

Medication Errors: More Basic Than a System Issue

E. Carol Polifroni, EdD, RN, CNAA; John McNulty, MS, RN; and Lynn Allchin, PhD, RN

ABSTRACT

The Institute of Medicine's 2000 report drew attention to both U.S. health care agencies and the medication errors that occur within them. However, this attention focused on a more basic and fundamental issue within the medication error concern: nurses' mathematical skills and competence. This article describes a nationwide study assessing processes to validate mathematical skills for medication administration. Practices within educational and acute care institutions are explored, and recommendations for future action are noted with a call for 100% accuracy on all mathematical examinations for medication administration.

The Institute of Medicine's (IOM) 2000 report focused attention on the 7,000 deaths that occur per year as a result of medication errors, as well as the dramatic effects of nonfatal medication errors. As attention increased, the major conclusion was that system issues were at the core of the medication error issue (Carroll, 2003). System issues such as physician order entry in computerized format, the need for unit dose (i.e., single-dose packaging), and the availability of pharmacy coverage throughout the workday for a 24-hour period were examined. However, the attention focused on a more basic issue within the medication error concern: nurses' mathematical skills and competence.

History

The authors found that during clinical experience, some students had significant difficulty preparing medications for administration and seemed stuck at the computation stage of the process. There was little formal discussion of mathematical competence until the authors spoke with each other, but it soon became apparent that all faculty working with undergraduate students cited examples of math-related difficulties in the clinical area.

At the same time, statewide, non school-based meetings suggested that nurses working in inservice education were concerned about new grad-

uates' inability to pass medication administration tests during their orientation in acute care institutions. Staff development nurses began to discuss the problem at statewide meetings, but the issue never moved beyond the discussion stage.

Being employed in a research-intensive agency and interested in determining whether the problem was unique to them or experienced by many, the authors conducted a literature review.

Literature Review

Nursing schools teach students the basics of safe medication administration, including what is known as the "Five Rights": administering the right drug to the right person in the right dose through the right route at the right time. Errors in the time of administration (Poster & Pelletier, 1988) and dosage amount (Worrell & Hodson, 1989) are the two most common medication administration errors (Ptaszynski & Silver, 1981). Segatore, Miller, and Webber (1994) found that 11% to 14% of medication errors are related to mathematical errors. The ability to pass a medication calculation test during RN orientation and the likelihood of future medication errors was studied by Calliari (1995), who found a significant direct correlation between initial test failure and future increased rate of medication errors.

Received: February 19, 2003

Accepted: April 30, 2003

Dr. Polifroni is Associate Professor, Mr. McNulty is Instructor, and Ms. Allchin is an Assistant Professor, University of Connecticut School of Nursing, Storrs, Connecticut.

The authors acknowledge and thank the fiscal funding from the University of Connecticut Research Foundation and Mu Chapter, Sigma Theta Tau International.

Address correspondence to E. Carol Polifroni, EdD, RN, CNAA, University of Connecticut School of Nursing, 28 Coldspring Drive, Storrs, CT 06066; e-mail: carolpolifroni@aol.com.

Several studies demonstrate that nursing students and other health care professionals lack the ability to calculate medication dosages accurately and consistently. During a 5-year period, Bindler and Bayne (1984) tested 700 junior-level baccalaureate nursing students and found that 9% to 38% of each group tested were unable to pass a seventh grade math proficiency examination at the 70% level. Blais and Bath (1992) administered a 20-item math calculation test to 66 baccalaureate nursing students and found that 89% of them failed to obtain a passing score of 90% or above. Analysis of their errors revealed that students made conceptual errors 68% of the time, demonstrating their inability to set up the problems correctly. Mathematical errors represented 19% of the total errors made, revealing students' inability to perform basic addition, subtraction, multiplication, division, or decimal point functions. Measurement data that required students to convert between metric and apothecary measurement systems accounted for another 13% of errors.

