

Paramedics' Ability to Perform Drug Calculations

Kathryn J Eastwood, BNurs, BSc
Malcolm J Boyle, PhD
Brett Williams

Monash University Department of Community Emergency Health and
Paramedic Practice, Victoria, Australia

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Background: The ability to perform drug calculations accurately is imperative to patient safety. Research into paramedics' drug calculation abilities was first published in 2000 and for nurses' abilities the research dates back to the late 1930s. Yet, there have been no studies investigating an undergraduate paramedic student's ability to perform drug or basic mathematical calculations. The objective of this study was to review the literature and determine the ability of undergraduate and qualified paramedics to perform drug calculations.

Methods: A search of the prehospital-related electronic databases was undertaken using the Ovid and EMBASE systems available through the Monash University Library. Databases searched included the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE, CINAHL, JSTOR, EMBASE and Google Scholar, from their beginning until the end of August 2009. We reviewed references from articles retrieved.

Results: The electronic database search located 1,154 articles for review. Six additional articles were identified from reference lists of retrieved articles. Of these, 59 were considered relevant. After reviewing the 59 articles only three met the inclusion criteria. All articles noted some level of mathematical deficiencies amongst their subjects.

Conclusions: This study identified only three articles. Results from these limited studies indicate a significant lack of mathematical proficiency amongst the paramedics sampled. A need exists to identify if undergraduate paramedic students are capable of performing the required drug calculations in a non-clinical setting. [WestJEM. 2009;10:240-243.]

INTRODUCTION

Paramedics, like many other healthcare professionals, are often required to conduct drug calculations in the daily management of their patients. However, unlike other healthcare professionals, they are often subject to unique pressures due to the dynamic and often unpredictable nature of their working environment. Their role requires them to treat a broad variety of patient complaints, from social issues to life-threatening situations. Their working environment can vary from a well lit bedroom to an overturned car in a ditch on a rainy night with limited lighting and difficult access to an unconscious patient still restrained in his car seat. This work environment requires extreme versatility, and these confounding factors often place extra pressure on them. However, it is still expected that they will care for the patient

appropriately, problem solve, recall vital information and perform drug calculations swiftly and accurately, as incorrect drug calculations undermine patient safety and outcome.

Errors associated with medications account for up to 20% of all hospital-based healthcare errors in Australia and cost approximately \$380 million to the public hospital system annually.¹ In the U.S. about 7,000 deaths in 1993 were due to medication errors. This number is higher than that of workplace deaths in the U.S., yet little money is spent on preventing this.² A study by Barker et al.³ found that 17% of the medication errors in 36 healthcare facilities were due to dosage errors. They also found that medication errors occurred in nearly 20% of all medication administrations. It is estimated that medication-related errors cost the U.S. about \$2 billion a year for in-patients.² While we found no evidence regarding

the cost of drug-dosage miscalculations in the prehospital setting, Vilke et al.⁴ found that there have been reports of both significant injuries and death as a result of prehospital medication errors. Two studies found that between 9% and 43% of paramedic respondents admitted to medication errors, and in one of these studies 63% of the errors were dose-related.⁴

Research into paramedics' abilities to perform drug calculation was first published in 2000 by Hubble et al.⁵ Their findings have been supported by many studies within the field of nursing, dating back to the late 1930s.⁵⁻²¹

A study by Beilock and Carr²² on pressure situations found that individuals who are more academically inclined have a larger negative variance in mathematical ability when under pressure. These findings were supported by studies on stress and high pressure situations, which demonstrated a decline in mathematical performance amongst both nurses and paramedics.^{14,23,24} There is also a correlation between a decline in mathematical ability and time pressures.²⁴

The drug calculations required of paramedics are the same as those used throughout the hospital and healthcare system. Paramedics must be able to calculate pediatric patient weights, drug dosages and volumes, weight-based drug doses, infusion rates, and weight and time-based infusion rates.²⁵ Deficiencies have been found amongst the nursing profession for many years, thus serving as a catalyst in determining if these same deficiencies exist amongst the next generation of university-educated paramedics.^{6-13,15-21} No studies to date demonstrate the drug and mathematical calculation ability of undergraduate paramedic students in a classroom environment. The objective of this study was to review the literature and determine the ability of undergraduate and qualified paramedics to perform drug calculations.

