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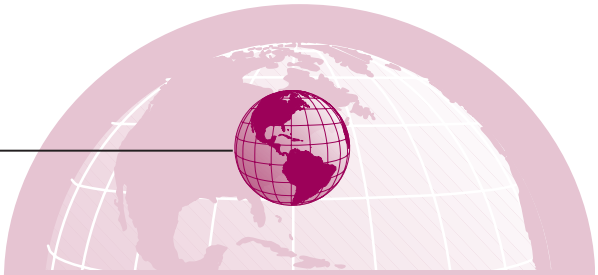
FEATURE ARTICLE



Nurses' Attitudes Toward the Use of the Bar-coding Medication Administration System

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This study determines nurses' attitudes toward bar-coding medication administration system use. Some of the factors underlying the successful use of bar-coding medication administration systems that are viewed as a connotative indicator of users' attitudes were used to gather data that describe the attitudinal basis for system adoption and use decisions in terms of subjective satisfaction. Only 67 nurses in the United States had the chance to respond to the e-questionnaire posted on the CARING list server for the months of June and July 2007. Participants rated their satisfaction with bar-coding medication administration system use based on system functionality, usability, and its positive/negative impact on the nursing practice. Results showed, to some extent, positive attitude, but the image profile draws attention to nurses' concerns for improving certain system characteristics. The high bar-coding medication administration system skills revealed a more negative perception of the system by the nursing staff. The reasons underlying dissatisfaction with bar-coding medication administration use by skillful users are an important source of knowledge that can be helpful for system development as well as system deployment. As a result, strengthening bar-coding medication administration system usability by magnifying its ability to eliminate medication errors and the contributing factors, maximizing system functionality by ascertaining its power as an extra eye in the medication administration process, and impacting the clinical nursing practice positively by being helpful to nurses, speeding up the medication administration process, and being user-friendly can offer a congenial settings for establishing positive attitude toward system use, which in turn leads to successful bar-coding medication administration system use.

KEY WORDS

BCMA • Medication errors • Nurses' attitudes

It is necessary to keep up-to-date with respect to new technology to provide optimum patient safety in the information era. One information technology (IT) system that can powerfully affect patient safety is the bar-coding medication administration (BCMA) system. The BCMA system helps prevent medication errors (MEs) by allowing the nurse to easily confirm the eight Rs (8Rs) of medication delivery that involve the basic nursing principles for medication administration at the point of care: right medication, right dose, right patient, right route, right time, right assessment, right reason, and right documentation.[1] These 8Rs were previously known as "5Rs" historically and were taught to nurses as a means of minimizing opportunities for errors.[2]

Many hospitals are deploying BCMA systems in an attempt to decrease the rate of MEs, creating a need to measure the success or efficacy of BCMA system deployment. Because system success depends on acceptance by users, it is essential to pay attention to system end users and organizational issues.[3,4] Essential issues include adequate preparation and training to enable users to appreciate the system's impact on work performance and on patient care.[5]

A key to successful BCMA system implementation is early identification of users' attitudes toward the system and their perception of its usefulness, so that early remedial steps can be taken if necessary.[4,6–8] Therefore, identifying users' dissatisfaction can help to uncover the reasons underlying system rejection, which can enhance the adoption process and eventually achieve system success.

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Together, IT designers and nurses can collaborate on BCMA systems so that implementation is successful.

BACKGROUND

The US Food and Drug Administration issued a rule in 2004 requiring drug manufacturers to use bar coding on medications, hoping to boost patients' safety. The bar-coding rule aims to protect patients against MEs, which are a leading cause of harm to patients. This rule calls for the implementation of a BCMA system that reads bar codes on the outside of medication containers or wraps to allow the healthcare professional to verify the 8Rs, as a replacement for manual checking. For this compulsory change, the successful deployment of a BCMA system is of concern to hospitals. Such technology has been in use for more than 10 years. However, system success depends on the level of user acceptance of such an IT application.

Currently, the use of the BCMA system is becoming so prevalent in hospitals in the United States that almost every RN working in hospitals with automation or hospitals on the way to automation has some experience with BCMA system use. There may be different attitudes and different system perceptions by BCMA system users, and each user inevitably develops a different generalized impression of such technology.

According to Rogers' diffusion of innovation (DoI) theory, technological innovation is communicated through particular channels, over time, among the members of a social system. A major focus of the DoI theory is how potential users' perceptions of an IT innovation influence its adoption. Moreover, users of technological innovations are expected to pass through five stages (Figure 1) prior to IT acceptance. To reach the acceptance decision, the innovation user rates the new innovation along five attributes: innovation relative advantage (the degree to which it is perceived to be better than what it supersedes), innovation compatibility (consistency with existing values, past experiences, and needs), innovation complexity (difficulty of understanding and use), innovation trialability (the degree to which it can be experimented with on a limited basis), and innovation observability (the visibility of its results).[9]

