Original Article

Drug calculation ability of qualified paramedics: A pilot study

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BACKGROUND: The inability of paramedics to perform accurate calculations may result in a compromise of patient safety which may result from under or over dosing of drugs, incorrect joules for defibrillation, or a major adverse event such as death. The objective of this study was to identify the drug calculation and mathematical ability of qualified operational paramedics.

METHODS: The study used a cross-sectional design with a paper-based calculation questionnaire. Twenty paramedics enrolled in an intensive care paramedic course were eligible to participate in the study. The questionnaire consisted of demographic, drug calculation (seven questions), and mathematical (five) questions. Students were given no notice of the impending study and use of a calculator was not permitted.

RESULTS: All eligible students participated in the study. The average time employed as a paramedic was 7.25 years, SD 2.5 years, range four years to twelve years. Four (20%) students got all 12 questions correct, and five (41.6%) got 50% or less. The average score was 8.6 (71.7%) correct, SD 2.8 correct, range 3 to 12 correct questions. There were eight (40%) conceptual errors, 12 (60%) arithmetical errors, and five (25%) computational errors.

CONCLUSION: The results from this study supports similar international studies where paramedic's ability to undertake mathematical and drug calculations without a calculator varies, with some results highlighting the paramedics mathematical skills as a potential risk to patient safety. These results highlight the need for regular continuing mathematical and drug calculation practice and education to ensure a lower error rate.

KEY WORDS: Emergency medical technician; Education; Medication errors; Safety management

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INTRODUCTION

The ability of paramedics to successfully undertake drug calculations was first studied back in 2000 by Hubble et al.[1] Hubble et al's findings are supported by studies from the nursing profession.[2-15] The inability to perform accurate calculations may result in a compromise of patient safety which may lead to an under-dosing, overdosing, or a major adverse event such as death.

The ability to perform calculations is a basic requirement for all healthcare professionals undertaking aspects of patient management.[16] Likewise, paramedics need to perform a variety of calculations to determine things such as joules for defibrillation, endotracheal tube size, fluid resuscitation volumes, and laryngeal mask size, based on a person's age, weight, or vital signs. Whilst calculation charts, paediatric tapes, and aide memoire are available, paramedics in particular need to be able to conduct these calculations in situations where these charts are not readily accessible or suitable. Likewise, mobile phones with calculators should not be relied upon as they can go flat when needed.

Most healthcare professionals face stressors and confounding factors that may inhibit their ability to perform calculations, including skills decay (the loss of the ability to undertake manual calculations over time), distractions, stress (where the paramedic is under actual or perceived pressure to manage the patient's condition, including time pressure to get the patient loaded for hospital), and fatigue.[2,5,14,17-19] In the out-of-hospital environment paramedics face additional distractions which may be caused by loud noise, poor lighting, hot and cold weather extremes, a life threatening situation with a child, pressure from relatives, bystanders, and a lack of resources compared to the hospital setting.[20]

Previous studies into the ability of paramedics to perform calculations without the aid of a calculator have identified low levels of accuracy with mean scores between 40% and 65%.[1,20,21] Research into the calculation ability of Australian paramedic students has found conceptual errors were the most common followed by arithmetical and computational errors.[22,23] This error classification system has been described and utilised in other research and will not be elaborated upon here.[22-24] One of the studies by Eastwood et al[25] found that paramedic students were unable to do long division without a calculator and that the mean score for mathematical and drug calculation accuracy was 39.5%. In a study of paramedic self-reported medication errors Vilke et al[26] found that 63% of the reported errors were related to drug dosage.

To date there have been no studies that demonstrate the drug calculation and mathematical ability of qualified paramedics in a low stress classroom environment in Australia. The objective of this study was to identify the drug calculation and mathematical ability of qualified operational paramedics.

METHODS

Study design

This study used a cross-sectional design with a paper-based questionnaire to elicit responses to a variety of mathematical and drug calculation questions.

Participants/population

Twenty qualified paramedics enrolled in the first semester of the Graduate Diploma in Emergency Health (MICA Paramedic) at Monash University were eligible to participate in the study. There were no specific exclusion criteria for this group.

Instrumentation

The paper-based questionnaire had been used in previous studies and consisted of a series of demographic, drug calculation, and mathematical questions.[23,24] The questionnaire consisted of twelve questions with five mathematical questions and seven drug calculations. The drug calculations incorporated commonly used drugs and situations that were familiar to paramedics, e.g. dose of midazolam for a child who is having a seizure. There was a range of drug and fluid related questions including the volume of drug drawn up, an infusion drip rate in millilitres per hour, an infusion with the number of drops per minute, the volume of a drug in millilitres to be administered to a patient, and the drug dosage. The mathematical questions were basic calculations, e.g. long division, and the conversion and operation of a fraction to a decimal equation.

