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Improving Medication Calculation Skills of Practicing Nurses and Senior Nursing Students

A Pilot Study

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Medication administration is an essential nursing competency as calculation difficulties can lead to serious medication errors. Nurses involved in staff education need to be aware of methods to assess for computation difficulty and develop strategies for nurses to improve their computation abilities. The purposes of this quasi-experimental pilot study were to assess the medication calculation skills of nurses and nursing students and to determine the effectiveness of teaching strategies aimed at improving these skills.

The Institute of Medicine's landmark publication, *To Err is Human: Building a Safer Health System* (Kohn, Corrigan, & Donaldson, 1999), reported that up to 98,000 Americans die each year as a result of preventable medical errors, making these errors the eighth leading cause of death in the United States. The National Coordinating Council for Medication Errors Reporting and Prevention (NCC-MERP) reported that human factors accounted for 42% of the medication errors reported in 2001. One of the human factors included in the taxonomy of medication errors is miscalculation of dosage or infusion rate. The NCC-MERP report found that 7% of reported medication errors were related to miscalculation (Thomas, Holquist, & Phillips, 2001).

Medication administration is an integral nursing function and an essential aspect of providing high-quality, safe patient care. The process of medication administration requires expertise in several distinct areas, including dosage calculation. Practice innovations in medication administration, such as unit dose, pharmacy dosage calculations, and integrated intravenous equipment calculation software, have reduced the nurse's need to use computational skills to administer medications. However, the ability to accurately compute medication doses is still an essential nursing competency. In fact, these practice innovations may actually increase calculation errors because they reduce the frequency with which nurses use these skills. Consequently, when nurses are faced with infrequent math computations, the risk for errors is significantly higher. Therefore, a well-selected teaching/learning strategy that is economical, easy to implement,

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and effective for adult learners in improving and maintaining nurses' computational skills is needed.

Purposes of the Study

The purposes of this study were to assess the medication calculation skills of practicing registered nurses and baccalaureate nursing students and to test the effectiveness of a teaching/learning strategy to improve their computation skills and reduce medication errors.

Research Questions

The specific research questions of the study were as follows:

1. What are the medication computation test scores of practicing nurses and senior nursing students?
2. Is there a significant difference between practicing nurses' and senior nursing students' computation test scores?
3. Does a teaching/learning strategy based upon adult learning theory improve practicing nurses' and nursing students' medication computation test scores?
4. Are the researcher-developed Medication Calculation Pretest and Posttest instruments reliable to assess computation skills of practicing nurses and nursing students?
5. What are the significant self-assessment predictors of computational success?

LITERATURE REVIEW

Medication errors are a multidisciplinary problem and can occur in any part of the medication process—ordering, dispensing, transcribing, or administration (Antonow, Smith, & Silver, 2000; Beyea, 2002; Carroll, 2003; Jech, 2003; Lesar, Briceland, & Stein, 1997; Nordenberg, 2000; O'Shea, 1999). According to the Food and Drug Administration, human factors are the most common cause of medication errors (Thomas, Holquist, & Phillips, 2001), but other causes include workplace stress, distractions, interruptions, inadequate training, fragmented information, and information overload (Gary, 2002; Schulmeister, 1999; Strom, 2003).

Math calculation errors are one type of human error linked to medication errors. Calliari (1995) and Conti and Beare (1988) found a significant correlation between the ability of nurses to pass a basic medication calculation test and the subsequent incidence of medication errors. In a sample of 66 nurses, Bayne and Bindler (1988) found that only 35% of them scored 90% or better on a test of their dosage calculation skills. More errors were made when calculating intravenous medications. Bindler and Bayne found similar results on a 20-item test with higher error rates on intravenous medication calculation in a 1991 study when only 19% of tested nurses scored 90% or better. A study by Ashby (1997) indicated that 56.4% of nurses could not calculate medication doses correctly in 90% of the problems. Bliss-Holtz (1994) delineated calculation errors as either mathematical or conceptual in nature, and their study results demonstrated that most medication calculation errors were related to nurses' lack of knowledge and skills to formulate and solve problems, rather than actual arithmetic skills. Brown (2002) administered a Computational Arithmetic Test to a national sample of 850 associate degree students and obtained an average score of 75%. The study concluded that nursing students are underprepared in mathematics.

