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Evaluation of the ability of pharmacy and medicine students to calculate drug dosage

LYNNE MEYLER[1], ZEBUNNISSA RAMTOOLA[1], JAMES BARLOW[1*]

[1]*School of Pharmacy, Royal College of Surgeons in Ireland, York St., Dublin 2.*

Abstract

Background: The skills and competencies of healthcare professionals have become an increasing focus of healthcare research. It has been reported that many newly graduated healthcare professionals have low levels of competency in the area of drug dose calculation.

Aims: To assess the ability of healthcare students at our institution to perform drug dose calculations and to obtain the opinions of those students regarding perceived calculations competency and training.

Methods: First and final year pharmacy students and final year medicine students were invited to complete a questionnaire, consisting of drug dose calculations and opinion questions.

Results: The results showed that final year students were competent in calculating dosages based on body surface area and those expressed in international units (IU). They were competent in calculating renal function and the number of tablets required for a prescription. However, 83.5% of students had difficulties interpreting strengths or doses of drugs.

Conclusion: Drug dose calculation continually provides challenges among healthcare graduates, and additional and varied learning resources may enable students to attain and retain an acceptable standard of skill throughout their professional careers.

Keywords: *Drug dose calculations, pharmacy, medical students*

Introduction

In healthcare, errors made with regard to drug therapy often lead to adverse drug reactions (ADRs) that may have serious implications for patients. Calculation-based errors have led to both accidental underdosing and overdosing of patients with serious consequences. Many preventable errors are made due to inappropriate levels of knowledge, lack of checking protocol and discrepancies between calculation methods (Oldridge, Gray, McDermott & Kirkpatrick, 2004). One of the leading causes of drug administration errors is dose miscalculation. Wheeler et al. (2004) found that there is the potential for confusion and order-of-magnitude errors, which can lead to adverse drug reactions and even death in patients. Wright (2006) stated that not only do healthcare professionals need to be taught how to calculate properly, they also need to have the clinical knowledge which allows them to judge when a drug dose is obviously incorrect. In another study by the same author (Wright, 2007), it was concluded that healthcare students make mistakes in carrying out basic arithmetic calculations and lack understanding of the mathematical or clinical concepts to be applied. It was found that while the use of calculators assisted in speeding up basic calculation processes and helped when a lack of basic mathematical skills was an issue, they did not help when the problem was an inability to conceptualise the calculation.

A number of studies focussed on drugs used in emergency scenarios in practice. Examples of these drugs include adrenaline, lidocaine, atropine, potassium chloride and heparin (B. Degnan et al., 2006; S. Rolfe & N. Harper, 1996; D. Wheeler et al., 2004; D. Wheeler & S. Wheeler, 2004; D. Wheeler, S. Wheeler, T. Ringose, 2007). In emergency circumstances healthcare professionals are required to quickly and accurately calculate doses and administer drugs. In busy, distracting, stressful situations such as these it is imperative that professionals are proficient in calculating drug doses. Oldridge et al (2004) observed that while a doctor may prescribe drugs and write doses in milligrams, etc. it is generally the remit of nurses and pharmacists to interpret prescriptions and patient charts in order to dispense and administer the drugs to patients. This might suggest that doctors do not need the same level of skill in the area of drug dose calculations. However, for safety and checking protocol it would be beneficial if all allied health professionals had the same degree of calculation skills, allowing them to check each other's work and ensure patient safety. Specialists should also have adequate skills in calculations before they are allowed to prescribe independently, especially in areas like paediatrics (Glover & Sussmane, 2002). While it is accepted that a good understanding of calculations and a high level of skill should be obtained by students initially in their various healthcare courses, it is necessary for these skills to be revised and reinforced through regular and continuous practice throughout their professional careers. It has been shown that intensive drug administration teaching using an online module and high fidelity simulation improves drug administration skills in the medium term (Wheeler et al., 2008). Studies have concluded that formal teaching should

*Correspondence: James Barlow, *School of Pharmacy, Royal College of Surgeons in Ireland, York St., Dublin 2. Tel: + 353 (0)1 402 8520. Email: jambarlow@rcsi.ie*