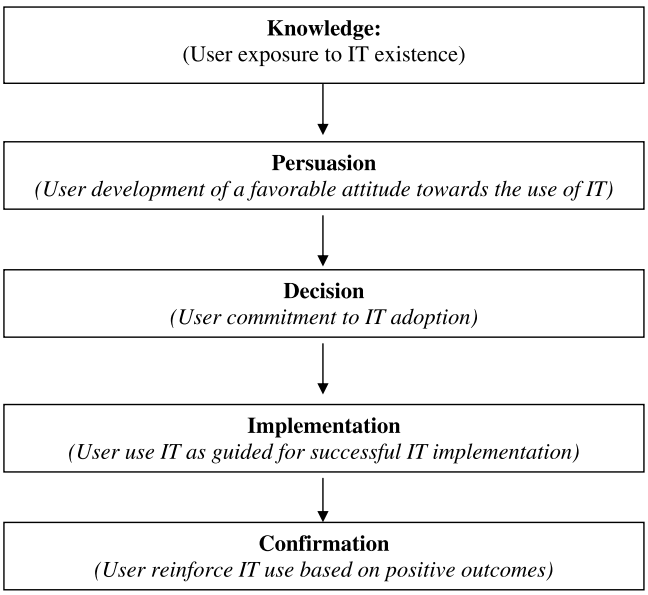

FIGURE 1. Stages of IT adoption according to DoI theory.

The theory of reasoned action (TRA) from psychology indicates that external stimuli influence the individual's attitude toward a behavior indirectly by influencing his/her salient beliefs about the consequences of performing the behavior.[10] Attitude toward using is a function of two beliefs: perceived usefulness and perceived ease of use. Therefore, individual demographic data and system experience (such as work experience, sex, age, level of education, BCMA system skills, having been involved in an ME), in conjunction with information communicated by others, become the basis for the development of images in the mind's eye of the person. These image profiles can eventually influence a user's perceptions of or attitude toward adopting and using an information system.

The attitude assumed regarding BCMA system use incorporates how nurses judge the system's usage profile, how much they like/dislike to use the system, how they usually behave regarding its use,[10] and how they perceive the impact of such a system on nursing practice and on patient safety. Attitude has long been used as a determinant for a user's intention to use or adopt an information system or any technology. Davis,[11] in his technology acceptance model, which is based on the TRA, included two constructs: perceived usefulness and perceived ease of use, which are analogous to the two attributes—perceived advantages and perceived complexity—mentioned in the DoI theory. Also, the attitude toward using the system is considered a function of the two beliefs: usefulness and ease of use, which, in turn, are both believed to be essential factors in determining acceptance level of IT use.[11–13] Within the proposed technology acceptance model, attitude toward using the system is defined as the degree of evaluative affect that an individual associates with using the proposed system in his/her job. Users' educational level, past experiences, and technology skills are recognized as barriers or facilitators to system use.[14]

This study was performed to answer the following research questions:

1. What demographic attributes and self-reported BCMA system skill level affect a nurse's attitude toward BCMA system use?
2. Does the BCMA system image profile affect a nurse's attitude toward system use?
3. Would the BCMA system image profile developed by the user act as a predictor of system success?

LITERATURE REVIEW

BCMA System Success and Nurses' Satisfaction With Its use

Studies showed that there are more than 65 steps in the drug therapy management process from the "tip of the prescriber's pen" to the "tip of the patient's tongue." Any one of these steps is vulnerable to human error, but most of the reported MEs occurred in the steps associated with prescriber ordering (39%) and medication administration (38%). Moreover, in these studies, nurses and pharmacists most often intercepted errors made in the ordering or prescribing stage. Around one-half of prescribing errors and approximately one-third of transcribing and dispensing inaccuracies were detected before these errors reached the patient. Only 2% of the nurse administration errors were intercepted, making nurses particularly vulnerable to causing medication mistakes that actually reach the patient.[15–17]

The use of the BCMA technology in medication administration was found to be effective in decreasing MEs and improving patient safety. Studies showed that the use of BCMA systems has resulted in a 65% to 74% documented decrease in MEs.[18,19]

Furthermore, the computerized physician order entry (CPOE) system was introduced in an attempt to decrease MEs at the prescription phase and was found to significantly reduce potential MEs. The use of the CPOE system made the rate of MEs fall by 81%. Large differences were seen for all main types of MEs: dose errors, frequency errors, route errors, substitution errors, and allergies. Furthermore, the CPOE system did not have the problem of handwritten prescriptions, where poor handwriting interpretation was a source of the ME.[20,21]

Successful deployment of BCMA requires system acceptance by nursing staff, who fulfill a many-faceted role in medication administration. Any medication administration system that will promote efficacy in nursing, patient safety, and easy access to data can be considered a supportive system in nursing practice, and is able to satisfy nurses.[22]

Furthermore, nurses' morale affects, to a large extent, the efficiency and quality of care of the healthcare organization. The positive correlation between job performance and job satisfaction makes job satisfaction and morale among nursing staff a current concern worldwide. Poor job satisfaction is a leading cause of increased staff turnover, which adversely affects the quality of care rendered by the healthcare organization. Moreover, nurses' dissatisfaction with the use of a BCMA system can have a negative effect on productivity and the provision of quality healthcare service. Also, nurses' satisfaction with the BCMA system will have a positive impact on their job satisfaction level. Consequently, nurses' satisfaction with the BCMA system will influence their physical and emotional well-being.[23]

The most widely used variables that predict IT success in the literature are (1) user satisfaction[11] and (2) system usage.[11,24]