The prevalence of medication calculation errors has led to research that examines the best method for teaching and improving calculation skills to prevent medication errors. Hutton (1998) studied the impact of a revision mathematics course on competency in dosage calculations. Students were provided with a self-study packet in addition to a tutor, if needed. Students commented that clinical reinforcement of calculation skills would improve their understanding. Hamner and Morgan (1999) found individual one-to-one instruction to be helpful. The authors noted that implementation of a refresher class might be a more cost-effective use of an educator's time. Bayne and Bindler (1997) demonstrated that nurses in computer-assisted instruction and group classroom formats significantly improved their scores on medication tests, whereas nurses in a self-study group showed no improvement. Martin (1994) encouraged organizations to be proactive in offering calculation skill updates but cautioned that traditional teacher-led classes may not be cost-effective.

THEORETICAL FRAMEWORK

The methodology of this study was based upon the theory of andragogy, developed by Malcolm S. Knowles, which focuses on adult learning needs. Andragogy makes the following assumptions: (1) adults need to know why they need to learn something, (2) adults need to learn experientially, and (3) adults learn best when the topic is of immediate value and experience (Kearsley, 2003, Overview section). Principles of Knowles' theory were used to develop educational strategies for this study to improve medication calculation test scores. Knowles (1980) argued that educational program designs "should include some preparatory experiences that will help adults get a new

way of thinking about the role of learner and some new skills in self-directed learning'' (p. 46). To establish the relevance of the study to daily nursing practice, participants were given national benchmark data about medication errors and calculation skills and specific information about medication errors at the organization. To reinforce the importance of participating in an intervention to improve their skills, participants received feedback on their performance on the pretest prior to participating in an intervention. Because adult learners want control over learning activities, the opportunity for the participants to choose the type of intervention that most closely matched their own preferred learning style was provided.

SAMPLE

A convenience sample of practicing registered nurses with a range of 4–34 years of experience and senior baccalaureate nursing students from a local college were approached to participate in the study.

INSTRUMENTS

The Medication Calculation Survey was a researcher-developed tool used to collect demographic data and to assess the following: comfort level with medication calculations, frequency of performing medication calculations, patient care workload, availability and accessibility of resources for medication calculations, and preferences for obtaining assistance with medication calculations.

Medication calculation tests used in previous studies included questions on metric conversions and oral and IV medications (Bindler & Bayne, 1991; Bayne & Bindler, 1988). Since this study focused on IV calculation skills, Medication Calculation Pretests and Posttests were developed to assess these skills (see Figure 1). Each test included 20 IV calculation questions. In an effort to decrease the potential for participants to focus on the medication as opposed to the calculation skill, no specific medication names were included in the test. A panel of experienced advanced practice nurses and pharmacists reviewed the medication tests that were administered for face and content validity. Reliability of the medication tests was evaluated using the Kuder–Richardson (KR20) test (Kuder & Richardson, 1937), one of the most common procedures used for estimating the reliability of a test. Kuder–Richardson measures inter-item consistency or the degree to which the test questions consistently measure the same content and skills. The calculated KR20 for this test was .764. According to Morrison, Smith, and Britt (1996), this demonstrates a moderate level of internal consistency and is acceptable for teacher-developed tests.

DESIGN/METHODS

Permission to conduct the study was granted by the Institutional Review Boards at PinnacleHealth System and Messiah College. A quasi-experimental design was used to compare the educational strategies. All participants viewed a 10-minute presentation that provided general information about medical errors, a brief literature review, and medication error data. Immediately following the presentation, participants completed the Medication Calculation Survey and received a calculator for use during the test. Participants were given 1 hour to complete the Medication Calculation Pretest to assess their baseline skills. After correcting their own tests with an answer key, participants were given the opportunity to choose among four interventions to improve computational skills: a 30-minute classroom tutorial session; a self-study using the workbook, *Calculating Drug Dosages* (Martinez de Castillo & Werner-McCullough, 2002); a self-study using their own references; or no intervention. Approximately 4 weeks later, participants completed the Medication Calculation Posttest and indicated what type of intervention(s) they used to review medication calculations.

