

Medication calculation competencies for registered nurses: a literature review

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KEY WORDS

dosage calculation, patient safety, nursing, education, professional knowledge.

ABSTRACT

Objective

To describe the literature that focuses on safe administration of medications, medication calculation skills development and maintenance of ongoing competence in nurses.

Setting

University and hospital nurse education departments.

Subjects

Theoretical and empirical literature focusing on nurse mediated medication administration errors

Primary argument

Nurse education departments devote a high proportion of time to medication calculation skill development and testing. Annual testing is time consuming for both nurse educators and nurses, and the validity, frequency, acceptable pass mark, self-efficacy and maintenance of skills related to medication calculation testing is largely unclear.

Conclusion

The theoretical literature focuses on drug administration errors, development of tools and techniques to improve nurses' medication calculation skills and guidelines. There is considerable debate as to nurses' self-perception of their arithmetical skills, their educational needs in this area and the relationship between skill level and patient outcomes. Empirical literature focuses on the incidence of errors, evaluation of medication calculation skills; the relationship between test results and errors, effectiveness of strategies to improve medication calculation skills and medication calculation testing and policy. Course content and delivery are thought to influence safe medication administration; however, there has been a lack of rigorous research demonstrating the efficacy of educational models. Several studies report low levels of calculation proficiency in nurses; however, it is unclear whether medication calculation testing affects medication administration error rates. Further research is required to determine the robustness of the current processes to assess nurses' medication calculation competence and ensure optimal patient safety.

INTRODUCTION

Promoting a culture of safety is a priority for healthcare providers today. International literature suggests medication errors occur in all health care settings. Adverse events, defined as incidents in which harm resulted to a person receiving health care (AIHW 2007), include medication errors. Medication errors are defined as “any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of health professional, patient or consumer” (National Coordinating Council for Medication Error Reporting and Prevention 2008). Of all hospital adverse events, medication errors are considered the most preventable (Williams 2007). Not only do they have an effect on patients and clinicians, they impact significantly on patient length of stay and financial cost to the health service.

In Australia it is estimated that medication errors are responsible for 27% of adverse event deaths (Runciman et al 2003), and hospital studies demonstrate that harmful medication errors are reported in approximately 1% of all admissions (Wilson et al 1999; Runciman et al 2003). This problem is not unique to Australia, medication error rates have similarly escalated in the United States of America (USA) and United Kingdom (UK). In the USA over 7,000 deaths occur annually as a result of medication errors (Kohn et al 2000) with more than 17% of these due to miscalculation of dosages (Bayne and Bindler 1988; Bayne and Bindler 1997; Phillips et al 1998; Kohn et al 2000; Capriotti 2004; Greenfield et al 2006; Harne-Britner et al 2006). There are limited data available from the UK, though it is broadly reported that medication errors account for 10-20% of all adverse events, many of which are preventable (Smith 2004).

The causes of medication errors or medication adverse events can be grouped into system, environmental and human factors (Wilson et al 1999; Deans 2005). Whilst adverse events such as medication allergy and anaphylaxis are largely unavoidable, one cause of medication adverse events, mediated by nurses, that may be able to be

ameliorated is dosage error caused by calculation error (Leape et al 1995; Lesar et al 1997; Balas et al 2004; Kopp et al 2006; Haw et al 2007). Consequently nurse educators have assigned a significant amount of time and effort to assessing medication calculation skills. In order to improve nursing competence in this area clear evidence of the effectiveness of different educational or systems interventions is required.

AIMS

The aims of this review are to describe the literature, both theoretical and empirical, that focuses on factors affecting safe administration of medications, medication calculation skills development and maintenance of ongoing competence in registered nurses. This review discusses the validity, frequency, acceptable pass mark, self-efficacy and maintenance of skills related to medication calculation testing.