The BCMA System Profile and Key Benefits

Information technology used for decreasing MEs consists of CPOE, automated dispensing carts, and BCMA. The BCMA system is a point-of-care application built on a design that complements the way nurses work in administering bedside medications. It allows automatic verification of all components of medication administration, including patient-specific information. Also, the BCMA system allows dose autocalculation and checking for various harmful drug interactions, whereas the CPOE system allows the flawless communication of medication order to the pharmacy, thereby reducing MEs. The BCMA system should be fully integrated with the patient electronic health record (EHR) and CPOE systems to enable seamless electronic medication management that "closes the loop" from order entry to medication administration.[25]

The medication administration process starts when the provider prescribes the medication using the CPOE system. The CPOE system is a computerized system for making drug orders that includes ME-prevention software. The CPOE system provides prescribers with a menu of medications from the formulary with default doses and a range of potential doses for each medication to ensure that all drug orders are legible. Furthermore, the CPOE systems display patient-specific, relevant laboratory results on the screen at the time of ordering and check for drug-allergy contraindications and drug-drug interactions.[26]

After prescription, the medication request is transmitted to the pharmacy by electronic order. The pharmacy uses a bar-code–based system to dispense the medications. All medications need to have bar codes on them. The pharmacy technician pulls the medication and scans it to verify if it is the right drug, then it is checked by the pharmacist and loaded in the automated dispensing cart by a technician. On the floor, the nurse has to look at the electronic medication administration record (eMAR) before taking the needed medications to the patient's room. Then the nurse uses a handheld scanner to check patient ID and medication information to make sure they match.[27] The BCMA system allows the nurse to track all medication doses due for assigned patients and provides individual reminders for each nurse along with updates on new and discontinued orders and individual reminders for follow-up documentation such as pain and vital signs. Furthermore, at the bedside, easy-to-read screen prompts guide the nurse through medication administration workflows and 8Rs checking. Customized prompts and warnings

ensure that medications are administered and documented correctly.[28]

The nurse is alerted for potential administration errors of drugs, dose, route, time, or patient. Clinical checks such as allergies, drug-laboratory, and drug-drug interactions can be performed at the time of administration. Moreover, all administered medications are documented in an eMAR; this allows administration details to be captured at the point of care and automatically documented in the patient's EHR. Other information such as injection site, vital signs, and pain assessments can also be captured. The system also enables nurses to electronically send messages to the pharmacy in the context of the administration process, potentially eliminating unnecessary telephone calls. In addition, access to the online drug monograph information allows nurses to check details about any drug,[18] which will streamline medication process for the hospital.[15]

Pitfalls of the Manual Medication Administration Process

The entire medication delivery process is complex; it involves coordination of various disciplines, implementation of system checks and balances, and standardization of delivery and administration procedures from the time the medication order is written until the patient receives the prescribed medication. A breakdown in any one of these systems can lead to adverse drug events (ADEs) for a patient.[29]

Medications are prescribed by a licensed prescriber—dentist, podiatrist, advanced practice nurse, physician assistants, and other healthcare providers—and are dispensed by the pharmacist, but the responsibility for correct administration at the bedside rests with the nurse. The nurse has to read the prescribed medications from the provider order sheet and then transcribe them manually to the nurses' medication sheet that guides administration of prescribed medications. During the transcription phase of the medication order, the nurse should be able to read the handwriting of the prescribing provider. The inability to read the prescriber's handwriting, the manual order verification, and the documentation of the medication administration on the patient chart may cause transcription errors. Using the nurse's medication administration sheet, the nurse manually confirms the 8Rs of the medication administration process.[29]

This manual method is not error-free, and patient misidentification, incorrect medication administration, and incorrect administration of dose, time, and route may occur,[29] besides incorrect documentation, incorrect indication, or incorrect assessment of the administered medication. Medication errors could be caused by incorrect drug prescribing by providers, drug interactions, drug allergies, repeated prescribing beyond intended discontinuation date, and improper drug dispensing. A single failure in any one of these processes can lead to ADEs for a patient. Furthermore, communication failure among the provider, nurse, and pharmacist; slips and memory lapses; lack of standardization of terms and procedures; and policy violation are factors that contribute to ADEs, which will raise healthcare costs.[30]

Medication Errors

In the United States, 44 000 to 98 000 annual deaths among hospital patients were reported as a result of preventable medical errors due to ADEs.[31] One in five American families (8.1 million households) experiences an ME during hospitalization.[32] It has been noted that in 36 healthcare facilities, MEs occurred as many as one error per five doses administered.[33] With the drastic rise in the rate of medication administration errors,[31] healthcare organizations are faced with increasing pressures to practically address medical errors, with special emphasis placed on reducing those that are preventable.

Contributing Factors to MEs

Several studies have identified various contributing factors to MEs. Some of these studies reported that drug calculation is a risk factor and a potential source of errors; hence, MEs may result from the poor arithmetic skills of nurses.[34–36] Another contributing factor is nurses' poor knowledge of medications. Nurses need to be accountable for the drugs they administer, and this necessitates knowledge of the action, dosage, interactions, contraindications, adverse effects, and indication of any drug to be administered.[37,38] It has been reported that nurses who repeatedly update their knowledge on medications make fewer MEs than do nurses who do not.[39] Length of nursing experience is another contributing factor. It was noted that nurses with more experience make fewer errors.[40] Another contributing factor is the type of shift worked.[41,42] Medication errors occurred significantly more often during the day shift than during the night shift. Workload and staffing levels have been shown to affect the rate of MEs.[43,44] Poor adherence to medication administration policies and distractions are considered contributing factors.[45,46] The quality of prescriptions contributes to MEs; nurses often encounter poorly written and even illegible prescriptions that conflict with policies for safe administration of medications.[47] Lack of patient background information such as age, allergies, weight, diagnosis, and pregnancy status. Knowledge about other drugs being taken and about monitoring parameters, for example, laboratory values, vital signs, and other physiological parameters that determine the

effect of medication, may also be factors in administration errors.