The physician orders 500 ml NSS to infuse over 4 hours. How many ml/hr will you set the IV Pump?

1 Unit PRBC is ordered to infuse over 3 hours. The IV tubing delivers 15 gtt/ml. Calculate the rate in gtt/min.

A drug is ordered to be administered at 1350 units/hour. The drug comes premixed 20,000 units/500 ml D5W. The IV pump should be set for _____ ml/hr

A drug is ordered for a patient at 6 mcg/kg/minute. The drug is mixed 500 mg/250 ml D5W. The patient weighs 186 lbs. The IV pump should be set at _____ ml/hr.

The physician orders 1 mg/kg of a drug for a 815 gm premature neonate. The drug is available in a vial containing 1 mg/ml. How many ml should the nurse administer?

FIGURE 1 Sample Medication Calculation Pretest Questions.

DATA ANALYSIS/RESULTS

Thirty-one senior baccalaureate nursing students participated in both pretest and posttest activities. On the 20-question test, the students' pretest raw scores ranged from 6 to 20, with an average of 15.9. The posttest scores ranged from 11 to 20, with an average of 17.4. This indicated an average increase of 1.5 points (see Table 1). Twenty-two practicing registered nurses participated in both pre- and posttest activities. The nurses' pretest raw scores ranged from 10 to 20, with an average score of 15.5. The posttest scores ranged from 15 to 20, with an average score of 18.6. This demonstrates an average increase of 3.1 points on the posttest score (see Table 1). The students' pre- and posttest scores were compared to the nurses' pre- and posttest scores using a *t* test. No statistically significant difference between groups was noted. Both groups demonstrated a statistically significant improvement in tests scores ($p < .01$) when pretest and posttest scores were compared using a *t* test.

Scores and overall improvement were compared between intervention groups using analysis of variance. All intervention groups demonstrated improvement. The group that used classroom education plus self-study (see Table 2) achieved the highest average improvement on student test scores. Registered nurses' posttest scores increased in all groups regardless of the type of educational strategy employed. Although no intervention showed statistical significance, the self-study group demonstrated the greatest improvement (see Table 3).

Relationships between test scores and study variables, including demographic information and participant responses on the medication calculation survey, were calculated using Pearson's *r*. Four statistically significant relationships were identified in the student population. Pretest scores were correlated to student self-rating of comfort level with calculating IV medication doses ($p = .008$) and IV flow rate ($p = .004$).

TABLE 1 Comparison of Average Pretest and Posttest Scores for Senior Nursing Students and Practicing RNs

Group	Pretest Score Average	Posttest Score Average	Significance ($p < .01$)
Senior Nursing Students ($n = 31$)	15.9	17.4	$p = .003$
Practicing RNs ($n = 22$)	15.5	18.6	$p = .000$

TABLE 2 Student Mean Pretest and Posttest Scores With Intervention

Intervention Groups	Pretest Score	Posttest Score	Change in Score
All ($n = 31$)	15.9	17.4	1.5
Classroom education ($n = 25$)	15.7	17.1	1.4
Classroom plus self-study ($n = 6$)	16.8	18.5	1.7

Posttest scores were correlated to student self-rating of comfort level with calculating IV medication doses ($p = .024$) and IV flow rate ($p = .011$). Those with low scores ranked themselves as less comfortable with the skill than those with higher scores.

A statistically significant relationship was identified in the registered nurse group. Pretest scores were correlated to nurse self-rating of frequency of performing medication calculation ($p = .017$). Those with low scores performed the skill less frequently than their colleagues who scored higher.

DISCUSSION

It is of significant concern that 41.6% of students and 54.8% of nurses could not calculate IV medication or IV flow rates with 90% accuracy. These results provide further support to the prior studies indicating that nurses are unable to correctly perform medication calculations an acceptable percentage of time (Ashby, 1997; Bayne & Bindler, 1988; Bindler & Bayne, 1991). However, both nurses and students were able to improve their IV calculation skills with a classroom or self-study educational intervention.