METHODS

The literature was accessed through the online bibliographic databases CINAHL and Medline using the MeSH headings: medication errors, registered nurses, dosage calculation, and mathematics. Cochrane and Joanna Briggs Institute databases were accessed to search for the existence of systematic reviews related to medication competency and medication error reduction. Articles were also sourced from citations in the reference lists of retrieved articles. Articles selected included primary research, academic reviews of literature, systematic reviews and papers containing current government statistics. Articles related to the performance of medication calculations were excluded. All articles were published in English and, with the exception of two research papers considered pertinent to the topic, were no older than 13 years owing to the fact that the focus on medication safety has come to the forefront since the mid-1990s (World Health Organization 2002). One systematic review, one best practice sheet, 38 research articles, 20 theoretical articles (reviews, guidelines, discussion papers and opinion papers), three reports, two electronic sources and one book were included in this review.

DISCUSSION

Nurses' medication calculation skills

Research studies have indicated that mathematical anxiety, negative attitudes and poor numeracy skills are evident in the nursing population at both undergraduate (Bayne and Bindler 1988; Brown 2002; Glaister 2005; Greenfield et al 2006; Jukes and Gilchrist 2006; Sredl 2006) and postgraduate levels (Bayne and Bindler 1988; Calliari 1995; Harne-Britner et al 2006). A substantial number of articles have identified that many nurses lack sufficient skill to calculate drug dosages correctly (Bayne and Bindler 1988; Polifroni et al 2003; King 2004; Ferri and Snyder 2005; Joint Commission Benchmark 2005; Grandell-Niemi et al 2006).

Two USA sources suggest only 35% of nurses achieve 90% proficiency in a medication calculations test at orientation (Bayne and Bindler 1988; Joint Commission Benchmark 2005). According to Bayne and Bindler (1988) nurses regularly score lower on medication calculation exams than doctors and pharmacists and years of experience does not necessarily improve their performance (Bayne and Bindler 1988). Some research papers report nurses who have been working for a few years often attain lower scores than graduate nurses and graduates do not have the required mathematical skills as their entry level maths proficiency is set at 80% which is below what is expected for medication administration (Polifroni et al 2003; Joint Commission Benchmark 2005).

US and UK studies similarly indicate general numeracy skills in nursing students is below par (Brown 2002; Wright 2004; Harne-Britner et al 2006; Jukes and Gilchrist 2006; Wright 2006; Wright 2007a) as nursing students were under prepared for the mathematical requirements of safe medication administration, and lacked the necessary skills to calculate dosages particularly when using fractions, percentages, decimals and ratios. Concern over the mathematical skills of undergraduate nursing students was also evident in studies from other countries (Gillham and Chu 1995; Kazaoka et al 2007) with the exception of two Finnish studies which

reported nurses and student nurses found maths interesting and self-rated their mathematical skills as sufficient (Grandell-Niemi et al 2003; Grandell-Niemi et al 2005).

Teaching medication skills

Basic medication calculation education and testing have been included in undergraduate nursing programs since their inception, however, it has been suggested that differences in students' baseline mathematical abilities, and not requiring mastery of calculation tests prior to graduation (Bayne and Bindler 1988), have resulted in inconsistencies in the medication calculation skills of graduate nurses. UK opinion papers claim falling standards of maths is not limited to nursing, but is community wide, and that more must be done to raise the accepted standards (Coombes 2000; Mathieson 2000). One Australian paper highlights the shortcoming, common in tertiary educational facilities, of using normative assessment to grade students when mastery should be required (Manias and Bullock 2002).

Various approaches to improving student performance have been suggested including: focusing on calculation from the beginning of the program (Brown 2002); pre-entry assessment of maths skills (Coombes 2000); assessment of maths skills every semester in both classroom and in practice settings (Brown 2002; Jukes and Gilchrist 2006). The employment of learning through practical sessions and assessments in safe environments has been shown to have benefit for the more hands on learner and also as a means to assisting undergraduate nurses to become more confident practitioners (Banning 2004; Warburton and Kahn 2007). Brown (2002) additionally contends that testing should be supported by remedial help for those who require it (Brown 2002).

There have been several research and discussion papers about the best way of teaching maths skills to undergraduate nursing students, with the majority acknowledging a large proportion of students do struggle with maths (Kelly and Colby 2003; Banning 2004; Maag 2004; Wright 2004; Greenfield et al 2006; Harne-Britner et al 2006; Jukes and Gilchrist

2006; Sredl 2006; Wright 2007a; Wright 2008). It is suggested a combination of teaching styles may prove more appropriate in situations where learners have different experiences, needs, motivations and learning styles (Brunt 2000; Wright 2004). Providing opportunities for practice is the key to enhancing math ability not only in the tertiary setting but also continuing into the workplace of the practising nurse (Polifroni et al 2003).