Administration is the stage most vulnerable to error, because there is no other eye to intercept any administrative error, whereas pharmacists or nurses may intercept errors occurring in the ordering stage. Relying on manual medication administration limits the nurse's ability to exercise optimal clinical judgment and opens the door for errors that might jeopardize the patient's life and lead to devastating consequences in patient care.[43] Lack of information access, failure to correctly verify medication dose, and patient identity are the most common bedside administration errors by nurses. High levels of inaccuracy are especially common when nurses are hurried, exhausted, or unfamiliar with a medication. Nevertheless, the nursing shortage, distractions, heavy workload, and inexperienced staff are the most common contributing factors associated with MEs.[48,49]

METHODOLOGY

Method

The purpose of this study was to determine if the BCMA system image profile influences nurses' attitude toward BCMA system use, which could be considered an evaluative measure to identify BCMA system success, and to identify the factors that affect nurses' attitudes toward and acceptance of BCMA systems. To determine whether image profile could serve as an evaluative measure to identify system acceptance and identify the need for a strategic approach to enhance the adoption process during system implementation, and to predict system success by determining users' attitudes toward system use, the model in Figure 2 was constructed. Four main factors were included in the BCMA system acceptance model: user acceptance is considered as a determinant for system deployment success, while attitude is used as a determinant for users' intent to adopt or accept use of the BCMA system. The image profile entails the three aspects: system functionality, system usability, and system impact on nursing practice. System functionality refers to the use of the BCMA system in ways that show its advantages over the manual medication administration process (addressed as IT advantage in the DoI theory). System usability refers to whether the system is effective in preventing medication administration errors (congruent to IT observability in the DoI theory). System positive/negative impact on nursing practice refers to whether the BCMA system is easy/difficult to use and if it allows the nurse to be efficient/inefficient while checking the 8Rs required for safe medication administration, and whether it will have a positive or negative impact on the flow of clinical nursing practice. (This conforms with the DoI theory under IT compatibility, IT complexity, and IT trialability.[11–13])

Regression analysis is conducted to identify variables that will predict attitude and, in turn, user acceptance level.

Data Collection Procedure

After receiving approval from the university institutional review board, the author generated an electronic questionnaire and hosted it in her Web account, developed a cover letter soliciting users of BCMA systems to voluntarily participate in the survey, and ensured anonymity. The author listed the URL of the e-questionnaire in the cover letter, which was sent via the Capital Area Roundtable on Informatics in Nursing (CARING) e-mail list in June 2007 to all CARING members. All 425 nurses on the CARING list[50] were invited to participate in the survey. At the time of data analysis, at the end of July 2007, only 67 nurses had submitted a survey. The survey was designed so that no missing data are allowed.

Development of the Instrument

The instrument comprised a 33-item questionnaire measuring nurses' image profiles on BCMA system use and their attitude toward its use in nursing practice for safe medication administration. To better determine the factors that may affect nurses' perceptions BCMA system usage and attitudes toward its use, the questionnaire started with a section containing sociodemographic questions that identified the sex, age group, level of nursing education, level of BCMA system skills, and years of service in nursing.

The second section of the questionnaire contained the 33 questions and was designed to obtain image profiles on BCMA system use as contained in the minds of the participants and their attitude toward system use in nursing practice to decrease MEs before administration. Following the recommendation of Fishbein and Ajzen[10] and to improve reliability, BCMA system usage was measured by multiple-act indicators (ie, different acts indicating the same behavior) rather than a single-act indicator for the reduction of ME contributors. Seven contributing factors to MEs were determined from the literature to formulate items on BCMA system use and were measured on a five-point Likert scale. The development of the questions was based on the results of several studies[11,27,28] assessing BCMA system use in eliminating MEs. These questions contained words or phrases that described the function and use of BCMA systems in nursing practice. Seven phrases were formulated negatively, and 26 phrases were formulated positively. The items were listed randomly, and the respondents selected the appropriate level of agreement with the phrase. For the positive phrases, strongly agree was given the value 5, and strongly