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be supplemented when health professionals enter practice to ensure they have the ability to calculate correctly (Wheeler et al., 2007; Glover & Sussmane 2002). From the perspective of entry-to practice in pharmacy in Ireland, this is reflected in the 2011/12 syllabus for the National Pharmacy Internship Programme (NPIP), where a module on patient care-safe dispensing encompasses calculations skills, and will be incorporated in the terminal assessment. The Pharmaceutical Society of Ireland (Registration) Rules 2008, Schedule 2, sets out the requirement for submission of proof that CPD (Continuing Professional Development) has been undertaken by the pharmacist when applying for continued registration. It is therefore the responsibility of the individual pharmacist to maintain an adequate level of calculation skill under these rules. Until 2009 at RCSI, formal calculations training was included in the first year of the pharmacy degree course only, although both medicine and pharmacy curricula included informal calculation applications throughout. The objective of this study was to evaluate and compare the ability of final year pharmacy and medicine students to calculate drug dosage as they were nearing the end of their formal training. The ability of first year pharmacy students subsequent to receiving their calculations training was also examined.

Methods

A survey questionnaire was designed to comprise of two distinct sections, the first containing opinion questions and the second consisting of drug-dose questions requiring use of calculation skills (see Appendix for content). The survey was conducted with first year pharmacy, final pharmacy and final medicine students in the Royal College of Surgeons in Ireland (RCSI). All 290 (56:49:185) students in the study population were informed of the survey by mass email, from their class representatives or lecturers. Of these, a total number of 137 (38:37:62) healthcare students were directly invited to take part in the survey, as they were present when the survey was conducted. Of the 137 students, a total number of 106 students participated giving an overall response rate of 77.4%. Response rates for first pharmacy and final pharmacy were 100%, as all first pharmacy students (n=38) and final pharmacy students (n=37) who were invited, participated in the survey. The response rate for final medicine was 50%, with 31 of the 62 final medicine students invited to complete the survey participated in the survey. The lower level and response rate of medical students may be ascribed to their commencement of clinical rotations at different sites over Ireland and hence all were not available at the survey time and venue.

To complete the survey students were permitted to use calculators. It was requested that they did not source answers from any additional resources or collaborate with each other. Students were informed that the survey should take approximately twenty minutes, however after this time period any students opting to complete the survey were allowed extra time. This was desirable as the aim of the survey was to assess skill levels of the students; time pressure to complete the questions was not an issue. Notification of the survey was sent to the students via email the evening prior to survey date in order to avoid the opportunity for revision of calculations by the students and subsequent influence on the scores. For the purpose of marking, answers to questions were either deemed as correct, incorrect or unattempted as per the method previously reported by Oldridge et al. (2004). These criteria were appropriate due to the nature of the questions being asked; if a student, as a qualified professional in the future, was unable to complete the questions correctly then it could lead to drug administration errors with associated health consequences for the patient.

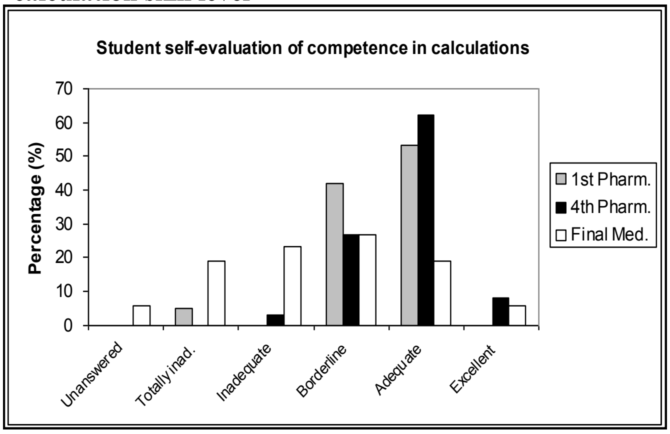
The results of the survey (including both opinion and calculation questions) were collated and analysed using Microsoft Excel. The results of questions were analysed in terms of total sample of students surveyed and then stratified into the different class groups for further analysis and comparison. Scores of individual questions were also analysed and compared.