Empirical studies in the UK call for strategies to focus on the conceptual skills of students so they can learn to interpret and think about numeracy before applying the principles to practice (Jukes and Gilchrist 2006; Wright 2007a; Wright 2008). Research evidence suggests using different educational strategies leads to positive changes in participants' mathematical knowledge (Kelly and Colby 2003; Banning 2004; Maag 2004; Greenfield et al 2006; Harne-Britner et al 2006; Sredl 2006). Revision, refresher classes and face-to-face tutorial sessions may also prove beneficial in facilitating retention of knowledge (Wright 2008).

Empirical studies undertaken in the US have similarly identified that interactive multimedia learning tools and online tutorials have benefit and are generally well accepted by nursing students and nurses (Maag 2004; Frush et al 2006; Harne-Britner et al 2006). Survey evaluation of these approaches has shown students have found them a more enjoyable, interesting, realistic and creative way to develop maths skills and have found the feedback available within these programs sufficient for their learning needs (Maag 2004; Frush et al 2006; Harne-Britner et al 2006). It is suggested that nursing student education should focus not only on basic maths skills but also on pharmacology and safe medication administration (Wright 2006). Further research is required to determine which strategies are the most effective in both the short and long term (Wright 2007a).

Ongoing maintenance of competence

It is expected nurses are able to calculate medication dosages precisely (Brown 2002). However, research studies show many nurses are insufficiently skilled

in performing this task and are unable to achieve the required proficiency set by individual institutions (Bayne and Bindler 1988; Calliari 1995; Joint Commission Benchmark 2005; Harne-Britner et al 2006). Proficiency marks range from 70-100% (Polifroni et al 2003; Grandell-Niemi et al 2006). In the US (Bayne and Bindler 1988; Calliari 1995; Joint Commission Benchmark 2005; Harne-Britner et al 2006) and UK (Trim 2004; Jukes and Gilchrist 2006) pass marks are commonly set at 90% whilst in Australia 100% is normally sought (Gillham and Chu 1995). It is also interesting to note that 75% is a frequently accepted college pass mark in the US (Brown 2002).

Two US studies identified a significant relationship between nurses who made medication errors and their ability to pass a medication calculation exam, in brief; nurses who failed were more likely to make errors than nurses who passed (Conti and Gauntlett Beare 1988; Calliari 1995). However, Conti and Gauntlett Beare (1988) conceded poor performance on medication calculation tests alone is not a reliable predictor of those most likely to make a medication administration error. One UK author argues strongly against the validity of medication calculation testing, asserting that written medication calculation tests are not a reliable indicator of the numeracy skills required for clinical practice (Wright 2007b). However, this lone opinion is contrary to the bulk of the literature which supports the testing of nurses' medication calculation skills as fundamental to ensuring medication safety (Bayne and Bindler 1988; Calliari 1995; Bayne and Bindler 1997; Hamner and Morgan 1999; Meyer 2004; Preston 2004; Ferri and Snyder 2005; Glaister 2005; Grandell-Niemi et al 2005; Grandell-Niemi et al 2006; Warburton and Kahn 2007).

There is no clear evidence regarding when and how regular testing should occur. Nor is there uniformity with regards to acceptable passing grades. An observational study found that some US hospitals do not impose medication calculation testing, as they feel that it is an expected skill in order to obtain a nursing license (Hamner and Morgan 1999). However, empirical research indicates that most US

hospitals and nursing educational facilities support medication calculation assessment establishing their own standards for testing (Bayne and Bindler 1988; Bayne and Bindler 1997; Hamner and Morgan 1999; Brown 2002; Greenfield et al 2006; Harne-Britner et al 2006). Several research studies and opinion papers suggest during orientation would be the ideal time to make an initial assessment of nurses' medication calculation abilities (Bayne and Bindler 1988; Calliari 1995; Hamner and Morgan 1999; Meyer 2004).