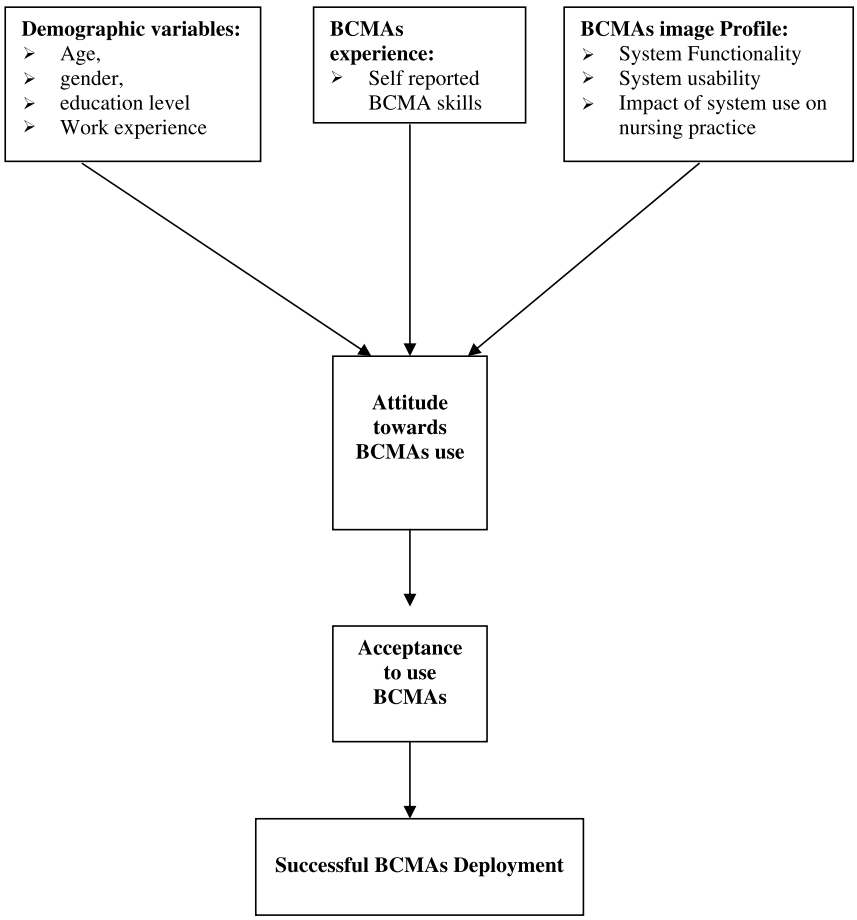

FIGURE 2. Model of successful BCMA system deployment.

disagree was given the value 1. For the negative phrases, the rating points were reversed.

Validity and Reliability of the Questionnaire

The instrument was reviewed by two experts for face and content validity. The reviewers' comments were integrated in the revised questionnaire. Construct validity was assessed by factor analysis of the 33 scale items using principle components extraction and oblique rotation. In the exploratory factor analysis, four factors were identified (Table 1). One factor clustered the BCMA system functionality items. A second factor clustered those items that identified the negative impact of BCMA system use on nursing practice. The third factor was a cluster of items that identified the positive impact of BCMA system use on nursing practice. The fourth factor was a cluster of items that examined the usability of BCMA system in eliminating ME. One item ("my job is no more interesting with the use of BCMA system") fell into more than one factor and was discarded.

The interitem reliability for the questionnaire was assessed by calculating a Cronbach α score (Table 1) to determine internal consistency, based on the average interitem correlation.[28] Selecting strongly agree or agree on the dimensions of respondents' image of the BCMA system displayed in Figure 3 reflects positive or negative attitude toward the use of the BCMA system. Choosing strongly agree or agree for a positively stated dimension listed in Figure 3 is considered a positive attitude, while choosing strongly agree or agree for a negatively stated dimension is a negative attitude.

Table 1

Cronbach α of the Computed Factors

The Four Constructs	Cronbach α
BCMA system functionality	.69
Negative impact of BCMA system use on nursing practice	.86
Positive impact of system use on nursing practice	.72
BCMA system usability	.89

