Arch Dis Child 1998;**79**:56–58

Errors by paediatric residents in calculating drug doses

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Abstract

***Background*—Errors in calculating drug doses in infants and small children can cause morbidity and mortality, especially with agents exhibiting a narrow therapeutic window. A previous study from this institution has detected potential life threatening errors in calculations performed by trainees while writing prescriptions.**

***Objectives*—To verify whether the true incidence of trainees' errors in prescribing can be explained by impaired calculation skills in written tests.**

***Setting*—A tertiary paediatric hospital; educational rounds for core paediatric residents.**

***Methods*—Two anonymous written tests, which included calculations of doses similar to those performed at the paediatric bedside; one was conducted in 1993 and one in 1995.**

***Results*—Thirty four paediatric residents participated in 1993 and 30 in 1995. A substantial number of trainees in both years committed at least one error. In general, there was no correlation between the length of training (0 to 4 years) and likelihood of making a mistake. Three trainees in 1993 and four in 1995 committed 10-fold errors. These seven residents committed significantly more errors than the rest of the group in each of the tests separately. All seven were in their first two years of training, and six were in their first year of residency.**

***Conclusions*—A substantial proportion of paediatric trainees make mistakes while calculating drug doses under optimal test conditions. Some trainees commit 10-fold errors, which may be life threatening. The results of these anonymous tests suggest that testing of calculation skills should be mandatory, and appropriate remedial steps should follow to prevent paediatric patients receiving wrong drug dosages.**

(*Arch Dis Child* 1998;**79**:56–58)

Keywords: prescribing errors; residents; toxicity

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Accepted 3 February 1998

Errors in calculating drug doses have long been recognised as an iatrogenic cause of morbidity and mortality. In infants and small children such errors are more likely to be life threatening. A variety of measures has been suggested to prevent these misadventures, including double checking calculations, and patient-unit doses prepared in the pharmacy department.[1] In a recent two month audit conducted at our institution, clinical pharmacists intercepted 19 cases of erroneous dose orders written by paediatric trainees, 10 of them of 10-fold magnitude or more, five of which would have resulted in serious morbidity or death.[2]

It could be argued that such errors may stem from many factors such as poor medical knowledge, excessive work load, and fatigue, and not from simple calculation errors. However, in a previous study of paediatric nursing and medical staff, we found that calculation errors were common.[3] In a typical North American setting, it is the paediatric resident who calculates and orders most drug doses. At present, the ability of house staff to calculate doses correctly has not been examined.[2] This study aimed to verify whether a written test, administered in optimal conditions, can detect residents who commit calculation errors in general, and 10-fold mistakes in particular. If such individuals can be detected, then remedial and preventive steps may be taken to decrease the risk of such errors from reaching the paediatric patient.

Methods

In January 1993 the medical advisory committee of the Hospital for Sick Children in Toronto, Canada formed a task force to review all practices involved in drug administration to children and to recommend how to reduce the risk of medication errors.[4] Among its recommendations this subcommittee acknowledged the need for an educational programme to ensure appropriate calculation skills of all trainees. Consequently, it tried to verify whether a written test can detect individuals with inadequate calculation skills; if yes, then such a tool may be used to screen trainees before allowing them to order drugs for paediatric patients.

Two tests were conducted two years apart (in 1993 and 1995). In the first test, eight computational questions were prepared, which covered calculations similar to those encountered by paediatric trainees while ordering drugs (questions 1–8, table 1). In addition to calculating doses, the participants were asked to comment in an open ended fashion on doses that seemed inappropriately large or small for the given age, and in several questions the doses were deliberately set to be too high. The trainees were also asked to specify their length of training (between R_1 and R_4 (residency years 1 to 4)). In the second test, two additional questions that required different types of calculation of doses, equally likely to be encountered by paediatric trainees, were added (questions 9 and 10, table 1).