METHODS

We undertook a search of the prehospital-related electronic databases using the Ovid and EMBASE systems available through the Monash University Library. The databases searched included the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE, CINAHL, JSTOR, EMBASE and Google Scholar, from their beginning until the end of August 2009.

The Medical Subject Headings (MeSH) and keywords used in the searches included emergency medical services, emergency medical technician, ambulance, air ambulance, military medicine, emergency treatment, emergency medicine, first aid, prehospital, pre-hospital, out-of-hospital, out of hospital, paramedic, drug calculation, medication calculation, maths, mathematics, students, nursing, maths skills, medication safety, drug administration errors, nurse education, numeracy skills, student nurses, dosage calculations, medication administration, pharmacological skills, problem solving, problem-solving, calculation, medication-related

errors, medication calculation skills, calculation methods, mathematical skills, drug calculation skills, conceptualizing drug calculations, drug dosages, mathematical anxiety, math anxiety, mathematical comprehension. The MeSH headings and keywords were used individually and in combination during the search process. We then combined all search results to remove duplicates and provide a list of articles for review.

We reviewed the references from articles gathered to identify additional articles not found in the electronic database search. We included articles if they contained information pertaining to paramedics and drug calculation or mathematical abilities. Articles were excluded if they were not written in English or did not involve paramedics.

RESULTS

The electronic database search located 1,154 articles for review. We identified six additional articles by reviewing the reference lists of the located articles. Of these 1,154 articles 59 were considered relevant to assist in answering the research question.

After reviewing the 59 potentially relevant articles only three met the inclusion criteria. The remaining 56 did not involve paramedics.

DISCUSSION

This study only located three small studies that reviewed the paramedic's ability to perform drug calculations or basic mathematical calculations in a variety of simulated non-clinical situations.

These studies asked fundamental drug calculation questions. The study by LeBlanc et al.¹⁴ gave only one example of a drug calculation (volume related) used in their questionnaire. Hubble et al.⁵ provided more detail about the calculations they used and some sample questions. They included drug-dosage calculations and medication and intravenous infusion rate calculations, some of which included weight- or percentage-based components. The study by Bernius et al.²⁶ asked eight basic drug calculation questions, two on calculating the appropriate endotracheal size for a pediatric patient and for paramedics qualified to perform RSI, and six questions about the RSI medications. All three studies on paramedics' mathematical abilities demonstrated an alarmingly low level of mathematic competence. Participants in both studies were qualified paramedics who had completed all appropriate training to practice. Despite completion of their basic training, the paramedics in the studies still displayed poor mathematical ability.^{5,14,26} None of the studies identified if any particular calculations caused more problems than others.

LeBlanc et al.¹⁴ tested 30 paramedics in Canada of two varying qualification levels, under high and low stress conditions. The high stress condition was created by conducting a scenario within a simulator ambulance vehicle with an adult mannequin. The participants were given a

respiratory failure scenario. Whilst the scenario was designed to be challenging it was within their skills and knowledge capabilities. The overall mean score for the more advanced paramedics was 61.1%, and the less qualified paramedics scored 39.8% (95% CI 50.6%-71.6% and 31.2%-48.4%, respectively). The study also found a decrease in mathematical performance when under the pressure of a patient-based scenario rather than a written scenario. Although the study sample was small, with only 30 participants, they comprised some of the ambulance services' most qualified paramedics.¹⁴

The study by Hubble et al.⁵ tested 109 practicing paramedics from various counties in North Carolina during a regular in-service meeting. The mean score for this 10-item test was 51.4% with a standard deviation of 27.40. No time limit was set, and these participants were allowed the use of a calculator. Theoretically, this means that for similar calculations required of them while on the job, excluding any work-related pressures, they will at best get it right only half of the time.