Participants were provided with calculators to perform arithmetic computations; therefore, results suggest that errors were because of lack of knowledge and skill to formulate and solve mathematical problems, rather than a deficiency in actual arithmetic functions. In addition, test results showed that nurses and students were more likely to err on more difficult questions requiring complex titration calculations rather than simple IV flow rates. The study indicated a statistically significant correlation in nursing student comfort level with calculating IV medication doses and IV flow rate with test scores. This suggests that students realistically assess their calculation skills and their assessment could serve as a catalyst to seek further medication calculation instruction.

Pretest scores of practicing nurses were correlated to frequency of performing medication calculation. The more often nurses performed the skill, the better the

TABLE 3 Registered Nurses Mean Pretest and Posttest Scores With Intervention

Intervention Groups	Pretest Score	Posttest Score	Change in Score
All (n = 22)	15.5	18.6	3.1
No education strategy (n = 9)	16.5	19	3.5
Classroom education (n = 7)	14.7	18	3.3
Self-study (n = 5)	14.7	18.7	4.0

test scores. This supports the premise that decreased use of a skill results in increased incidence of error.

LIMITATIONS

The results of this study are limited by several factors. The overall sample of staff nurses and students was small, resulting in limited ability to determine any statistical differences between them. Random assignment of staff to the various educational strategies would have made the groups equal but would not have supported adult learning principles. However, the majority of student and nurse participants chose an educational intervention based on convenience rather than on their preferred learning style. The classroom educational intervention was offered immediately after the pretest was administered, which made it more convenient. Consequently, the majority of participants chose this as their educational intervention. Some participants had difficulty accessing the self-study workbook, which may have limited the size of that group. These factors influenced the number of participants for each intervention group.

The staff nurse participants were all members of a Nurse Practice Council, which is composed of representation from each clinical unit. These participants may be a more experienced and motivated group than a random sample of staff nurses. The nursing student participants were from one section of a nursing research course at a small college and may not represent all senior nursing students. Although the initial reliability testing of the medication calculation pretests and posttests was acceptable, further testing and refinement of the tool are necessary.

IMPLICATIONS FOR PRACTICE

Despite the limitations, the study provided a baseline assessment of staff nurses and senior nursing students at both settings and identified a weakness in medication calculation skills. In the practice setting, results were presented to several committees and raised many concerns about nurses' abilities to perform medication calculations. As a result, the medication pretest will be given to all newly hired staff nurses during orientation to provide an assessment of their medication calculation skills. Some clinical units have identified medication calculation as a high-risk skill and have chosen to incorporate the topic into educational offerings or competency formats. Other units plan to use the tests and self-study options as remediation efforts for nurses with identified needs. This will allow further reliability and validity testing of the tools.

To facilitate use of the educational strategies in the study, a self-study module was developed for staff and nurse educator use. The module includes the medication calculation pre- and posttests, a medication calculation competency, instructions for use of the workbook and CD-ROM, *Calculating Drug Dosages* (2002) by Martinez de Castillo and Werner-McCullough, and links to reference articles. It will be available online and offer continuing education credits.

In order to collect specific data on medication errors, several revisions are being made to the institution's medication error report form. Miscalculation is being added to the list of causes and contributing factors, and nurse managers will be encouraged to use and document the use of the medication calculation self-study module for staff remediation. This information will help to evaluate the impact of the self-study module on medication error rates in the practice setting.

In the academic setting, the study results were shared with the curriculum committee and revisions are being implemented to increase opportunities for students to learn and practice medication calculations in class and clinical rotations.

Recent efforts to prevent medication errors have focused on improved technology and processes to decrease the risk. These improvements have not reduced the need for staff nurses and students to be competent in medication administration. Medication calculation skills are essential to ensure that patients receive the correct medication dose. Nurses are the final checkpoint in the medication administration process and it is imperative that they maintain competency in medication calculation skills.

The results of this study and previous research indicate that medication calculation is a weakness among most nurses and nursing students. Nurse educators are in an essential role to assess medication calculation skills and assist staff in finding creative ways to maintain and/or improve these skills.

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