The Effect of Implementing Bar-Code Medication Administration in an Emergency Department on Medication Administration Errors and Nursing Satisfaction

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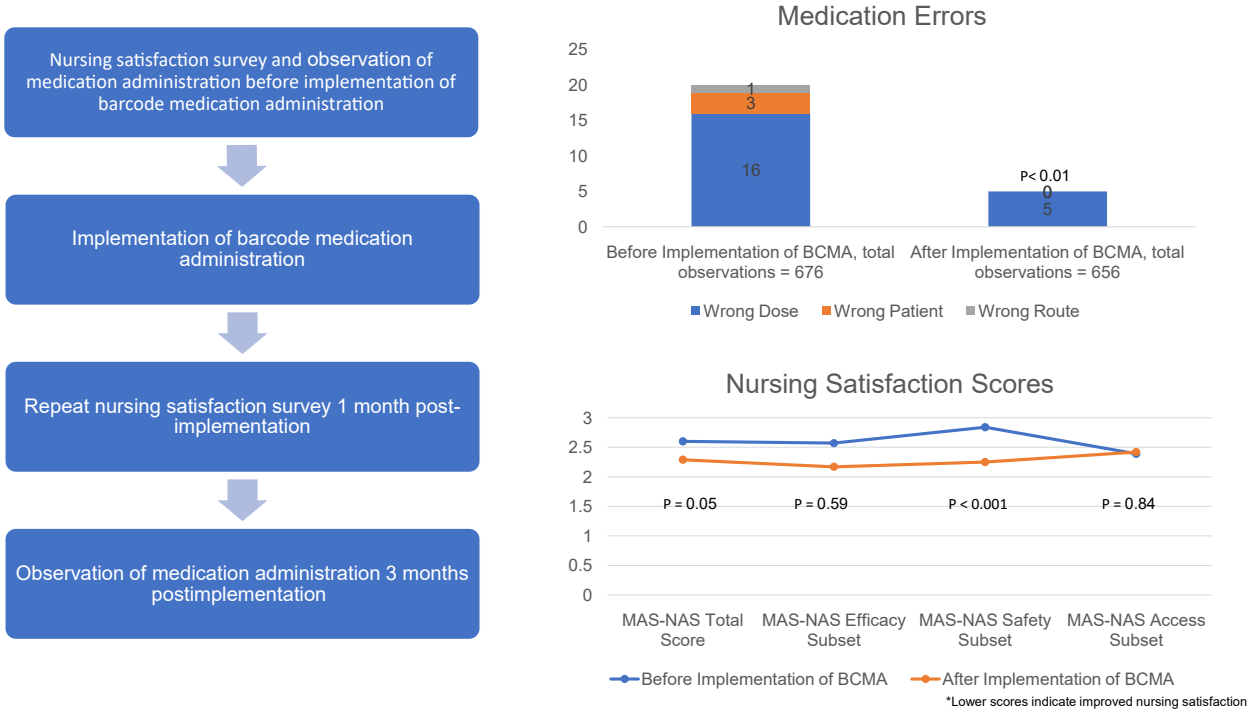
Graphical abstract



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Contribution to Emergency Nursing Practice

- The current literature on bar-code medication administration in an emergency department indicates that implementing bar-code medication administration may reduce medication administration errors, but there is an unknown effect on nursing satisfaction.
- This article contributes that bar-code medication administration implementation reduces medication administration errors by 74.2% and improves nursing satisfaction with medication administration systems.
- Key implications for emergency nursing practice found in this article are that bar-code medication administration may be implemented in an emergency department to reduce medication administration error rates while improving nursing satisfaction with medication administration systems.

Abstract

Introduction: Bar-code medication administration has been shown to reduce medication errors in inpatient settings with limited studies on its use in emergency departments. In addition, no studies have evaluated nursing satisfaction with implementing bar-code medication administration in an emergency department. This study was designed to determine the impact of implementing bar-code medication administration in an emergency department on medication errors and nursing satisfaction.

