Can medical students calculate drug doses?

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Abstract

Objectives: A doctor's ability to calculate drug doses is a skill that is generally assumed. We assessed medical students' performance when given four types of dosing calculations typical of those required in an emergency setting.

Design: Longitudinal study.

Setting and subjects: Students were assessed at the beginning of the third year, and repeatedly during the third and fourth year while receiving training in dosage calculations. Competence was defined as correctly answering all four categories of calculation at any one time, i.e. a score of 100%. Failure to respond correctly to the individual questions was also analysed because an incorrect calculation could be equated with a "patient" receiving a wrong dose.

Outcome measures: Outcome measures were the percentage of students achieving competence and the proportion of times students showed competence relative to their total number of opportunities. A further outcome was the percentage of calculations incorrect i.e. potential "patients" harmed.

Results: Of the 364 students, 23% were competent at the beginning, while 66% achieved competence at least once by the end of the study. Students were competent 31% of the time and calculated the wrong dose for 34% of "patients". Eighty-two students were competent at baseline, 157 became competent and 125 never achieved competence. They calculated the wrong dose for 9%, 31% and 51% of "patients" respectively. Although race and home language were predictors of performance at baseline, both associations had been lost by the time competence was achieved. All students experienced the most difficulty with calculations when the drug concentration was expressed either as a ratio or a percentage.

Conclusion: Our findings support calls for the standardised labelling of drugs in solution and for dosage calculation training in the medical curriculum.

Introduction

Medicine errors, which affect 50% of hospital admissions, are a source of morbidity and mortality in patients worldwide.[1,2] Prescription writing was the worst performed skill of those tested, with an achieved score of 55.3% in a South African study of students who had graduated, but not yet registered.[3] Errors in administration, particularly those relating to dosing, were one of the key findings in a UK report by the National Patient Safety Agency.[4] It is important that attention is paid to trying to ensure that drug doses are calculated correctly. Prescribers recognise this. In a USA study, 83% of 175 respondents reported that they considered prescribing errors to be unacceptable.[5] In an Australian study, 190 doctors who were given a 12-item dosage calculation test felt that achieving 91.6% (11 out of 12 correct) was acceptable. However, they scored at a significantly lower level than this, attaining a mean of 72.5%. The authors of the study were concerned that the majority of participants (79%) reported that they had not been tested for this ability previously, a finding which suggests that this skill is assumed.[2]

Wheeler et al[6] found that the majority of tested medical students were unable to correctly determine what mass of a drug was contained in a particular volume of solution.

These authors believe that this skill is overlooked in medical education and recommended that students should be familiar with such arithmetical concepts when they begin prescribing. Burch et al[7] pointed out that in the South African context, academic performance may be a particular problem for students who enter university with a poor educational background. Such students arrive at medical school and are at a particular disadvantage in terms of the literacy and numeracy skills that are needed to extract, interpret and manipulate relevant information for the appropriate administration of medication.

In the present study, we investigated the ability of medical students at the Nelson R Mandela School of Medicine in Durban to calculate drug doses.

Method

Ethical approval (Reference No BE185/09) was obtained from the University's Biomedical Research Ethics Committee. After students entered the third year, they provided written informed consent and received an hour-long introductory lecture before relevant questions were included in their first test (the baseline assessment). They were then tested repeatedly until the end of fourth year. Questions were included in the formal exams and tests that the students wrote. Questions were answered under exam conditions. Because some students failed and wrote supplementary exams, some of the students were not tested the same number of times. During the course of the study, training involved formal lectures and tutorials, as well as assignments with model answers for self-assessment.

There were four dosage calculations in every test. One involved the drip rate, while the other three focused on the required volume of a medicine to be administered when the drug concentration was expressed either as a mass per unit volume, a ratio or as a percentage.

A student was only considered to be competent provided he or she had all four types of calculation correct in a particular test, i.e. attained 100%. An investigation was carried out into how many students began competently after the brief introductory lecture. It was determined how many tests were required to achieve competence for those who were not. The progress of the students was then followed to establish whether or not they had retained the ability to score 100% over time. The percentage of time that they were competent was also computed: the number of tests in which each student scored 100%, i.e. was competent, in relation to the total number of tests written, was then determined.

Although competence was defined as getting all four types of calculations correct at one attempt, each calculation represented a patient in real life with the potential to receive an incorrect dose. Accordingly, the findings for each student were broken down into success, or otherwise, using individual questions. Thus, in effect, the number of "patients" who would have received the wrong dose and had the potential to have been harmed by the students could be investigated. The number of incorrect answers provided by each student was determined in relation to the total number of questions answered throughout the course of the study.