Bayne and Bindler's (1988) study recognised that nurses who have practised for more than three years tend to have greater difficulty performing medication calculations, and thus there would additionally be a need for nurses' medication calculation competence to be assessed at regular intervals (annually or bi-annually) (Bayne and Bindler 1988). The inclusion of medication calculation skills in continuing nursing education programs, subject to periodic review and updating of skills, was also supported in Capriotti's (2004) guidelines paper.

Many nurses consider medication calculation testing to be highly stressful and exceptionally challenging (Bayne and Bindler 1988; Glaister 2005). In studies that tested self-efficacy versus knowledge, most nurses were able to accurately predict their maths ability before they sat the exam (Bayne and Bindler 1988; Grandell-Niemi et al 2003; Maag 2004; Glaister 2005; Grandell-Niemi et al 2005; Grandell-Niemi et al 2006; Andrew et al 2009). This empirical research demonstrates that nurses have insight into their weaknesses and strengths with regard to maths ability. Bayne and Bindler (1988) recommended that opportunities for self-assessment prior to sitting a medication calculation exam may help identify problem areas and minimise anxiety (Bayne and Bindler 1988). It has been suggested that the keys to increasing nurses' confidence with medication administration and reducing anxiety lie within ongoing education and training in mathematical skills (Brown 2002) and regular practice reviews (Dixon and Evans 2006).

There has been limited research which has assessed nurses' medication calculation scores in the UK. US and Finnish studies indicated the average score attained by nurses on medication calculation exams was approximately 75% (Bayne and Bindler 1997; Grandell-Niemi et al 2006; Harne-Britner et al 2006) with only a very few attaining close to the 90% score which some had imposed (Conti and Gauntlett Beare 1988; Greenfield et al 2006). Research studies undertaken in both the US and UK, identified the main areas of difficulty included those calculations which involved percentages, ratios, fractions, multiplying fractions, place values and interpreting information (Salvucci 2000; Brown 2002; Capriotti 2004; Wright 2004; Rice and Bell 2005; Wright 2006; Wright 2007a). Bayne and Bindler's (1997) research demonstrated intravenous dosages and flow rates are equally problematic for nurses who find them significantly more challenging than intramuscular, subcutaneous or oral dosages (Bayne and Bindler 1997). Salvucci's (2000) study suggested this may be a result of the infrequency with which these calculations are undertaken, and thus training in less frequently used skills may need to be provided (Salvucci 2000). Nurses further found calculations difficult when they had to apply formulas or conversions which were not on hand (Bayne and Bindler 1997). Trim (2004) maintains it is essential that formulas are readily available and that nurses are familiar with and have a basic understanding of the formulas that exist and how to apply them to calculate the correct dosages when preparing medications.

Many authors recommend that nurses' involvement in the review of reported medication errors raises awareness (King 2004; Glaister 2005; ISMP 2005; Joanna Briggs Institute 2005; Hodgkinson et al 2006; McBride-Henry and Foureur 2006). Through medication safety focus groups, review of the safety literature, provision of updates and close monitoring of reporting of medication errors, nurses' can make suggestions on how to avoid future errors (King 2004; Glaister 2005; ISMP 2005; Joanna Briggs Institute

2005; Hodgkinson et al 2006; McBride-Henry and Foureur 2006). Raising awareness of medication calculation errors and the provision of practical initiatives to improve nurses' medication calculation skills will likely result in improvements in nurses' abilities to administer medications in a correct and safe manner for best patient outcomes (Gray and Jackson 2004). More research is still required to determine the impact that raising awareness has on reducing error rates. What is known, however, is that the current approach to reducing medication errors is inadequate, reporting of errors is generally poor and this will only improve through education and a change in culture towards this issue (Coombes 2000; Preston 2004; Greenfield et al 2006).

Openness in identification and reporting of drug errors by nurses is vital if medication calculation error is to be addressed and improved. Nurses who report errors honestly should not receive disciplinary action (Preston 2004). Similarly nurses who do not make the grade during medication calculation assessments should not be subject to punitive or embarrassing remediation processes (Coombes 2000). Practice development initiatives including education, realistic practice sessions, review of adverse medication event incidents, medication safety focus groups, regular updates, and the time to achieve competency can positively affect medication administration outcomes and ultimately result in better patient safety (King 2004; Glaister 2005; Joanna Briggs Institute 2005; Hodgkinson et al 2006; McBride-Henry and Foureur 2006).