Methods: This is a before-and-after study, with no control group, of a bar-code medication administration intervention conducted in a community hospital emergency department. Direct observation was used to compare medication error rates before and 3 months after implementing bar-code medication administration. The Medication Administration System—Nurses Assessment of Satisfaction survey was used to assess the impact on nursing satisfaction before and 1 month after bar-code medication administration implementation.

Results: A total of 676 medication administrations were observed in the period before bar-code medication administration implementation and 656 after. The medication administration error rate preimplementation was 2.96% with "wrong dose" errors being the most common. After bar-code medication administration implementation, the medication administration error rate fell to 0.76%, a relative reduction of 74.2% (Fisher exact $P < 0.01$). The average (SD) Medication Administration System—Nurses Assessment of Satisfaction score preimplementation was 2.60 (0.75) and improved to 2.29 (0.66) ($t = 2.00$, $P = 0.05$) 1 month post implementation.

Discussion: Implementing bar-code medication administration in a community emergency department was associated with a decrease in medication administration errors and an improvement in Medication Administration System—Nurses Assessment of Satisfaction scores. The results of this study suggest a benefit of bar-code medication administration in reducing medication administration errors and improved nursing satisfaction in the emergency department.

Key words: Bar-code medication administration; Nursing satisfaction; Medication errors; Medication administration

Introduction

As much as health care workers try to do no harm, medical errors are still a frequent occurrence in hospitalized patients and attributed to as many as 98,000 patient deaths annually.[1] Errors related to the medication administration process contribute to the overall clinical mistakes that could lead to patient harm. Whereas errors related to medications can arise from the ordering or preparation process, one third of the errors occur during the administration process.[2] One way hospitals have combated medication errors is by implementing electronic medication administration record (eMAR) and bar-code medication administration (BCMA) systems in inpatient hospital settings, with studies showing a reduction in errors of as much as 40% to 70%.[3-7] However, limited studies have been reported on implementing these systems in emergency departments to reduce medication errors.[8,9]

Medication administration in the emergency department differs greatly from that in the inpatient setting.[10] For example, the emergency department receives patients with unknown health care issues who undergo medical evaluation for their condition. Because medical information evolves with further assessments, the medical record has limited information on medication allergies, weight, and height, and most treatment with medications are one-time-only or a loading dose for medications that continue after admission. Other challenges faced in the emergency

department are an increased number of verbal orders, a chaotic environment with rapidly changing census, and a variable patient type and load. Some medication orders are given when patients are being examined by the physician or another provider, and variation exists on order entry or processing. This also presents a challenge for pharmacists to properly reconcile medications and allergies before administration. In addition, most nurses draw medications from an automated dispensing cabinet without the aid of bar-coding or other systems to avoid errors related to a wrong drug or dose.

A bar-coding system for medication administration is one method to improve accuracy and safety in medication administration, such as by identifying and linking the patient to the medication order and reconciling this at the point of care. Whereas most reports are on BCMA implementation in inpatient settings, less information is available about its implementation in the ED setting. Implementing BCMA with integrated eMARs in the emergency department has shown a reduction of medication administration errors. Bonkowski et al[8] conducted a before-and-after observational study on medication errors during the implementation of an electronic medical record with BCMA capacity. They found an 80.7% relative reduction in medication administration errors, with wrong dose errors having the greatest reduction. However, in their study, implementation of BCMA with eMAR technology concurrently may have confounded results. In a study by Seibert et al,[9] results showed a 65% relative reduction in all medication administration errors after implementation of BCMA in the emergency department, although the study was underpowered to detect a statistical difference.

Along with reducing medication administration errors, BCMA has been shown to increase nurses' satisfaction with administration systems. A validated study tool created by Hurley et al[11] Medication Administration System–Nurses' Assessment of Satisfaction (MAS-NAS) survey, can be used to measure nursing perceptions of safety, efficacy, and access before and after the implementation of point-of-care technology. Hurley et al[12] found that implementing BCMA and eMAR technology in an academic medical center increased nurses' satisfaction with medication administration systems, improving scores in all 3 areas of the scale (safety, efficacy, and access). However, this study was limited to only 13% of available users of the system and did not include those from the emergency department.