To establish which type of calculation the students found to be the most difficult, the number of times each student made an incorrect calculation as a percentage of the total number of opportunities available to answer that type of question, was determined. Differences were assessed using a paired Student's t-test. A p-value of < 0.05 was considered to be statistically significant.

Demographic factors, such as gender, race, English as a home language and school-leaving score were investigated as predictors of performance using Epi Info™ version 3.5.3. To assess significance, the chi-squared test was used for the categorical data (gender, race and English as a home language), while Student's t-test was used for school-leaving scores. Relative risks were also calculated. A p-value of < 0.05 was considered to be statistically significant.

Result

The majority of the 364 students in the study were women (59%). One hundred and eighty-seven (51%) spoke English as a home language. African students accounted for 50%, Indian students 40% and the remaining 10% were white or of mixed race. Of the 336 (92%) who had written the official South African school-leaving examination before entry to medical school, the average (standard deviation) school-leaving score was 44 (5.6) out of a possible 50 points.

Table I: Student outcomes

Group (the number of students)	Students who were competent at the start	Fraction of time that the students were competent	Overall "patients" receiving the wrong dose	Students retaining competence	Median tests after competence (range)	"Patients" receiving the wrong dose after competence
Group 1 (82)	100%	75%	9%	44%	2 (1-7)	13%
Group 2 (157)	0%	39%	31%	71%	1 (0-4)	20%
Group 3 (125)	0%	0%	51%	N/A	N/A	N/A

N/A: not applicable
Competency equated to all four question or calculation types being correct
Each calculation represented a patient in real life with the potential to receive an incorrect dose
Group 1 was competent at the start; Group 2 became competent; Group 3 was never competent

Of the 364 students, 23% (82) were competent at the beginning, while 66% (239) were able to score 100% at least once by the end of the study. Although this represents an overall improvement, detailed analysis of individual students' progress revealed three distinct groups: those who were competent at the start (82), those who developed competence in a later assessment (157), and those who never achieved competence (125).Thus, approximately one third were never competent, even by the end of their fourth year. Some students failed to retain competence in the first two groups. These results are summarised in Table I.

The 82 students in group 1 were competent 75% of the time because only 36 continued to answer all of the questions correctly in the tests. Of a total of 968 questions ("patients"), group 1 students made 85 mistakes. In other words, despite starting out competent, in a real-life situation they would have calculated the wrong dose for 85 patients (9%).

Although 157 students were not competent to start with, they achieved competence and were competent 39% of the time. Most of them (88%) needed only two or three attempts to become competent. The average number of attempts required was three. Details of the number of attempts required by all 364 students to achieve competence are shown in Figure 1.

In total the157 students made 664 incorrect calculations out of a possible 2 156 ("patients"). Overall, they could have negatively impacted 31% of "patients". However, once they became competent, this figure was reduced to 20% (87 incorrect calculations out of 440).
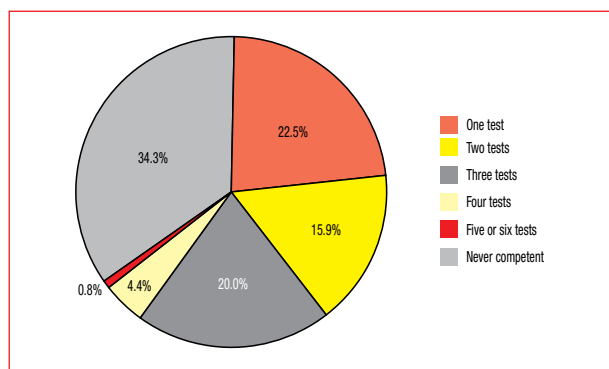

Figure 1: Proportion of attempts required to achieve competence (364 students and 1 258 tests)

Although 125 never became competent, they correctly calculated 943 doses out of a possible 1 908. Conversely, they made 965 errors. Therefore, they would have administered the wrong dose of drug to 51% of their "patients".

Considering all 364 students, they were competent 31% of the time. Overall, they calculated the wrong dose for 34% of "patients".

Even though, as expected, group 1, 2 and 3 performed best in that order, calculations when drug concentrations were expressed as a ratio and percentage presented more of a challenge than the mass per volume and drip rate calculations. These differences were statistically significant (p-value < 0.05) (Table II).