The literature does not offer any clear standard related to what constitutes mathematical competence (Pape, 2001). Therefore, it is important to describe current teaching and validation practices related to mathematical competence for medication administration of nursing students within the United States. The related issues are:

- Validation procedures (if any).
- Required passing scores.
- The actual test used for validation.
- Outcomes if the identified passing rate is not achieved.
- Frequency of validation.
- Use of calculators during the validation examination.
- Use of equivalency charts during the examination.
- Remediation activities for students requiring help with these essential mathematical skills.

The authors conducted a Connecticut statewide review of mathematical validation procedures

in all nursing programs (88% response rate) for students throughout the curriculum, as well as in acute care institutions (77% response rate) for new graduates. A new graduate was defined as an individual employed in nursing for the first time after graduation. All schools except one and all acute care institutions except one assessed mathematical competence for medication administration. However, this was the only common area.

The one consistent finding in both these surveys was inconsistency. No clear pattern of processes and outcomes emerged for either the schools or the acute care institutions. In addition, no significant differences between program types of diploma, associate, baccalaureate, or generic master's degree programs appeared in the findings.

Twenty-three percent of the schools assessed mathematical competence at the beginning of the nursing program, 60% in a specific course, and 23% at various other times during students' academic tenure. Of the schools responding, 66% permitted the use of calculators, whereas 26% did not, and the remainder did not answer the question. Although only 3 schools permitted use of equivalency charts, all of them tested for this knowledge of conversion.

Some schools established passing rates as a matter of policy, whereas others did not. All acute care institutions reported a specific passing rate ranging from 70% to 100%. All but two of the acute care institutions required a passing score of 80% or above.

The data from the pilot study were both encouraging and discouraging because they showed a national study was needed and warranted but confirmed that basic mathematical abilities were an issue for students within all educational programs and for new graduates employed in acute care institutions.

Research Questions

- How are mathematical competence skills for medication adminis-

tration validated in nursing programs throughout the United States?

- How are mathematical competence skills for medication administration validated for new graduates in acute care institutions throughout the United States?

Method

The rather high response rates from the nursing programs and acute care institutions within Connecticut (88% and 77%, respectively) provided the authors with both the encouragement to conduct the national study and additional insight into the importance of the issue and the amount of concern among educators in both educational and service institutions.

In 1997, there were 1,219 approved and National League for Nursing-accredited programs preparing individuals for RN licensure examinations (National League for Nursing [NLN], 1997). The NLN arranges the schools into four geographic regions, which the authors used to create the sample for this study. Using proportional sampling techniques, 594 schools were randomly selected, producing a sample stratified by region and program type. The total sample reflects the overall national percentages of program types: 9% diploma programs, 51% associate degree programs, and 40% baccalaureate degree programs.

A response rate of 53% or higher was received from every program type, for a final sample size of 318. The final sample consisted of 21 responses from diploma programs (7%), 167 responses from associate degree programs (53%), 122 responses from baccalaureate degree programs (38%), and 8 responses from programs that did not identify themselves.

In addition, in early 2002, the 42 acute care institutions designated with the Magnet Program Recognition Award were also invited to participate in the study. Funding did not permit a complete nationwide sample, so it was concluded that the mathematical competence issue could be reasonably assessed in those insti-

tutions deemed excellent in a variety of areas by an independent body of the American Nurses Credentialing Center. Although there may be few acute care institutions with the designated Magnet status, the authors decided they could reasonably hypothesize that the concerns were similarly present in those institutions who did not have a Magnet designation. Fifty-five percent of these institutions responded to the survey.

The researcher-designed questionnaire initially used in the statewide test (deemed as a pilot) had been modified based on the use and comments made by the statewide participants, and was mailed to all participants in the nationwide survey. The questionnaire consisted of 28 items assessing practices, policies, and procedures related to validation of mathematical competence for medication administration and some demographic information required for analysis and reporting purposes. The questionnaires were returned anonymously via postage-paid envelopes but were coded by region to ensure national and programmatic representation.