Studies on the impact of BCMA on medication errors in the ED setting are limited and may have been confounded by concurrent eMAR implementation, and no studies have been reported on emergency nurses' satisfaction related to BCMA implementation.[8,9] Thus, the purpose of this study was to add to the body of knowledge about the impact of implementing BCMA independent of eMAR in a community hospital emergency department on medication errors and nursing satisfaction.

Methods

STUDY DESIGN

The study design was a before-and-after study in a single emergency department without a control group. This study is a replication of a study conducted by Bonkowski et al[8] with the addition of a nursing satisfaction survey. The investigators used direct observations of medication administration modeled after the study conducted by Bonkowski et al[8] and a validated survey of nurse satisfaction before BCMA implementation and 1 month after implementation of BCMA technology. The Orlando Regional Medical Center's Institutional Review Board determined the study protocol was exempt from review (17.058.05).

SETTING AND SAMPLE

This study was conducted in a 55-bed emergency department at a community hospital in the southeastern United States that included acute, fast-track, and rapid assessment areas. The inclusion criteria for subjects in the study were a convenience sample of registered nurses who were employed in the emergency department at the study facility and who administered medications to patients.

DATA COLLECTOR TRAINING

Nurses on the hospital nurse practice council from inpatient units and pharmacists were given the opportunity to participate in this study as observers and external reviewers of medication administration practices in the emergency department and to avoid bias from peer observations. A total of 14 observers completed a 3-hour training session on the method of observing medication administration in the context of the study using an observational tool developed by the investigators. Inter-rater reliability was measured before clinical observations. After education and training, the observers then performed a simulated observation of medication administration using the tool, while being evaluated by 2 study investigators for completeness. The observers achieved 100% if they successfully marked all observations using the tool. All observers met this requirement before making study observations.

PARTICIPANT RECRUITMENT FOR OBSERVATION AND SURVEY

Nurses were invited to participate in the medication administration observation portion of this study before medication dispensing. If a nurse verbally consented to being observed by trained research personnel during the medication administration process, the trained observer proceeded with the observation.

All nurses who administered medications in the emergency department were invited to complete the survey portion of the study, irrespective of participation in the medication observation portion of the study. A study information sheet was provided to eligible nurses for an opportunity to participate. Consent was implied by their voluntary completion of the MAS-NAS survey after reviewing the study information sheet.

DATA COLLECTION AND STUDY PROCEDURES

Medication Administration Error Rates

Direct observation of medication administration was used to determine medication administration error rates. Direct observation is a scientifically validated method of measuring medication errors and is nonpunitive.[8,9] The trained observers were blinded to the medication orders. In contrast to the study by Bonkowski et al,[8] this study included both nurse and pharmacy observers that were known to the emergency nurse personnel to dampen the potential of the Hawthorne effect associated with unfamiliar observers.

Before the intervention with BCMA implementation, the observers collected data on medication administration using the tool for 1 month. All medications administered, except those given during emergency conditions such as cardiac or respiratory arrest and rapid sequence intubation, were included in the analysis. The observers documented the patient medical record number; medication name, route, and dose; and time of administration. The observations were conducted in all shifts across all days of the week in the emergency department and were based on observer availability.

After the observations were completed, nonobserver nurses and a pharmacist compared the medications observed during administration with the medication orders entered into the eMAR by the provider. Medication errors were defined according to 4 of the 5 rights of medication administration: right patient, right drug, right dose, and right route. Right time was excluded because most of the medication orders in the emergency department are one-time or stat orders. The medication administration error rate, the primary end point, was calculated as the number of medication administration errors observed divided by the total number of medication administrations observed in each time period.