The study by Bernius et al.²⁶ assessed 523 practicing paramedics; 277 undertook pediatric calculation mentally or using paper (unaided), whilst the remaining participants used a pediatric code card (aided) with all the necessary drug calculations. The paramedics, from five Maryland counties, undertook the study during a mandatory continuing education class. Bernius found a statistically significant difference between the unaided group and the aided (code card) group for mean percentage of correct questions with a 29% difference between the two [65% questions answered correctly (unaided) vs. 94% (aided), $p < 0.001$]. The study also found a statistically significant difference between the unaided and aided group in percentage of total question errors [33% vs. 6.6%, respectively ($p < 0.001$)]; severe errors [20.9% vs. 4.9%, respectively ($p < 0.001$)]; tenfold errors [6.2% vs. 0.76%, respectively ($p < 0.001$)]; hundredfold errors [0.4% vs. 0.05%, respectively ($p = 0.025$)]; correct ETT calculation [23% vs. 98%, respectively ($p < 0.001$)] and time taken to complete the questionnaire [11.4 minutes and 7.1 minutes, respectively ($p < 0.001$)].

Many factors have been attributed to this lack of mathematical ability within both the prehospital and nursing fields. One of the major factors is pressure. Within the prehospital setting the varying pressures and extraneous variables present at any given time are potentially unique to this discipline. These include time, environment, management of distressed individuals and other agencies at incident sites, and the management of the critically ill patients. Other factors attributed to poor mathematical performance include skills decay and poor initial mathematical education.^{14,22-24}

Zautcke et al.²⁷ found that skills diminished amongst paramedics with length of time in the job. Cartwright and Hutton found that nurses' mathematical skills diminished over time due to a lack of opportunity to practice these skills and the availability of medical equipment that provides

automatic calculations.^{12,28} While skills decay is one reason for mathematic inability, evidence suggests it may not be the main reason for the poor results in the mathematical calculations found in many studies.^{5,12-14,19,21,29}

All of the testing in the studies by Hubble et al.,⁵ LeBlanc et al.,¹⁴ and Bernius et al.²⁶ were conducted under controlled conditions where many of the confounding factors associated with working as a paramedic were excluded.^{5,14,26} Even in the high stress condition in the LeBlanc study, the patient was a mannequin and the paramedics were in a simulator ambulance. They were not faced with a real patient (or even an actor displaying the features of respiratory distress) or with any of the environmental conditions commonly encountered by paramedics, such as cramped conditions, poor lighting, weather and distressed family members. Despite the lack of "reality" in the testing, the performance level was still poor.¹⁴

Conceptual errors, where the operator is unable to formulate a mathematical question from the information given, have been identified as the most common type of error amongst the paramedics investigated, indicating issues other than infrequent use of mathematical skills or inability to perform calculations while under pressure.²⁴ While these elements are acknowledged to affect mathematical ability, other education issues may have arisen throughout the participants' secondary education.³⁰

There is a need for further studies into the ability of qualified paramedics and undergraduate paramedics to perform basic mathematical calculations and drug calculations normally required in the prehospital setting. Curriculum changes, including a revision of fundamental mathematical principles and scenario-based mathematical practice, may need to be implemented to address any mathematical deficiencies that may be identified with further investigation.

LIMITATIONS

This study is potentially limited by the use of English-only articles and the paucity of literature on drug calculation ability among paramedics, especially involving undergraduate or Australian paramedics.

CONCLUSION

There have been few studies into the mathematical calculation abilities of paramedics. The results of the three studies we looked at indicate a significant lack of mathematical proficiency amongst the paramedics sampled. These findings are supported by a significant amount of literature within the nursing discipline suggesting a widespread problem. The literature highlights a need for studies to be conducted amongst the Australian paramedic discipline, including undergraduate paramedic students, to determine if the mathematical competence of student paramedics is sound at the beginning of the paramedic education, or whether they are entering their careers with deficiencies already present.

Address for Correspondence: Malcolm Boyle, Department of Community Emergency Health & Paramedic Practice, Monash University, PO Box 527, Frankston 3199, Victoria, Australia.
Email: mal.boyle@med.monash.edu.au

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