Basic statistical analysis was carried out using Microsoft Excel. The Data Analysis Toolpack was used in order to generate descriptive statistics for the groups. The chi-squared test was used to determine if a significant difference between groups existed (Preacher, 2001). Permission to conduct the survey was obtained from the College Dean and from the participating students themselves.

Results

Students were asked to rate their level of calculation skill prior to completing the calculations section of the survey. Results for first pharmacy, final pharmacy and final medicine are presented separately in Figure 1.

Figure 1: Student baseline opinions of drug dose calculation skill level



Overall 5 students (3 final pharmacy and 2 final medicine students) rated their level of skill as excellent and of these one (in final pharmacy) received a score of 10/10; the other two final pharmacy students had a score of 5/10 each and the two medicine students scored 7/10 and 4/10 respectively.

Regarding the calculations section of the survey, scores for each individual participant were ascertained. Scores and averages for final year pharmacy and final year medicine (denominator 10) and for first year pharmacy (denominator 8) were given as they were asked to complete only the first 8 questions which were relevant to the calculations module they had completed prior to the survey. Both groups of final year students, pharmacy and medicine, attempted a higher proportion of questions asked (98.9% and 78.4%, respectively) than first year pharmacy students (71.4%), with a higher percentage of correct answers (68.6% and 40.0%, respectively) in comparison with the first year pharmacy students (33.2%). The scores and percentages for

Table I: Results of calculations questionnaire

Question	Number of students	Correct answer	Incorrect answer	Unattempted
Strength & unit conversion (Epinephrine)	All students (n=106)	19 (17.9%)	76 (71.7%)	11 (10.4%)
	First pharmacy (n=38)	2 (5.3%)	32 (84.2%)	4 (10.5%)
	Final pharmacy (n=37)	13 (35.1%)	24 (64.9%)	0 (0%)
	Final medicine (n=31)	4 (12.9%)	20 (64.5%)	7 (22.6%)
Strength & unit conversion (Epinephrine)	All students (n=106)	16 (15.1%)	69 (65.1%)	21 (19.8%)
	First pharmacy (n=38)	2 (5.3%)	26 (68.4%)	10 (26.3%)
	Final pharmacy (n=37)	14 (37.8%)	22 (59.5%)	1 (2.7%)
	Final medicine (n=31)	0 (0%)	21 (67.7%)	10 (32.3%)
Dose based on body surface area (Methotrexate)	All students (n=106)	87 (82.1%)	10 (9.4%)	9 (8.5%)
	First pharmacy (n=38)	24 (63.2%)	7 (18.4%)	7 (18.4%)
	Final pharmacy (n=37)	36 (97.3%)	1 (3.2%)	0 (0%)
	Final medicine (n=31)	27 (87.1%)	2 (6.45%)	2 (6.45%)
Number of tablets required to fill a Rx (Prednisolone)	All students (n=106)	61 (57.5%)	41 (38.7%)	4 (3.8%)
	First pharmacy (n=38)	19 (50.0%)	15 (39.5%)	4 (10.5%)
	Final pharmacy (n=37)	27 (73.0%)	10 (27.0%)	0 (0%)
	Final medicine (n=31)	15 (48.4%)	16 (51.6%)	0 (0%)
Millimoles (KCl)	All students (n=106)	38 (35.9%)	47 (44.3%)	21 (19.8%)
	First pharmacy (n=38)	14 (36.8%)	18 (47.4%)	6 (15.8%)
	Final pharmacy (n=37)	23 (62.2%)	14 (37.8%)	0 (0%)
	Final medicine (n=31)	1 (3.2%)	15 (48.4%)	15 (48.4%)
IU (International units) (Heparin)	All students (n=106)	76 (71.7%)	16 (15.1%)	14 (13.2%)
	First pharmacy (n=38)	17 (44.7%)	8 (21.1%)	13 (34.2%)
	Final pharmacy (n=37)	35 (94.6%)	2 (5.4%)	0 (0%)
	Final medicine (n=31)	24 (77.4%)	6 (19.4%)	1 (3.2%)
Calculation of renal function	All students (n=106)	63 (59.4%)	18 (17.0%)	25 (23.6%)
	First pharmacy (n=38)	11 (28.9%)	5 (13.2%)	22 (57.9%)
	Final pharmacy (n=37)	33 (89.2%)	4 (10.8%)	0 (0%)
	Final medicine (n=31)	19 (61.3%)	9 (29.0%)	3 (9.7%)
Nomogram use (Paracetamol overdose)	All students (n=106)	57 (53.8%)	26 (24.5%)	23 (21.7%)
	First pharmacy (n=38)	12 (31.6%)	5 (13.2%)	21 (55.2%)
	Final pharmacy (n=37)	24 (64.9%)	12 (32.4%)	1 (2.7%)
	Final medicine (n=31)	21 (67.8%)	9 (29.0%)	1 (3.2%)
Infusion rate calculation (drops min^{-1})	All students (n=106)	30 (28.3%)	31 (29.2%)	45 (42.5%)
	First pharmacy (n=38)	0 (0%)	4 (10.5%)	34 (89.5%)
	Final pharmacy (n=37)	25 (67.6%)	12 (32.4%)	0 (0%)
	Final medicine (n=31)	5 (16.1%)	15 (48.4%)	11 (35.5%)
Syringe driver calculation (mm hr^{-1})	All students (n=106)	32 (30.2%)	20 (18.9%)	54 (50.9%)
	First pharmacy (n=38)	0 (0%)	3 (7.9%)	35 (92.1%)
	Final pharmacy (n=37)	24 (64.9%)	11 (29.7%)	2 (5.4%)
	Final medicine (n=31)	8 (25.8%)	6 (19.4%)	17 (54.8%)