The key to minimising the risk of medication error is through the adoption of commonsense approaches (Preston 2004). Nurses should be encouraged to check medication dosages with another nurse (Grandell-Niemi et al 2005; ISMP 2005; Joanna Briggs Institute 2005; Hodgkinson et al 2006; Mulloney and Moloney-Harmon 2006), avoid distractions (Capriotti 2004; Grandell-Niemi et al 2005) and not rush (ISMP 2005). Use of vests or do not disturb signs as a strategy to prevent interruptions when calculating and dispensing medications has been successfully implemented in several facilities as

part of a transforming care at the bedside approach to patient safety (Bennett et al 2006; Kaiser Permanente 2009). Use of calculators and conversion charts may be helpful but should never be used as a substitute for taking into consideration the logical or expected answer (Capriotti 2004; Trim 2004; Pentin and Smith 2006).

Commentators suggest medication administration skills, particularly maths, be a core component of all nurses' continuing education (Capriotti 2004) and be regularly maintained. In one study over half of the nurses (54%) said they retained their skills by practising (Grandell-Niemi et al 2003), other means included attending lectures (6%); use of textbooks (33%); calculating with peers (43%) and use of computer assisted programmes (2%) (Grandell-Niemi et al 2003). Practice appears to be the key to maintaining skills, however, practising to maintain calculation skills is not regular among nurses and students (Grandell-Niemi et al 2005). Practice opportunities need to be provided within the undergraduate curriculum and continue into the workplace (Bayne and Bindler 1988; Polifroni et al 2003).

CONCLUSION

There is considerable debate regarding nurses' self-perception of their arithmetical skills, their educational needs in this area and the relationship between skill level and patient outcomes. A substantial number of international papers have identified that many nurses lack sufficient skill to calculate drug dosages correctly raising concern about the mathematical skills and preparedness of student nurses for practice. Course content and delivery are thought to influence safe medication administration. A combination of teaching styles may prove more appropriate where learners have different experiences, needs, motivations and learning style; however, there has been a lack of rigorous research demonstrating the efficacy of educational models. Several research studies report low levels of calculation proficiency in RNs, however, it is unclear whether medication calculation testing affects medication administration error rates.

Research has identified a significant relationship between nurses who have made medication errors and their ability to pass a medication calculation exam, however, poor performance on medication calculation tests alone is not a reliable predictor of those most likely to make a medication administration error and research studies do not show high error rates attributed to drug calculation.

There needs to be further discussion with regards to acceptable pass marks and how regularly nurses should have their medication calculation skills evaluated. Statistical data and research studies show many nurses are insufficiently skilled in medication calculations with the average score attained by nurses on exams reported as 75%. Further research is required in this area.

RECOMMENDATIONS

Nurses need to maintain their mathematical skills to safeguard against medication errors (Capriotti 2004) and employers need to encourage this through the incorporation of practice development initiatives (King 2004; Joanna Briggs Institute 2005; Hodgkinson et al 2006; McBride-Henry and Foureur 2006). In order to improve nurses' and student nurses' mathematical skills educational programs should implement effective strategies, such as on-line training, refresher classes, face-to-face tutorials and practice sessions. Remedial education should be tailored to the individual knowledge deficits that surface during testing.

The evaluation of different educational and testing models should address the issues of access and the time burden associated with assessment of the large numbers of nursing staff which is currently undertaken by most institutions on an annual basis. Practical assessment of nurses' medication administration skills must also be considered to ensure nurses are able to practice within safe guidelines as set out by the institution and relevant safety councils.

Recommendations from research and opinion papers by practising nurses and educators have called for 100% mastery to be imposed across the board,

especially when there is no room for less than 100% accuracy in practice (Polifroni et al 2003; Meyer 2004). The key to minimising the risk of medication error is through the adoption of commonsense approaches such as double checking of medication dosages with another nurse, avoiding distractions and not rushing. Finally, further research is required to determine the robustness of the current processes in place to assess nurses' medication calculation competence and ensure optimal patient safety with regards to medication administration and drug error.

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