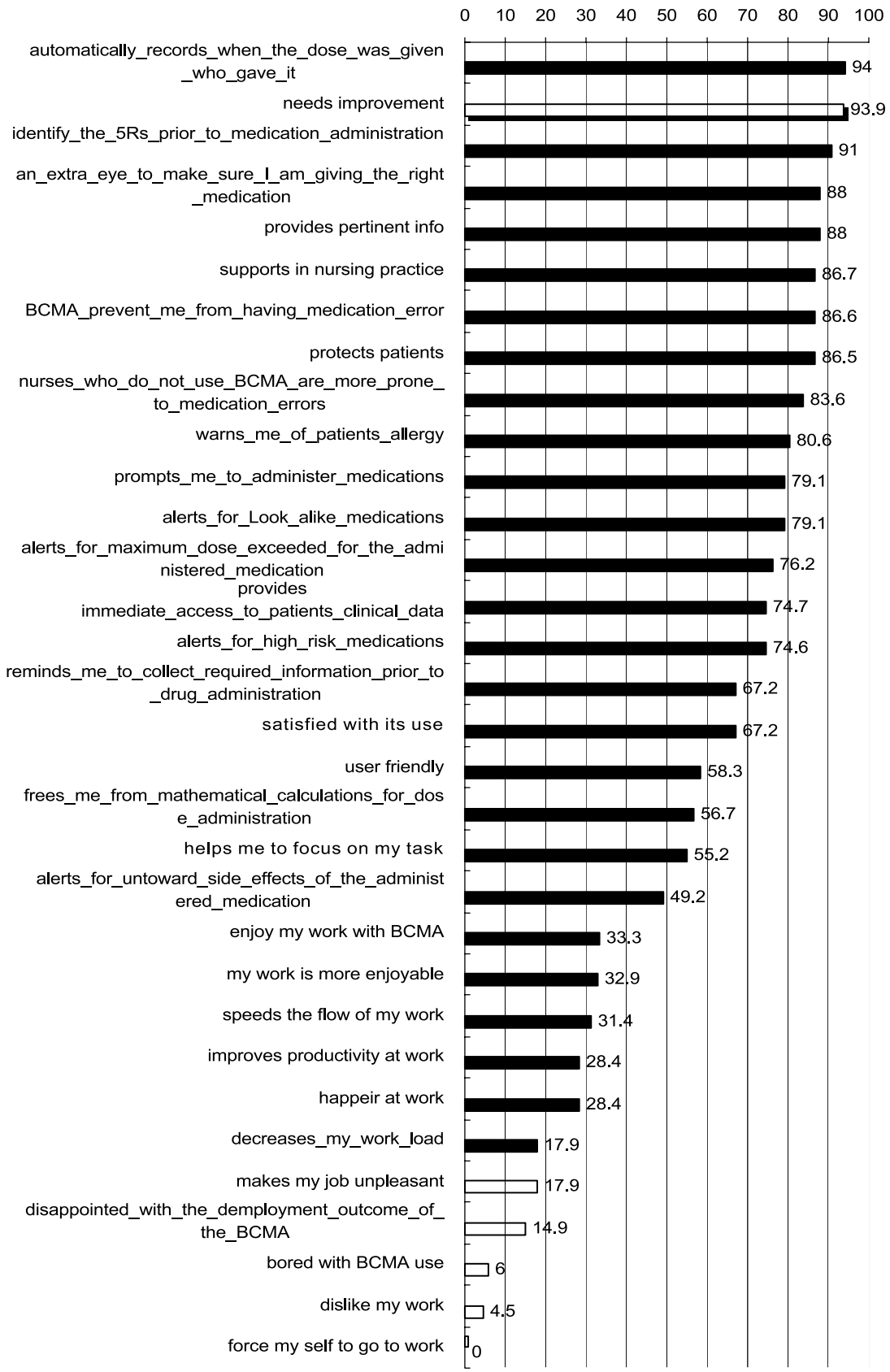

FIGURE 3. BCMA system images recorded by first rating (strongly agree + agree) and ranked based on highest percentage of respondents' choice (the shaded bars denote negative image factors).

Purpose of the Study

The purpose of this study was to evaluate the usability of BCMA systems designed to improve the accuracy of the medication administration process, and to identify some of the factors underlying successful use, which are viewed as a connotative indicator of attitude. The specific purpose was limited to describing the attitudinal basis for adoption and use decisions in terms of subjective satisfaction. Results of the study would then permit nurse system specialists to suggest future modifications to BCMA systems that will meet the essential requirements and standards for medication administration technology systems.

Design and Sampling

The research study uses a descriptive, cross-sectional design to assess nurses' attitudes toward BCMA systems' functionality/advantages, usability, and impact on nursing practice. The study was conducted online in the United States. The principal investigator used the CARING list server to invite participants from various places in the United States to voluntarily participate in the survey. The sampling method was convenience sampling of all RN users of BCMA systems in various hospitals in the United States. Sample size calculation before data collection was not performed because we had no control over the response numbers. Nonetheless, power analysis done after data collection revealed that, for a sample size of 67, the analysis had enough power to detect a Pearson correlation coefficient r as small as 0.35 and a score difference as small as 0.3 using either the independent t test or the analysis of variance (ANOVA) F test and to be able to handle a multivariate regression with as many as five variables using the rule of thumb of 10 observations per variable.

Data Analysis

Descriptive statistics were used to analyze data. All statistical analyses were done with the statistical software program SPSS version 15 (SPSS Inc, Chicago, IL).

Pearson correlations were used to examine the relationship among the four factors. Bivariate association of the general sample characteristics with the factor scores was assessed using the t test or ANOVA. Multivariate associations were assessed using multivariate regression models, and goodness of fit was assessed using the R^2. All analyses were carried at the .05 significance level.

RESULTS

The participants' general characteristics are summarized in Table 2. The education level was defined as below BSN, BSN, and above BSN. As for the years of service, two categories were identified: less than 5 years and 5 years and above.

Thirty-three participants (49%) rated their BCMA system skills as good to average and 34 participants (50.7%) as excellent (Table 2). The computed factor scores were summarized as follows (Table 3): functionality of the BCMA system had a mean (SD) of 3.36 (0.64) with a minimum of 1.50 and a maximum of 5.00, negative impact of BCMA system use had a mean (SD) of 1.98 (0.77) with a minimum of 1.00 and a maximum of 5.00, positive impact of BCMA system use had a mean (SD) of 3.19 (0.60) with a minimum of 2 and a maximum of 5.00, and usability of the BCMA system in eliminating ME had a mean (SD) of 3.72 (0.58) with a minimum of 2.38 and a maximum of 5.00.

The correlation coefficients between the computed scores are reported in a two-dimensional correlation matrix (Table 4). All four factors were significantly correlated with one another ($P < .0001$ for all), with the negative impact score having a negative correlation with the three other factors. The strongest correlation was for functionality and positive impact ($r = 0.79$), followed by functionality and usability ($r = 0.77$) and positive impact and usability ($r = 0.65$).