each individual calculation question for each group of students surveyed are shown in Table I. The overall average score for the student sample surveyed was 4.53. The average score for final pharmacy was 6.86 (SD=1.81), for final medicine it was 4 (SD=1.73) and for first pharmacy it was 2.7 (SD=1.95). Only four of all healthcare students surveyed answered all questions correctly, these consisted of three final year pharmacy students scoring 10/10 and one first pharmacy student scoring 8/8. The highest individual score for final year medicine students was 7/10. The lowest score achieved for final year pharmacy was 3/10, for final year medicine was 1/10 and for first year pharmacy was 0/8. A chi-squared test was used to test if the percentage of correct and incorrect answers was significantly different for each sub-group of students surveyed. A significant difference was found between the scores of the three groups of students, chi-squared value of 36.906 ($P<0.01$). The scores of final year pharmacy were significantly different to the scores of the final year medicine students, chi-squared value of 38.139 ($P<0.01$), and were also significantly different to the scores of the first year pharmacy students, chi-squared value of 80.603 ($P<0.01$).

Students were asked to indicate which of the following five resources they would find useful to aid development of their calculation skills; e-learning modules with self-assessment, extra lectures, a calculations handbook, tutorials and calculations workshops. Among the top rated were the calculations handbook (68.9%), tutorials (63.2%) and e-learning (41.5%)

Discussion

During their studies, both pharmacy and medicine students develop a problem solving skill base and an ability to conceptualise a question and devise their own method of solving it without the need for direct teaching, even though some of the final year students surveyed had difficulty carrying out certain types of calculations. First year students however have not yet developed the skills and confidence to work calculations out without guidance.