The mean school-leaving score was a predictor of achievement at the beginning (p-value = 0.0001), and to a lesser extent by the time competence was achieved (p-value = 0.0046). However, the differences were very small: 3 and 1 points in the scores respectively. Although there was a relative risk at baseline of 1.2 (1.1-1.4) for not speaking English at home, this effect was lost by the time competence was achieved 1.3 (1-1.7). The relative risks for black Africans were 1.2 (1.1-1.3) and 1.3 (1-1.8), respectively. Gender was not associated with competence at either stage.

Discussion

Our finding that 23% of the students achieved 100% in their baseline assessment was similar to the results of the Australian study in which 28% of participants scored over 90% in a test comprising dosage calculations typical of those required in emergency settings.[2] The Australian participants had the advantage of being qualified doctors so they would already have benefited from clinical experience, whereas our students were given an introductory lecture, which was not offered in the Australian study. Our students had the disadvantage of the stress induced by an examination environment and the fact that the paper cases lacked the contextual setting of the "real world". Another difference was that besides questions involving the concentration of medicine in solution, expressed in different forms (included in both studies), our study also tested the ability to determine drip rates.

Table II: Percentage of time a particular type of question or calculation was answered incorrectly (or, by definition the percentage of time a "patient" would have received the wrong dose)

Group (number of students)	Drug concentration given as a mass per volume	Drug concentration given as a percentage	Drug concentration given as a ratio	Calculation of drip rate
Group 1 (82)	5%	12%	13%	6%
Group 2 (157)	22%	38%	41%	21%
Group 3 (125)	37%	64%	64%	37%
Total (364)	25%	43%	44%	24%

Competency equated to all four question or calculation types being correct
Group 1 was competent at the start; Group 2 became competent; Group 3 was never competent

Training was of value to the extent that of the 282 students who were incompetent at the start, 157 achieved competence and needed on average three tests to achieve this. Although these findings are in broad agreement with those of Wheeler et al,[8] it is very worrying that even after repeated training sessions and assessments over approximately 18 months, 125 students never became competent and calculated the wrong dose of drug in 51% of their attempts.

Overall, students who were competent in the first test performed the best. They were competent 75% of the time, almost twice as often as those who became competent during the course of the study (39% of the time). Although more of the students who became competent during the study retained their competence (71% versus 44% for those who were initially competent), this was not a reliable figure because students in this group had fewer opportunities to remain competent. This was because they had exhausted tests in the early part of the study to gain competence. Because competence was defined as achieving 100%, loss of competence did not reflect the incorrect calculations, i.e. the number of "patients" who received the wrong dose, which, as a result, is a better guide. Overall, students who were initially competent would have administered the wrong dose of drug to only 9% of patients, in comparison to the group who achieved competence, who had the potential to harm 31% of patients. Also, when considering post-competence performance for both groups, the initial achievers would have administered the wrong dose to 13% of patients, approximately half as many as the 20% in the later competent group. Thus, obtaining a good grounding in school of basic arithmetical concepts is particularly important.

Training is perhaps especially critical in our setting as we showed that the relative risks of not speaking English at home and of being a black African were lost by the final opportunity. This suggests that repeated practice and training opportunities allow time to resolve language-related difficulties that might otherwise hamper dosage competence.

Our students performed best when calculations involved mass per volume and drip rate. The finding that ability was influenced by the way in which concentration was expressed confirms that of previous studies in the UK and Australia, where, like ours, candidates fared significantly worse in the ratio and percentage questions.[2,9] These types of calculations were the most problematic, even for our "best" students who were competent at the start of the study. Personal communication with students suggested that they had difficulty conceptualising concentrations that were expressed in this way. For example, when asked to determine the amount of drug in 5 ml of a 10% solution, many students thought this meant that 10% of 5 ml was required.

These calculations also require an additional step, the conversion of the concentration in its ratio or percentage form to one expressed in units of mass per volume. Wheeler et al[9] noted that in other fields of research it was shown that an increase in the number of actions required to complete a process increased the risk of error. Accordingly, they called for the labelling of drugs in solution to be standardised to mass per unit volume.

Smith and Wheeler also stated that until such drug labelling changes are made, the problem will need to be addressed by appropriate undergraduate training.[10] We agree with both their call for labelling changes and for training, and have now made further adjustments to our curriculum to introduce dosage calculation tuition even earlier.

Acknowledgments

Conflict of interest

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this paper.

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