Table 1 Questionnaire used to test paediatric residents' drug dose calculation skills

This is an anonymous questionnaire

Please make the following dose calculations. Use a calculator or any other means you use routinely

If you have any comments about any of the doses, please write in the "comment" space

1	A 3 day old baby is treated with 15 mg of phenytoin intravenously. The ampoule contains 50 mg/ml. The baby should receive _____ml.
Comment:______	
2	98 mEq of potassium chloride has to be added to intravenous fluids. The ampoule contains 20 ml with a potassium concentration of 3.2 mEq/ml. You should inject ____ml of the solution.
Comment:______	
3	A child with hyperglycaemia has to receive 8 U of insulin. The solution contains 40 U/ml. The child should receive _____ml.
Comment:______	
4	A preterm infant is to receive 0.3 g of calcium gluconate intravenously. The solution contains 10% calcium gluconate (10 g/100 ml of the solution). The infant should receive _____ml.
Comment:______	
5	A toddler is treated with 32 mg of gentamicin intravenously. The solution contains 40 mg/ml of gentamicin. The baby should receive _____ml.
Comment:______	
6	A baby is treated with theophylline intravenously. The order was for 35 mg. The ampoule contains 250 mg/5 ml (50 mg/ml). The child should receive _____ml.
Comment:______	
7	A 12 month old child is to receive 0.625 mg of intravenous digoxin during digitalisation. Each millilitre of Lanoxin contains 0.250 mg. How many millilitres of Lanoxin should be received? _____ml.
Comment:______	
8	A 2 kg child received 1.6 ml of Lanoxin (0.250 mg/ml). How many milligrams did the child receive? _____mg.
Comment:______	
9	A 2 month old infant was prescribed 0.3 ml of phenobarbital for seizures. The concentration of the solution is 30 mg/ml. She received 3 ml instead. How many milligrams were given? _____mg.
Comment:______	
10	A child weighs 74 lbs. How many kilograms does he weigh? ____kg
Comment:______	
I am a:	paediatric postgraduate year 1 paediatric resident surgical resident family practice resident other (specify):
Years in training ____	

To test the questionnaire for clarity, the first version was administered to 24 trainees in the Division of Clinical Pharmacology during their weekly round, following which typographical errors and unclear sentences were changed, and a larger variety of possible situations was added.

The first test (1993) was given to 34 core trainees in paediatrics (R_1 to R_4) during their weekly educational round. The second test (1995) was given to 30 core trainees during a similar round. Participants who did not have a calculator were offered one, and all were asked to solve the problems independently and anonymously. The participants were allowed unlimited time to answer the questions, and all were handed in within 20 minutes.

The test was followed by an educational session that highlighted the seriousness of these errors, examples of common errors, and the correct solution to the questions. Comparison between groups was performed by the Student's *t* test for unpaired data. Correlations were tested by last square regression analysis. Data are presented as means (SD).

Table 2 Errors in calculations among paediatric residents in two tests

	1993	*1995*	*p value*
Number of participants	34	30	
Number (%) committing > 1 error	19 (5.6)	9 (3.0)	0.03
Number (%) of wrong calculations	26 (8.45)	13 (4.3)	0.01
Number (%) of 10-fold errors	3 (8)	4 (7)	NS

Results

FIRST TEST

Thirty four paediatric residents participated in the first test in 1993 (nine at R_1 level, and seven of each of R_2, R_3, and R_4; four participants did not specify their length of training). Overall, 19 participants committed at least one error (table 2); 26 calculations were wrong, (8.45% of all calculations). There was no correlation between the length of training (0 to 4 years) and likelihood of erring. Three trainees committed one 10-fold error each and overall these three committed significantly more errors (2 (1) per person, range 1–3) than the rest of the group (0.8 (0.8) per person, range 0–3) ($p = 0.03$). Two of the trainees committing 10-fold errors were R_1 and one was R_2.