Procedures

The students were invited to participate in the study at the end of a lecture in the first week of the teaching semester. They received an explanatory statement containing details about the study and were advised that their participation in the study was voluntary and that they could withdraw at any stage up until the questionnaire was submitted. The students could not withdraw from the study following submission of the questionnaire due to the anonymous nature of the questionnaire.

The students were given no notice of the impending study so they were not able to revise drug calculations or mathematical formula. The use of a calculator by students was not permitted, they were to show their working on the questionnaire. There was no set time in which to complete the questionnaire. Consent to be involved in the study was implied by the students depositing the questionnaire in a drop box when they left the room.

Data analysis

Data were analysed using SPSS (Statistical Package for the Social Sciences Version 23.0, IBM Corporation, Armonk, New York, U.S.A.). Descriptive statistics, medians, means and standard deviation (SD) and ranges were used to describe the demographic data and some of the drug calculation data. The differences between each error type (conceptual, arithmetical or computational) was described using proportions. Inferential statistics, *t*-test, was used to compare differences between the genders and an ANOVA was used to compare time as a qualified paramedic to the number of correct answers. All tests were two tailed unless otherwise stated. All confidence intervals (CI) are 95% with the results considered statistically significant if the P value was < 0.05.

Ethics

Ethics approval for the study was granted by the Monash University Human Research Ethics Committee.

RESULTS

There were 20 (100% participation rate) students who participated in study. The group consisted of 16 (80%) males. The average age of the group was 32.2 years, SD 6.4 years, median 30 years, and a range of 25 years to 46 years. The average time employed as a paramedic was 7.25 years, SD 2.5 years, median 6.5 years, and range four years to twelve years.

There were 50% (n=10) of students who stated they did not have issues with drug calculations and 55% (n=11) who stated they had poor drug calculation education during their undergraduate paramedic course. There were 74% (n=15) of students who stated they frequently did drug calculations and they were well skilled at it.

Four (20%) students got all the answers correct and five (41.6%) students got 50% or less of the calculations correct. The average score was 8.6 (71.7%) correct answers, SD 2.8 correct, median 8.5 correct, range 3 to 12 correct answers. There were eight (40%) conceptual errors, 12 (60%) arithmetical errors, and five (25%) computational errors.

There was a statistically significant difference in the total correct answers between the males and females, mean difference –3.938, 95% *CI* –6.496 to –1.379, P=009. There was no statistically significant difference between the length of time as a qualified paramedic and the type of calculation error. Likewise, there was also no statistical significant difference in the student's perceived mathematical and drug calculation ability and the result they obtained.

The Cronbach's Alpha score was 0.695 demonstrating moderate internal consistency.

DISCUSSION

This is the first study, to our knowledge, where Victorian or other Australian paramedics have had their ability to undertake mathematical and drug calculations, without a calculator, in a non-stressful classroom environment investigated. This study demonstrated that the main area of deficiency was with the arithmetical errors followed by conceptual and computational errors.

The results produced in this study were marginally better than in previous international studies investigating practicing paramedic mathematical and drug calculation ability. The average correct score of 71.7% was higher than the 39.8% to 65% achieved in other international research.[1,20,21] Despite the better average score, some of the paramedics managed 50% or fewer correct answers, which corresponds with the findings from the other international paramedic drug calculation studies.[1,20,21] The paramedics who obtained 50% or less in the study may benefit from some ongoing mathematical and drug calculation education to improve their skill in the area and decrease the potential patient safety issues.

In this study 50% (n=10) of the paramedics stated they did not have issues with performing drug calculations which is lower than that reported by Hubble et al[1] where 63.5% of paramedics stated "drug calculations were not stressful at all". There was no correlation between the paramedic's belief in their calculation ability and their actual calculation ability identified by this study, this finding is also supported by Hubbell et al's[1] study.