Students from first pharmacy, final pharmacy and final medicine consistently scored lowest in those questions based on strength and units conversion. This indicates that students have a poor understanding of the concepts of dilution e.g. 1 in 1000 and concentration e.g. % w/v. It has been stated in a number of studies that many qualified healthcare professionals have trouble in this area of calculations (Oldridge et al., 2004; Wheeler et al., 2004). The results of the survey also revealed that final year students performed better in questions within a clinical scenario (Q6-10) than those not directly so presented (Q1-5). The results of other studies also confirm this theory (Wright, 2006; Wright, 2007; Wheeler et al., 2008). The survey results also showed that while some students rated their calculation skill highly this did not necessarily correlate with a high score in the calculations section and many students achieving high scores did not always rate their level of skill highly. There was a significant difference between the levels of drug dose calculation skills of first pharmacy, final pharmacy and final medicine students. Final pharmacy students had received most formal education and practice in calculation skills of the three groups of students surveyed and this correlated with a higher overall average score in the calculations survey. Scores for final medicine and final pharmacy also correlated with their level of experience and education in calculations with final year students having a higher average score than first year pharmacy students. The survey has found that healthcare students in RCSI have a positive attitude towards calculations as part of their education and future career. Students have a realisation of the importance of calculations in the healthcare setting and the consequences of errors on the treatment of their patients. Students are also interested in receiving extra training and/or additional resources to aid in the improvement of their calculation skills. It has been suggested that guided teaching sessions using a combination of practical and online resources may be the most valuable approach to addressing this issue (Smith & Wheeler, 2010).

Conclusion

In agreement with studies of similar student cohorts, low levels of competency in the area of drug dose calculation is still an issue. Continuing education for newly qualified and experienced healthcare professionals is advisable in order to promote higher levels of skill and maintain calculations skills throughout professional careers. Partly as a result of this study, extra formal calculations training have been subsequently introduced into an inter-professional foundation year module for both medicine and pharmacy students.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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Appendix: Calculations questionnaire

Strength and units conversion

A patient is presented to you in anaphylactic shock. They are carrying an Epi-pen™ device containing 2ml of a 1 in 1000 adrenaline (epinephrine) solution.

1) What is the strength of adrenaline (epinephrine) in the device in mg/mL?

[mg/mL]

2) Using your answer from question 1) determine the total amount of adrenaline (epinephrine) in micrograms that is contained in the Epi-pen™ device.

[mcg]

3) **Dose based on body surface area**

A 14 year old child with leukaemia has been prescribed methotrexate. The dose is 15mg/m^2 weekly.

Using the table below, determine the approximate body surface area of the child and use this value to calculate the total weekly dose of methotrexate.

Age	Weight (kg)	Height (cm)	Body surface (m^2)
Full-term neonate	3.5	50	0.24
1 month	4.2	55	0.27
2 months	4.5	57	0.28
3 months	5.6	59	0.33
4 months	6.5	62	0.36
6 months	7.7	67	0.41
1 year	10	76	0.49
3 years	15	94	0.65
5 years	18	108	0.74
7 years	23	120	0.87
10 years	30	132	1.10
12 years	39	148	1.30
14 years	50	163	1.50
Adult male	68	173	1.80
Adult female	56	163	1.60

[m^2]

[mg]

4) **Number of tablets**

Prednisolone (Deltacortril enteric™) therapy for your patient is described as follows: 30mg per day for one week, then 15mg per day for one week, then 7.5mg per day for one week. How many 5mg and 2.5mg prednisolone (Deltacortril enteric™) tablets need to be dispensed?

[(5mg tabs)] [(2.5mg tabs)]

5) <u>Millimoles</u>
How many millimoles of potassium ions are contained in 500mL of a potassium chloride infusion?

Strength of potassium chloride infusion = 0.3% w/v
Molecular weight of potassium chloride = 74.5

[ ] millimoles

6) <u>IU (International Units)</u>
A 60kg patient needs treatment for deep-venous thrombosis (DVT) with sodium heparin. The patient requires a loading dose of 5000 IU followed by continuous infusion of 20 IU/kg/hour.

What is the total amount in units required to treat this patient for 24 hours?

[ ] units

7) <u>Renal function</u>
A 52kg, 78 year old lady is admitted to hospital suffering from a severe urinary tract infection that has not responded to other drugs prescribed by her GP. Her creatinine level is 230µmol/L.

<u>Cockcroft + Gault equation</u>

<u>Male</u>

$$\frac{1.23\,(140 - \text{age})\,.\,\text{weight in kg}}{\text{serum creatinine }(\mu\text{mol/L})} = \text{ml/min}$$

<u>Female</u>

$$\frac{1.04\,(140 - \text{age})\,.\,\text{weight in kg}}{\text{serum creatinine }(\mu\text{mol/L})} = \text{ml/min}$$

What is the patient's creatinine clearance in ml/minute?