In two questions the dose was deliberately set to be excessive for the given age group. Only four of 34 participants detected both inappropriate doses; overall 41 of the inappropriate doses were missed (60.3%), an average of 1.2 out of 2 per participant.

SECOND TEST

The second test was given to 30 paediatric residents in 1995 (14 R_1, 10 R_2, two R_3, three R_4, and one R_6). Nine participants (30%) made at least one error in calculation (table 2); 13 (4.3%) calculations were wrong. Four trainees made five 10-fold errors; on average these four committed 1.4 (0.45) errors, significantly more than those who did not commit 10-fold errors (0.27 (0.12)) ($p < 0.01$).

Four questions in the second test had erroneously excessive doses. Only one of 30 candidates recognised all four inappropriate doses, one other candidate detected two of the inappropriate doses. Therefore, 114 of the 120 inappropriate doses were missed (95%). Again, there was no correlation between the length of training and overall tendency to make a mistake; however, all four individuals committing 10-fold errors were in their first year of training.

Overall, between the two tests there was a 50% decrease in errors between 1993 and 1995 ($p < 0.01$), however, no difference was detected in the percentage of trainees committing 10-fold errors.

Discussion

The severity and seriousness of paediatric medication errors have been highlighted predominantly through case reports and mainly to appraise successful management of toxicities.[5 6] However, little has been done to measure the incidence of these, often life threatening, misadventures. In a recent audit of our pharmacy practice we detected a clinically important number of errors in prescriptions written by trainees during a two month survey.[2]

Nursing schools dedicate time and efforts to teach their students how to calculate drug doses and subsequently test them for these skills. Medical schools do not follow suit, thus passively assuming that students who have made it thus far can be trusted to perform such calculations without errors. In setting out to test calculation skills of paediatric trainees we wished to verify whether there is a subgroup of individuals for whom such an assumption may not be correct.

During the preparatory phase of this questionnaire some of our colleagues were doubtful whether such a simple test could have the sensitivity to detect individuals who make calculation errors. It was argued that on the ward, because of work load and fatigue, residents are likely to make mistakes that they may not make under ideal test circumstances.

The rationale for repeated tests two years apart was to validate trends more accurately and to avoid generalisations stemming from a single group of trainees. The trends between the two groups of trainees were very consistent.

Our data reveal that a substantial number of participating trainees committed at least one calculation error. The lack of correlation with length of training suggests that clinical experience has little to do with making these mistakes, and that the necessary skills for appropriate calculations are obtained (or missed) much earlier during one's education.

Of special concern are the residents who committed 10-fold errors. Our results suggest that these were not randomly committed, because these trainees made significantly more mistakes than the rest of the group in both years tested. Although impossible to prove, it is very likely that trainees with impaired calculation skills during a written test may perform even worse during work overload and fatigue commonly encountered during a typical paediatric residency. The fact that all seven individuals committing 10-fold errors were in the first two years of their training, and six of them in their first year, suggests that training and experience may be important factors in preventing such mishaps.

Even if the test results are a conservative estimate of the incidence of such errors, these would translate in an intensive care nursery where many infants receive 10 different drug orders each day,[7] to one 10-fold error for each 10 infants; if not intercepted by other members of the medical, nursing or pharmacy staff, they can often be life threatening.[2] In most cases the residents were not able to identify deliberately excessive doses; this means that once a 10-fold calculation error has been made, it is not likely to be intercepted by housestaff based on knowledge of the right dose.

The overall decrease in rates of calculation errors between 1993 and 1995 may be the result of a concerted educational effort at our institution after 1993, following identification of this problem to be a high priority institutional issue.[4] Conversely, it may be chance or unrecognised differences in the quality of trainees at the two tests. The consistent trends and rates of 10-fold errors in a group of "accident prone" individuals who were in their first years of training, is important both clinically and educationally.

Our data document that a simple test can detect individuals with impaired calculation skills. We believe that such individuals should be screened before starting their paediatric training and undergo a remedial programme before being allowed to prescribe for sick children.

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