Results

In nursing programs throughout the United States, the required high school math courses were fairly comparable by program type. The majority of students in all program types were required to satisfactorily complete high school algebra (70%), whereas less than 30% of the sample required algebra II or geometry. Fifteen percent of the sample did not require any high school math courses for admission to the nursing programs. These were primarily diploma programs.

Validation Procedures

Ninety-eight percent of the nursing programs and 100% of the acute care institutions surveyed validated math skills prior to medication administration. Regardless of program type, 87% of the nursing programs had policies in place addressing mathematical skills. Specifically,

73% of the schools' policies discussed the use of calculators, 47% addressed the use of equivalency charts, 78% specified the frequency of examinations (i.e., validation testing), 82% addressed a specific passing score on the test, and 67% addressed remediation activities. However, no such consistency existed within the acute care institutions surveyed.

Actual Test Used for Validation

The acute care institutions and nursing programs were similar in that the majority of the tests used were faculty designed and not assessed for a specific grade level of mathematical or test-taking skills.

Required Passing Scores

The required passing score was an issue of significant variation. Ten percent of the baccalaureate degree programs, 5% of the diploma programs, and 17% of the associate degree programs required 100% accuracy. The most frequently cited required passing score was 90% correct, with several programs requiring at least 80% correct, and less than 15% of programs requiring a score of 70% correct. All acute care institutions surveyed required 80% correct to pass, although none required 100% accuracy.

Within the nursing programs, 30% required a math test during every clinical course in which medications are administered. Math-related questions on every nursing examination, regardless of medication administration, were required by 13% of the schools. There is no relationship between these policies and required passing scores.

Consequences if Required Passing Score is not Achieved

Both the acute care institutions and the nursing programs reported widely varying policies related to the consequences of not achieving the required passing score on the first completion of the tests. Of the nursing programs, 6% did not permit retaking the tests, whereas all acute care institutions did. In addition, 19% of the nursing programs, particularly

baccalaureate degree programs, permitted students to take the tests as often as necessary to achieve the required passing score, and 52% permitted students to repeat the tests either once or twice. The majority of the acute care institutions followed a similar pattern, some allowing new graduates to repeat the tests three times, if necessary.

Eventually, 19% of the nursing programs dismissed students from the program if passing scores were not achieved, 45% dismissed students from the courses, and 30% made case-by-case decisions. All of the responding acute care institutions made case-by-case decisions.

Frequency of Validation

All the acute care institutions tested for mathematical competence skills prior to medication administration. A few (5%) tested during the hiring phase, but the majority tested during orientation, immediately prior to the actual administration of medications. However, the initial testing period for nursing schools varied. Fifty-six percent tested during the first clinical course, which may occur at any time from the first through the third year of the actual program, but 8% tested on admission to the program, and 11% tested before admission. The remaining time points of initial validation of mathematical competence were prior to the first clinical course (12%) and in a general, nonclinical nursing course (3%).

Use of Calculators

Fifty percent of the nursing programs and 65% of the acute care institutions permitted the use of calculators during the mathematical test.

Use of Equivalency Charts

Equivalency charts were not permitted in 75% of the nursing programs and 43% of the acute care institutions, although conversion ability was always tested.

Remediation Activities

To assist with remediation, 20% of the acute care institutions and less

than 40% of the nursing programs used computer-assisted instruction. The majority of nursing programs and acute care institutions used person-to-person tutorials accompanied by self-learning modules. The majority of the nursing programs (64%) also required students to practice in simulation laboratories, but it was unclear what materials were actually used within the laboratories. Most nursing programs (95%) and all the acute care institutions provided learners with practice exercises and expected them to use them prior to retaking the test.

Although data were also collected on students' Scholastic Aptitude Test scores and grade point averages, they were too limited to conduct any meaningful analyses related to the above data.