After the initial observations, the Informatics Services initiated BCMA with medication administration and documentation processes and added scanners to the ED computers. Over a 2-week period, the Informatics Services team provided education and training to nurses in the emergency department on BCMA processes. BCMA was then implemented throughout the emergency department. After a 3-month lead-in period to reinforce and coach the use of the new BCMA process, a postimplementation observation period of medication administrations was repeated using the same process as previously described. This was similar to the study by Bonkowski et al.[8]

Nursing Satisfaction Survey

The MAS-NAS survey is an 18-item survey with 3 subscales with a Likert-type scale ranging from "Strongly agree" to "Strongly disagree."[11,12] Thus, lower scores indicate higher satisfaction with the item. The authors of the MAS-NAS survey reported the reliability coefficient for the 18-item scale as 0.86 using the Cronbach alpha. Hurley et al[11] conducted a principal components analysis to test validity and revealed 3 subscales including efficacy, safety, and access with individual factor loadings for items ranging from 0.36 to 0.80. The survey was conducted 2 weeks before

TABLE 1
Medication administration errors

Medication administration errors	Preimplementation period (n = 676)		Postimplementation period (n = 656)		*P value*
Total errors, n	20	2.96%	5	0.76%	< 0.01
Wrong dose, n	16	2.37%	5	0.76%	0.03
Wrong patient, n	3		0		NS
Wrong route, n	1		0		NS

Fisher exact test results.
NS, not significant.

implementation of BCMA and 1 month after the implementation of BCMA.

DATA ANALYSIS

For the medication administration errors primary end point, all data were transcribed into an Excel spreadsheet (Microsoft Corp., Redmond, WA) for analysis. The primary end point was evaluated using the Fisher exact test for the detection of error rates that were anticipated to be low in number. To determine the sample size for the medication administration errors portion of the study, an a priori power analysis using G*Power 3.1 was done. Using an estimated baseline error rate of 6% found in the study by Bonkowski et al[8] and an expected error reduction of 50%, 748 medication administrations were needed in each study period to show an effect at α of 0.05 and 80% power. Because the survey was based on a convenience sample, a power analysis was not conducted for the survey part of the study.

Responses on the MAS-NAS survey were entered into an Excel spreadsheet and imported into Statistical Package for the Social Sciences software version 20 for analysis. Data analysis was conducted on the basis of pre- and postimplementation groups and matched pairs as available because the sample of nurses in the emergency department varied over the study period and not all nurses participated in both phases. Changes in MAS-NAS total scores and subscale scores were analyzed using an independent sample t test and paired-sample t test for matched pairs. The MAS-NAS survey has 3 section scores and a total score. When less than 20% of the respondent's data were missing for any of the 3 subscales, a computed mean was used for the subscale. If more than 20% of data were missing for a subscale in the survey, the participant's responses were not used in the final data in those sections of the survey. Any survey with insufficient data for the total score was eliminated from analysis. Descriptive statistics were used to define participant demographics.

Results

A total of 676 medication administrations were observed in the emergency department before BCMA implementation and a total of 656 in the period after implementation. The number of observations did not reach the a priori estimation of a sample size of 748 for this study. Table 1 summarizes the medication administration errors. The Fisher exact test was used to evaluate differences between pre- and postintervention medication error rates owing to small errors detected in the postobservation period. A total of 20 medication administration errors were found in the preimplementation period (2.96% error rate) and 5 medication administration errors (0.76%) in the postimplementation period. There was an absolute rate reduction in medication errors of 2.20% (Fisher exact test $P < 0.01$), which represented a 74.2% relative rate reduction in medication