The bivariate association of general characteristics with factor scores (Table 5) showed that nurses' attitudes toward BCMA system use were affected by their BCMA system skills and appears also to be affected by their age,

Table 2

General Characteristics of the Participants

	No.	%
Age groups, y		
20–29	11	16.0
30–39	12	17.9
40–49	25	37.5
≥50	19	28.4
Total	67	100.0
Sex		
Male	4	6
Female	63	94
Total	67	100.0
Education		
BSN and above	36	53.7
Below BSN	31	46.3
Total	67	100.0
Years of service		
≥5	46	68.7
<5	21	31.3
Total	67	100.0
BCMA system skills		
Excellent	34	50.7
Good-average	33	49.3
Total	67	100

Table 3

Summary Statistics of the Computed Factors

	Mean (SD)	Median	Minimum	Maximum
Functionality of BCMA system in medication administration process	3.36 (0.64)	3.50	1.50	5.00
Negative impact of BCMA system use on nursing practice	1.98 (0.77)	2.00	1.00	5.00
Positive impact of BCMA system use on nursing practice	3.19 (0.60)	3.12	2.00	4.50
Usability of BCMA system in eliminating MEs	3.72 (0.58)	3.68	2.38	5.00

although not at a statistically significant level. More specifically, nurses in their 30s appear to give a lower score (mean, 3.00) to functionality of the BCMA system than do other nurses, namely, nurses in their 20s (mean, 3.59) and in their 40s (mean, 3.52) (P = .060). Furthermore, nurses with excellent skills with the BCMA system gave, on average, a 0.31-point lower score to functionality of the BCMA system than did nurses with good to average skills (3.20 vs 3.51; P = .048). Other findings with respect to the BCMA system skills of nurses show that those with excellent skills gave higher scores (mean, 2.19 vs 1.79; P = .038) on the items for negative impact of BCMA system use on nursing practice.

In addition, the bivariate association of the general characteristics with the factor scores (Table 5) indicates that nurses with an educational level below BSN give a higher score (mean, 3.92) to BCMA system usability in eliminating MEs than did nurses with an educational level of BSN or above (P = .012). As for sex, male nurses scored the BCMA system higher on usefulness in eliminating MEs (mean, 4.28) than did female nurses (mean, 3.69) (P = .05).

Multivariate regression analysis (Table 6) was performed on three factors (negative and positive impact, and usability). The determinants for the negative impact score were sex (men gave, on average, a 0.9 higher score than women did) and functionality of the BCMA system in eliminating MEs (for every unit increase in functionality, a 0.7-unit decrease was reported in negative impact). This model had an R^2 of 42%. Functionality was the only factor associated with positive impact score, where for every unit increase, a 0.74-unit increase in the positive impact score was observed. The R^2 for this model was 62.2%. The R^2 for usability was similar (62%) to that of the last mentioned model, with education and functionality as the only predictors. The model showed that with higher education, nurses reported a lower score on usability (−2.14), and as functionality increased, so did the usability (0.66).

DISCUSSION AND CONCLUSION

Although some studies have emphasized barriers to BCMA system adoption and use, other studies described the acceptance process as a progression to competence: potential users learn to operate the system, after which they are able to adapt its features to the requirements of their work.[51] Consistent with this view, system implementation is seen initially to involve the process of acquiring skills needed to manage the system hardware and software and a minimum level of competence to operate the system.

Why do some users exhibit greater acceptance of BCMA system use? This is because user acceptance is affected by BCMA system image profile such as system characteristics, perceived usefulness, perceived ease of use, and attitude toward usage, which are considered as external stimuli that influence a person's attitude toward a behavior indirectly by influencing his/her salient beliefs

Table 4

Correlation Among the Factor Scores[a]

	Functionality of BCMA System	Negative Impact of BCMA System Use	Positive Impact of BCMA System Use	Usability of BCMA System in Eliminating MEs
Functionality of BCMA system in medication administration process	1.00	−0.58	0.79	0.77
Negative impact of BCMA system use on NP		1.00	−0.49	−0.33
Positive impact of BCMA system use on NP			1.00	0.65
Usability of BCMA system in eliminating MEs				1.00

Abbreviation: NP, nursing practice.
[a]All correlations were significant at the .001 level.

Table 5

Means and SDs of the Factor Scores by Sample Characteristics (Bivariate Association of the General Characteristics With the Factors Scores)

	Functionality of BCMA System	Negative Impact of BCMA System Use on NP	Positive Impact of BCMA System Use on NP	Usability of BCMA System in Eliminating MEs
Age, y				
20–29	3.59 (0.56)	2.07 (1.04)	3.41 (0.62)	3.77 (0.66)
30–39	3.00 (0.57)	2.40 (0.73)	2.90 (0.59)	3.56 (0.55)
40–49	3.52 (0.62)	1.75 (0.57)	3.09 (0.61)	3.83 (0.56)
≥50	3.25 (0.69)	2.00 (0.80)	3.20 (0.61)	3.68 (0.61)
P	.060	.120	.112	.614
Sex				
Male	3.69 (0.31)	2.63 (1.66)	3.38 (0.67)	4.28 (0.59)
Female	3.34 (0.66)	1.95 (0.69)	3.18 (0.61)	3.69 (0.57)
P	.301	.477	.548	.050
Education				
BSN and above	3.26 (0.65)	1.96 (0.74)	3.12 (0.59)	3.56 (0.57)
Below BSN	3.48 (0.62)	2.02 (0.83)	3.29 (0.62)	3.92 (0.54)
P	.182	.732	.262	.012
Experience, y				
≥5	3.31 (0.61)	1.93 (0.66)	3.14 (0.61)	3.71 (0.55)
≤5	3.48 (0.71)	2.12 (0.99)	3.32 (0.60)	3.78 (0.66)
P	.331	.357	.280	.630
BCMA system skills				
Excellent	3.20 (0.64)	2.19 (0.93)	3.12 (0.61)	3.69 (0.66)
Good-average	3.51 (0.62)	1.79 (0.53)	3.27 (0.61)	3.77 (0.50)
P	.048	.038	.302	.556

Abbreviation: NP, nursing practice.

about the consequences of performing the behavior. Therefore, the BCMA system image profile affects a nurse's attitude toward the system use, which in turn can influence system acceptance and system success.