Discussion

The issue of mathematical competence for medication administration is significant. The findings of this study are alarming but consistent throughout the United States. Nursing students and, subsequently, new graduates have difficulty with basic math.

This study did not examine the specific areas of mathematical difficulty, but the literature provides some insight regarding both computational ability and conceptual processing. In either case, the required mathematical competence for medication administration is at the 7th grade level (D. McGarvan & J. Lewis, personal communication, July 12, 2002). Therefore, it is inappropriate to have this content taught in college-level courses.

However, something must be done to enhance the mathematical ability of nursing students and new graduates. It cannot be left solely to system-issue solutions. In the authors' conversations with two mathematicians and educators of college-level math courses, as well as two high school math teachers, the most fre-

quently recommended and unanimously endorsed solution was practice. They suggested that the time between when skills are learned and when they are applied may be too long. Therefore, educational and acute care institutions must provide many practice opportunities for students and graduates to hone their skills. These practice activities need to occur both before and after testing. In other words, practice opportunities must be part of the entire curriculum within nursing programs and those opportunities need to be followed through in the real world of health care delivery. One of the authors frequently alludes to the world of sports, in which practices occur 5 to 6 days per week in preparation for 1-hour games on Sundays. Nursing education and health care delivery must embrace this type of practice approach.

Furthermore, there needs to be some national discussion as to how and why a 70% score can be passing when one medication error would never be acceptable. The authors recommend that all nursing programs and acute care institutions adopt a required 100% passing score. Although this will not guarantee the elimination of medication errors, it will greatly decrease the number of medication errors made due to either conceptual processing or computational ability.

In addition, if calculators are permitted within the acute care world of health care, why are they not permitted within nursing programs? There may be rare times when calculators are unavailable, but they are as routine as syringes, tea spoons, and other assistive devices. Therefore, the knowledge of how to use them will be as basic a need for a nurse as the knowledge of how to use a syringe.

Finally, there needs to be more consistency on whether equivalency charts are useful within educational and acute care institutions. The pattern of current behavior varies great-

ly, and there does not seem to be any agreement concerning usefulness of equivalency charts.

Summary

This national survey on mathematical competence for medication administration demonstrates that the current approach to reducing medication errors through addressing system issues is inadequate and will continue to be until the basic mathematical skills of practitioners are addressed. Individuals need to be held accountable for the basic skills necessary for minimum safe practice, and educational and health care institutions must assume the responsibility of ensuring the minimum preparedness of their practitioners.

References

- Bindler, R., & Bayne, T. (1984). Do baccalaureate students possess basic mathematical proficiency? *Journal of Nursing Education*, 23, 192-197.
- Blais, K., & Bath, J. (1992). Drug calculation errors of baccalaureate nursing students. *Nurse Educator*, 17(1), 12-15.
- Calliari, D. (1995). The relationship between calculation test given in nursing orientation and medication errors. *The Journal of Continuing Education in Nursing*, 26, 11-14.
- Carroll, P. (2003). Medication issues: The bigger picture. *RN*, 66(1), 52-58.
- Institute of Medicine. (2000). *To err is human*. Washington DC: National Academy Press.
- Pape, T. (2001). Searching for the final answers: Factors contributing to medication administration errors. *The Journal of Continuing Education in Nursing*, 32(4), 152-160.
- Poster, E., & Pelletier, L. (1988). Primary versus functional medication administration: Monitoring and evaluating medication error rates. *Journal of Nursing Quality Assurance*, 2, 68-76.
- Ptaszynski, E., & Silver, S. (1981). Experience in posology. *Journal of Nursing Education*, 20(8), 41-46.
- Segatore, M., Miller, M., & Webber, K. (1994). Medication out of control. *The Canadian Nurse*, 90(8), 35-39.
- Worrell, P.J., & Hodson, K.E. (1989). Posology: The battle against dosage calculation errors. *Nurse Educator*, 14(2), 27-31.