TABLE 2
MAS-NAS survey baseline characteristics

Participant characteristics	Preimplementation n = 41	Postimplementation n = 49	Matched pairs n = 23
Age in y, mean (range)	37 (24-63)	38 (24-63)	37 (24-63)
Sex, n (%)			
Female	32 (78)	34 (69.4)	14 (60.1)
Male	4 (9.8)	7 (14.3)	3 (13.0)
Highest nursing degree, n (%)			
AS/AD	4 (9.8)	5 (10.2)	2 (8.7)
BS/BSN	31 (75.6)	34 (69.4)	18 (78.2)
MS/MSN	1 (2.4)	1 (2.4)	0
Years of nursing experience, mean (range)	9.9 (0.5-38)	9.7 (0.5-40)	8.0 (0.5-31)
Number of hours worked in a typical week, mode (range)	36 (20-48)	36 (24-45)	36 (24-45)

MAS-NAS, Medication Administration System—Nurses Assessment of Satisfaction; AS, associate of science; AD, associate degree; BS, bachelor of science; BSN, bachelor of science in nursing; MS, master of science; MSN, master of science in nursing.

TABLE 3
Nursing satisfaction survey scores for unmatched and matched pairs

MAS-NAS	Unmatched MAS-NAS scores						Matched pairs MAS-NAS scores n = 23					
	Preimplementation n = 41		Postimplementation n = 49		*t*	*P* value	Preimplementation		Postimplementation		*t*	*P* value
	Mean (n)	SD	Mean (n)	SD			Mean (n)	SD	Mean (n)	SD		
Total MAS-NAS	2.60 (39)	0.75	2.29 (46)	0.66	2.00	0.05	2.54 (20)	0.63	2.26 (20)	0.77	1.63	0.12
Efficacy	2.57 (41)	0.96	2.17 (48)	0.99	1.91	0.59	2.54 (23)	0.92	2.27 (23)	1.07	0.96	0.35
Safety	2.84 (40)	0.85	2.25 (48)	0.63	3.71	< 0.001	2.94 (22)	0.79	2.33 (22)	0.73	3.30	<0.01
Access	2.39 (40)	0.74	2.42 (46)	0.75	−0.21	0.84	2.23 (21)	0.56	2.16 (21)	0.66	0.80	0.43

Scores from MAS-NAS survey.[11]
MAS-NAS, Medication Administration System—Nurses Assessment of Satisfaction.

administration errors with BCMA implementation. Wrong dose errors were also significantly reduced from 2.37% preimplementation to 0.76% in the postimplementation period (absolute rate reduction 1.97%, Fisher exact test $P = 0.03$).

Nearly half of the emergency nurses participated in the MAS-NAS surveys. Of the 89 nurses, 41 participated in the MAS-NAS before implementing BCMA and 49 participated in the MAS-NAS after implementing BCMA. Two survey scores from the preimplementation and 3 survey scores from the postimplementation periods were excluded from the total MAS-NAS scores because of missing data. The respondents were predominately female with an average age of 38.2 years (range 24-63) and 10.5 years of nursing experience (range 0.5-40) (Table 2). An independent sample *t* test was used to evaluate differences in MAS-NAS scores for total (unmatched) pre- and postsurvey scores. The average total MAS-NAS score before implementation was 2.60 (0.75) (n = 39), and the average MAS-NAS score 1 month postimplementation was 2.29 (0.66) (n = 46; difference of 0.31; $P = 0.05$; 95% confidence interval [CI] 0.001-0.61). The safety subscale also showed improvement from the pre- to postimplementation periods from 2.84 to 2.25 (difference of 0.59; $P < 0.001$; 95% CI 0.27-0.90); however scores in the access and efficacy subscale did not significantly improve. The scores for each item and subscale are found in Table 3. In the matched pairs group (n = 23), the total MAS-NAS scores did not significantly improve from the pre- to the postimplementation period (2.54 [0.63] and 2.26 [0.77] respectively; difference of 0.28; $P = 0.12$; 95% CI −0.08 to 0.64). The safety subscale in the matched pairs group did show improvement from the pre- to the postimplementation period from 2.94 to 2.33 (difference of 0.61; $P < 0.01$; 95% CI 0.23-0.997) respectively.

