** = every '*x*' hours; **tid** = three times daily.

In a study from a paediatric hospital in the UK,[4] there was one medication error per 662 admissions. Fifteen (8%) of these medication errors were tenfold errors. However, this study did not report on patient dose data, and the overall rate of tenfold errors (15 cases detected over 4 years) is substantially lower than our 20 such errors over 7 months. Our data suggest that such a low rate indicates a low reporting rate rather than a truly low incidence of tenfold errors. Indeed, when pharmacy auditing was used to detect medication prescribing errors, 200 cases of tenfold prescribing errors were detected over an 18-month period in a teaching hospital in New York.[17] These findings are consistent with one previous study that showed that only 6% of adverse drug events are reported through voluntary reporting systems.[18] Thus, the true incidence of tenfold errors may be much higher because of under-reporting of such incidents. As this paper indicates, it is possible that other tenfold errors were neither detected nor intercepted and therefore went unreported. The finding that during mock resuscitations four tenfold errors occurred in only eight scenarios with 125 medication orders, is very disturbing. This incidence is substantially higher than that found using chart auditing and implies that many errors can go undetected unless a very meticulous observation process is in place.

Our analysis of the incident reporting reveals several trends that may have potential importance in prevention.

1. The drugs involved were often highly potent molecules that were given in doses of <1 mg/kg and created a potential source of confusion during the conversion of mg to μg. Most other drugs are given in doses of mg per kg bodyweight. The obvious difference between the identity of these drugs and those given commonly to patients suggests that the tenfold medication errors in children are not a random phenomenon.

2. Physicians committed most tenfold errors. In seven cases the drugs were prescribed by physicians either in the operating room, two different intensive care units or the ED, thus avoiding the 'safety net' offered by our pharmacy through the patient unit-dose system. This lack of a pharmacy safety net is inherent in situations such as resuscitation, which is the same situation in which, as this study shows, the incidence of tenfold errors is the highest and very potent drugs are involved.

It is evident that calculation errors occur even in optimal conditions,[9] such as a test with unlimited time and the use of a calculator. The best way to avoid such errors from reaching paediatric patients is by programming the computer system that transfers drug orders to the pharmacy not to accept doses exceeding the recommended per bodyweight. This means that bodyweight will have to be entered with the name of the drug. Such a system will work only for institutions that can afford patient-dose units. Similarly, it will not help in cases where the doses need to be prepared immediately on the ward (as in seven of our cases). Such a system is presently being piloted in our institution.

Physicians erring in tenfold calculations of drug doses represent a subgroup that may not be random, as these individuals also commit significantly more non-tenfold errors.[9] Among nurses, dose calculation courses and tests are performed in nursing schools. In our institution, nurses are tested for their computational skills before being hired. If they fail such tests, a remedial programme is offered. Repeated failure after the remedial process precludes hiring. Although physicians committed all of the tenfold errors detected in our survey, no similar process, indeed no process at all, exists for physicians.

The fact that in fifteen cases the error was intercepted before harm was done highlights the importance of pharmacy auditing of drug orders and the use of unit administration. Similar to others,[2,19,20] we believe that identifying drug errors, even ones that are intercepted, is important in developing strategies to reduce adverse drug events. This may even be more important in emergencies, where the use of unit dose and computerised drug orders is not feasible.

Computerised medication orders, unit-dose dispensing and pharmacy auditing of drug preparation in the wards are examples of such strategies. Introducing an educational programme on dose calculations for medical students and residents should also be considered. However, as this study demonstrates, some errors occur despite the use of these methods and in circumstances in which these strategies cannot be implemented.

By comparing the data from three different sources we were able to show that the incidence of tenfold errors in paediatrics varies dramatically when different detection approaches are used. These variations should be considered when the effects of different interventions on the rate of tenfold errors are tested.

Conclusion

The incidence of tenfold errors in paediatrics varies dramatically when different detection approaches are used. The rate of tenfold errors may be especially high in resuscitation situations and is underestimated by spontaneous reporting.

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