For this study five mathematical questions were used, including long division and converting a fraction to a decimal, and seven drug calculation questions, including amount of drug required and volume of drug required. In the study conducted by LeBlanc et al[20] they reported an example of the drug calculation used which was related to the volume of drug required. In the study by Hubble et al[1] they used drug dosage and IV infusion rate calculations where some calculations required the drug calculation to incorporate the patient's weight or a percentage of a drug as a component of the calculation. In the study by Bernius et al[21] they used eight drug calculations, two questions about paediatric endotracheal size calculation and for paramedics qualified to perform rapid sequence intubation (RSI) there were six questions about the associated drugs. Even though there was some variation in the questions used across all the studies, the consistently poor mathematical and drug calculation ability of practicing paramedics demonstrated in these studies is compelling evidence that a problem exists.

In this study the overall average score was 71.7% with four paramedics achieving 100%, which is what would be expected of practicing paramedics. Overall, there were seven students who gain greater than 90% with five paramedics obtaining 50% or less. Whilst these results are better than those found for paramedics in other countries, the results suggest there may be some drug calculation knowledge decay from their paramedic undergraduate education. Meaning that some paramedics struggle to recall some of the formulas required and some may have lost the ability to undertake manual drug calculations. This is concerning given these paramedics were commencing a course to upgrade their level of practice to intensive care level, and mathematical competency is assumed in this education program. The relatively high number of arithmetical and conceptual errors suggest that these paramedics may benefit from regular mathematical and drug calculation modules as part of their continuing professional development as the errors are not simply miscalculations. Frequent and compulsory mathematical and drug calculation modules may alleviate the issue of knowledge decay and decrease any potential issues associated with patient safety.

The most common errors were arithmetical errors (*n*=12, 60%), which demonstrated that the paramedics were unable to operate the equation they had identified based on the information they had before them. The conceptual errors were the next most common (*n*=8, 40%), which demonstrated that the paramedics were not able to identify the relevant information to construct a mathematical equation based on the information they had before them. This is disconcerting given these are practicing paramedics. Finally, there were the computational errors (*n*=5, 25%), which demonstrated basic miscalculations in addition, subtraction, division or multiplication. This type of error may have decreased if paramedics were permitted to use calculators, however, this option is not always available in the prehospital environment. Even though there are two paramedics working together on an ambulance and the checking of drug dosages is normal practice, two paramedics who have deficiencies in drug calculation ability working together may be more prone to drug errors, even with the use of drug dosage aides.

Paramedics working with drug ampoules/vials/polyamps in the prehospital environment may receive cues as to whether the amount to be drawn up is correct by the number of ampoules/vials/polyamps they require. This may be another informal checking mechanism that was not readily available in the classroom situation. This phenomenon was identified in several studies that found the students who were having difficulty with calculations in the classroom setting appeared to improve their drug calculation ability once they were exposed to the actual drug presentation in clinical practice.[8,14,18] However, this phenomenon does not hold true in all situations, two studies identified that practicing paramedics and nurses obtained less than satisfactory results in their ability to undertake drug calculations in a non-stressful situation.[1,27]

In the studies by Hubble et al[1], LeBlanc et al[20], and Bernius et al[21] the testing of paramedics was conducted under classroom type conditions where many of the prehospital environment factors such as poor light, excessive noise, and aggressive bystanders were missing. In the study by LeBlanc et al,[20] a simulated high stress situation was created using a mannequin as the patient in a simulated ambulance. Even though this study used simulation it still lacked realism, and some of the challenging conditions found in the prehospital environment. In both of these seemingly ‘safe’ environments the calculation results were still poor.

Aide memoirs such as paediatric charts or tapes and procedure checklists should be tested in the Australian prehospital environment to see if the results provide an improvement in the ability to produce correct results similar to the study by Bernius et al.[21] It should be noted that these aids may not always for available or relevant, e.g., grossly obese patient, and therefore the paramedic still needs to know how and be able to undertake drug calculations without aids.

The results from this study demonstrate that there needs to be ongoing education with mathematical and drug calculation sessions on a regular basis for qualified practicing paramedics to ensure they are competent in a non-pressure situation so that the potential for errors is reduced in a pressure situation.

This study is potentially limited by the small sample size, and the location it was undertaken in, being in a low stress situation in a classroom. Additionally, only students from one Australian university were included thereby limiting the external validity of the findings to clinical practice.

CONCLUSION

The results from this study supports results from other international studies where a paramedic’s ability to undertake mathematical and drug calculations without a calculator varies with some results highlighting that paramedic’s mathematical skills are a potential risk to patient safety. The majority of errors identified in this study are similar to other international studies where paramedics are either unable to construct an appropriate equation to use or were unable to operate the equation they identified with the information provided. These results highlight the need for regular continuing mathematical and drug calculation practice and the use of aide memoirs to ensure a lower error rate.

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