The aspect of successful BCMA system deployment involves the ability of the users to use the four factors of the system most effectively in their work. Based on this research, when the BCMA system was not viewed as a user-friendly system, nor competent in providing needed data at the point of care to assist in decision making for medication administration, nurses depreciated its functionality score, an aspect that can be a barrier to the system's successful use. Furthermore, nurses who felt bored at work or disliked their job due to BCMA system use rated the BCMA system's negative impact on the nursing profession higher, which can be another barrier to successful system use. Moreover, nurses who used the BCMA system to correctly identify the 8Rs as a required

Table 6

Multivariate Regression Models[a]

Variables	Negative Impact of BCMA System Use on NP	Positive Impact of BCMA System Use on NP	Usability of BCMA System in Eliminating MEs
Age	NS	NS	NS
Sex[b]	.934 ± .312	NS	NS
Education[c]	NS	NS	−.214 ± .091
BCMA system skill	NS	NS	NS
Experience	NS	NS	NS
Advantage of BCMA system in eliminating MEs	−.744 ± .116	.744 ± 0.072	.664 ± .71
R^2	0.419	0.622	0.619

Abbreviations: NP, nursing practice; NS, not statistically significant.
Data are presented as β ± SE.
[a]Significant at the .05 level; all other coefficients significant at the .001 level.
[b]Reference = female.
[c]Reference = below BSN.

nursing practice during the medication administration process scored high on system usability. Therefore, being able to value the system use for preventing MEs, for making better decisions concerning medication administration, and for promoting patient safety is an important predictor or indicator for system usability, which is another aspect that, when taken into account, will facilitate successful system implementation.

Participants who gave high ratings to BCMA system functionality, usability, and BCMA system positive impact on the nursing practice reflected a positive attitudinal basis toward system use, an aspect that predicts a system's successful implementation.

Based on this research, it appears that the major factors that influence nurses' perceived functionality of the BCMA system are system characteristics, such as being user-friendly and providing pertinent information. Nurses consider the BCMA system to have a positive impact on nursing practice if it supports medication administration decision making, speeds up the flow of work, and enhances productivity. Furthermore, the main factor in nurses' satisfaction with BCMA system use was its ability to eliminate MEs by assisting the nurse to identify the 8Rs at the bedside, alerting them to medication adverse effects and high risk, exceeding dose, look-alike medication, prompting the administration of medication, freeing the nurse from medication calculation, warning about patient allergy, and providing immediate patient clinical data.

In the past 10 years, continuous efforts have been made to upgrade BCMA systems to meet the required standards of medication administration. Concurrently, studies on BCMA system use showed that the deployment of such an IT reduced MEs by 54%.[52] It is true that barriers to any system use are expected, yet end-user input helps to better define the extent of problems and barriers encountered.

This study has shown how users of the BCMA system rated their satisfaction with and perceptions of BCMA system use. Based on these results (93.9% agreed that there are characteristics of the BCMA system that should be improved, and 41.7% indicated that the system is not user-friendly), we suggest to BCMA system software developers in general to consider user feedback and to conduct a thorough review of current system characteristics, then introduce modifications according to gathered comments on system usefulness and ease of use.

In the eyes of the nurse users in this sample, the BCMA system can significantly reduce MEs by cotrolling or eliminating many of the contributing factors. However, many viewed the use of the system as a burden for them at work and the system did not help in decreasing the nurses' workload. These results emphasize that system usage is an appropriate indicator of IT acceptance and can be considered as a measure of system success.

It is vital for researchers and developers of IT to determine nurses' attitudes toward and satisfaction with the use of any IT in the constantly evolving healthcare system. Recommendations to ensure that future modifications to existing BCMA systems would be functional and meet nurse-user needs would include the following:

- To conduct further studies during which researchers can accurately identify the characteristics of the BCMA system nurses consider problematic and in need of modification
- To encourage system developers to perform a thorough review of system design reflecting on nurses' considerations with respect to system usability, functionality, and impact on nursing practice

This study has several limitations: one cohort of nurses subscribed to a single e-mail list was used, and the statistical calculation of the study was based on a convenience sample, which did not permit generalization of results. However, it presents a literature review that demonstrates the nature of system use acceptance that is mediated by distinct factors related to the psychology of the users, ease of system use, and user perceptions of system usability in improving patient safety and decreasing MEs. Furthermore, it presents approaches that can support the derivation of predictors of system user acceptance. This study, in terms of its implications about users' level of acceptance based on BCMA system scores on factual effectiveness, can be of interest to researchers in a variety of fields, to consumers of technology, and to BCMA system designers.

Through appropriate use of BCMA systems and together with the professional skills of the nursing staff, the incidence of MEs can be significantly reduced and patients' safety can be greatly improved and secured.

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