Discussion

Implementing BCMA technology is aimed at reducing medication administration errors to improve patient safety. This study's results showed a 74.2% reduction of medication administration errors after implementing BCMA technology in an emergency department. This is consistent with previously published studies in inpatient units and emergency departments.[3-8] Although this study showed a reduction in errors, the rate of medication administration errors in the preimplementation phase was lower than previously reported in ED studies.[8] This may be due to the fact that our study facility already had an eMAR system in place for electronic documentation before BCMA implementation unlike the study by Seibert et al[9] in which

BCMA was implemented concurrently with the eMAR technology and may have confounded the results in.

Wrong dose errors accounted for a significant portion of medication administration errors in both study periods. This was due to BCMA technology being able to associate medication orders with specific medication dosage packages that contain the exact dose if possible. However, there were still wrong dose errors in the postimplementation period owing to the manipulation of oral and injectable dose forms to administer a partial dose. One way to possibly further reduce these errors is to provide nurses with more medication package options that match ordered doses.

Implementing BCMA in our study also prevented 2 medication errors from reaching patients. BCMA stopped 2 medications from being given to the wrong patient during the postimplementation study period. These were not included in the wrong patient errors in the postimplementation period because they did reach the correct patient after the nurse was alerted to the potential medication error once she scanned the patient's bar-code. This further shows how implementing BCMA technology can reduce medication errors in emergency departments.

Our results demonstrated that it is feasible to improve nursing satisfaction with the implementation of BCMA technology with the medication administration system in the emergency department. This improvement in the MAS-NAS scale was predominately driven by the safety subscale, which could be expected when implementing a technology aimed at improving patient safety. This is the first study to show reduction in medication administration error rates with the implementation of BCMA in the ED setting that also showed a corresponding improvement in nursing perceptions of safety, as well as overall satisfaction with the medication administration system. The results from the matched pairs showed no significant differences and this may be due to the small sample size that may have been underpowered.

Limitations

This study was conducted in only one emergency department in a larger health care system, thus may not be generalizable across all settings. Further replication of this study is needed to substantiate the results more broadly with control and contemporaneous comparison groups to address potential confounding. Although this study did not meet the a priori sample size for medication administration observations owing to the prescheduled implementation of BCMA, a post hoc power calculation showed that our study was still powered to detect a difference with an α of 0.05 and power of 84.4%. Although medication administrations were observed during all days of the week, only 12.7% and 12.5% of the total administrations were observed on weekends in the pre- and postimplementation periods, respectively. In addition, more medication administration observations were completed between the hours of 7:00 AM and 3:00 PM than any other period (preimplementation, $n = 430$ medication administrations and postimplementation, $n = 547$ medication administrations). The timing and date of medication administrations may have confounded the results. Medication administration observations were conducted on the basis of the availability of nurse observers with more observations occurring between 7:00 AM and 11:00 PM; however, this coincides with the peak volume of patients seen in our emergency department. In addition, there may have been seasonal bias based on the times of year when the medication administration observations were completed. However, during the study periods before and after implementation of BCMA, our study site saw an average of 237 patients per day and 243 patients per a day, respectively, indicating similar patient volumes. Future studies could include a 1-year postimplementation medication administration observation period to further confirm a reduction in medication errors. In addition, although this study used nursing colleagues and pharmacists as observers, a Hawthorne effect could not be excluded. Finally, the MAS-NAS scores statistically improved in the postimplementation period, but the statistical significance was not maintained in the matched pair subgroup owing to the small sample size.

Implications for Emergency Nurses

For many health systems, the complexity of medication administration in the emergency department has limited the ability to implement BCMA technology in the emergency department. This study offers support for implementing BCMA technology in emergency departments despite the difference in practice from inpatient nursing units. Implementing BCMA can reduce medication administration errors and may improve overall nursing satisfaction.

Conclusions

Implementing BCMA in a community-based emergency department can reduce medication administration errors and improve nursing satisfaction, with an emphasis on safety of the medication administration process.

Author Disclosures

Conflicts of interest: none to report.

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