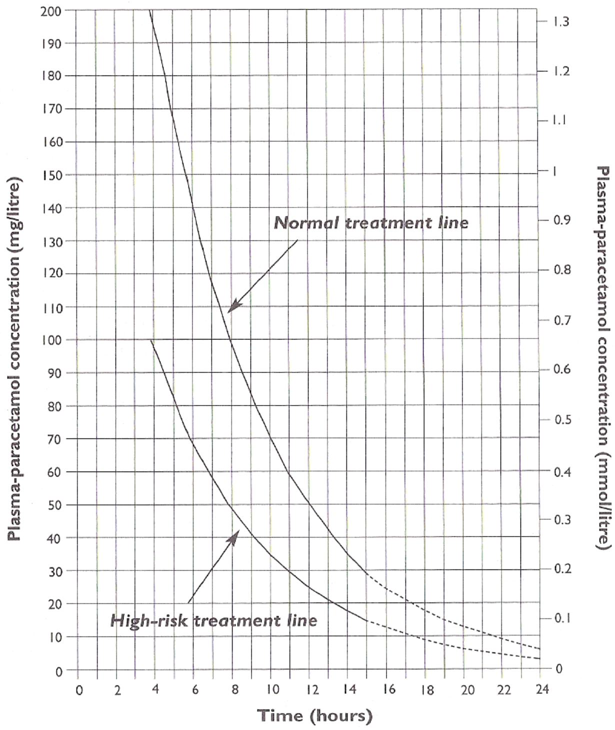
[ ] mL/min

8) <u>Nomogram use</u>
A 70kg man presents to hospital after taking a paracetamol overdose. He is not taking any other medication. A blood sample is taken and it is determined that the patient has a plasma-paracetamol concentration of 110mg/litre approximately 8 hours after taking the overdose.

With reference to the nomogram below, determine if this patient needs to be treated with acetylcysteine?

Yes [ ]   No [ ]

The BNF states that if a patient has a plasma-paracetamol concentration above the normal treatment line they should be treated with acetylcysteine by intravenous infusion. Also patients taking enzyme-inducing drugs or malnourished patients should be treated if their plasma-paracetamol concentration is above the high-risk treatment line.



Patients whose plasma-paracetamol concentrations are above the **normal treatment line** should be treated with acetylcysteine by intravenous infusion (or, if acetylcysteine cannot be used, with methionine by mouth, provided the overdose has been taken **within 10–12 hours** and the patient is not vomiting).

Patients on enzyme-inducing drugs (e.g. carbamazepine, phenobarbital, phenytoin, primidone, rifampicin, alcohol, and St John's wort) or who are malnourished (e.g. in anorexia, in alcoholism, or those who are HIV-positive) should be treated if their plasma-paracetamol concentration is above the **high-risk treatment line**.

The prognostic accuracy after 15 hours is uncertain but a plasma-paracetamol concentration above the relevant treatment line should be regarded as carrying a serious risk of liver damage.

Graph reproduced courtesy of University of Wales College of Medicine Therapeutics and Toxicology Centre

9) Infusion

A 35kg child requires an intravenous infusion of Tacrolimus after a liver transplant. The prescribed dose is 50micrograms/kg over 24 hours. A 1ml vial containing Tacrolimus concentrate 5mg/ml is available and should be diluted with glucose 5% to a concentration of 8micrograms/ml.

What is the rate of administration in drops/minute if the administration device is set at 20 drops = 1ml?

drops/min

10) Syringe driver

A cancer patient in palliative care requires a continuous subcutaneous infusion of cyclizine to control nausea and vomiting. The recommended dose is 150mg in 24 hours. The drug is provided in concentrated form as a 1mL vial of cyclizine 50mg/mL.

The syringe driver capacity is 7.5mL and is 100mm in length.

At what rate in millimeters per hour (mm/hr) must the syringe driver be set in order to deliver the correct dose of cyclizine?

mm/hr

(You will need to complete a number of steps)