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Improving Medication Administration Safety in Solid Organ Transplant Patients Through Barcode-Assisted Medication Administration

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Abstract

Solid organ transplant recipients are prescribed a high number of medications, increasing the potential for medication errors. Barcode-assisted medication administration (BCMA) is technology that reduces medication administration errors. An observational study was conducted at an academic medical center solid organ transplant unit before and after BMCA implementation. Medication accuracy was determined and administration errors were categorized by type and therapeutic class of medication. A baseline medication administration error rate of 4.8% was observed with wrong dose errors representing 78% of the errors. During the post-BCMA period the medication administration error rate was reduced by 68% to 1.5% ($P = .0001$). Wrong dose errors were reduced by 67% ($P = .001$), and unauthorized medication administrations were reduced by 73%. Steroids were associated with the highest error rate. The results of this study suggest that routinely adopting BCMA has the potential to reduce medication administration errors in transplant patients.

Keywords

medication safety, barcode scanning, quality improvement

Solid organ transplantation is definitive treatment for end-stage organ failure. Therefore, transplantation is lifesaving but has the potential for significant complications including organ rejection, infection, electrolyte imbalances, surgical site pain, and blood pressure abnormalities. These complications are prevented and managed primarily with complex drug regimens. For example, at The Ohio State University Wexner Medical Center (OSUWMC), patients admitted to the transplant unit average 25 medication doses administered daily, increasing the potential for medication administration errors and interactions. In addition, various formulations of antirejection medications are not therapeutic equivalents and generic and branded formulations may have clinically significant variations in pharmacokinetic profiles.[1] Based on previously published reports citing hospital medication administration error rates of up to 10%, patients on the transplant unit at OSUWMC may be at risk for more than 2 medication administration errors every day.[2]

Medication errors in transplant patients have the potential to cause significant harm. Medication errors in one study of 93 transplant recipients resulted in 9 episodes of acute rejection with 6 graft failures.[3] Kidney transplant recipients who experience acute or chronic cellular rejection can survive on hemodialysis and potentially receive another kidney, but chronic dialysis for 1 patient costs the American health system $82 285 per year.[4] Moreover, liver transplant patients have no other alternative treatment for graft failure except retransplantation. Therefore, implementing strategies to reduce medication errors can improve outcomes for patients, protect transplanted organs, and minimize harm.

Hospitals and health systems have employed technology to reduce medication errors and improve medication safety. To that end, barcode-assisted medication administration (BCMA), a prominent example of medication safety technology, has been adopted to reduce medication

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administration errors by 40% to 70% in hospital inpatients.[5-9] BCMA assists the nurse to assure medication administration accuracy by comparing a scanned medication to an electronically placed medication order. If the scanned medication does not match any order for the patient, the system triggers an appropriate alert for the nurse to prevent a medication administration error. Nurses on the transplant unit can benefit from warnings presented by the BCMA system and reduce the potential of medication administration error caused by complicated transplant regimens.

Introduction

OSUWMC implemented an integrated electronic medical record (EMR), replacing 19 department- or specialty-specific clinical systems. This implementation placed all electronic processes related to medication management on the same system, including prescriber order entry, order verification, medication dispensing, and administration. The implementation of the integrated EMR allowed for the adoption of BCMA across all inpatient units of OSUWMC. BCMA was implemented 2 weeks after the implementation of the EMR.

BCMA implementation was preceded by a significant planning effort involving practitioners from a variety of disciplines. The interests of the transplant unit were well represented by a participating staff nurse. Time during the planning meetings was dedicated to specific workflows on the transplant unit. Functionality was built into the application to support these workflows.

The primary end point of this study was the medication administration error rate on an inpatient solid organ transplant unit before and after implementation of BCMA. The rate of specific error types and medications associated with errors were the secondary end points of the study.

Methods

Study Site

This study was performed in an academic inpatient solid organ transplant unit at OSUWMC. The transplant center at OSUWMC performs nearly 400 kidney, liver, and pancreas transplants annually. The transplant unit treats patients immediately after surgery, as well as for any episodes of rejection, infection, hypertension, or other complications.

Medications administered to patients on the transplant unit are available from several different locations. High-volume medications and commonly scheduled medications are obtained from automated dispensing cabinets (ADCs) located in locked medication rooms. The medication orders dispensed from ADCs are reviewed prospectively by pharmacists prior to administration. Medications that are ordered infrequently are delivered to locked patient-specific drawers on carts that are in several locations on the unit. These carts are replenished once every evening and as new orders are entered. Posttransplant maintenance medications are delivered to the patient bedside as part of a patient compliance education program.

Study Design

Review Board Approval. Institutional review board (IRB) approval was obtained from The Ohio State University IRB prior to data collection (2011H0163).

Naïve Medication Observation. Baseline nurse medication administration was observed on the transplant unit in September and October of 2011, prior to implementation of an integrated EMR and BCMA. Postimplementation medication administration was observed 9 months after an integrated EMR with BCMA had been implemented system-wide (June 2012). Nurses were eligible for observation for the duration of the medication administrations for that day if the nurse provided consent. Trained observers, who were naïve to the clinicians' orders, shadowed nurses from medication retrieval from the ADC or medication drawer to the patient bedside for medication administration. After documentation of a medication pass for a given patient, the observer obtained consent from the nurse for observation. Medication administration observations were scheduled for the major medication passes each day across all days of the week. The majority of medication administrations occur during the morning medication pass from 0700 to 0930 and the evening medication pass from 1900 to 2130.

Observer Training. Observers were trained on the observational technique through a 2-hour lecture on medication administration and observational technique concepts.[10] Topics included medication administration, unobtrusive behavior, and blinding to the physician's order. The technique was practiced on a unit not included in the study. The principal coinvestigator (JJB) and 2 volunteer pharmacy students conducted observations.

Observer Documentation. Observers documented the medication name, dose, route, formulation, and time of medication administration by the nurse. If a partial package of the dose was administered, the observer documented the amount administered. Large-volume maintenance fluids without additives, respiratory therapy medications, and nystatin oral solution were excluded from data collection. Inhaled respiratory medications and nystatin oral solution

Table 1. Medication Administration Error Rate Reduction.

Errors	Pre-BCMA	Post-BCMA	Relative Rate Reduction	*P* Value
Total	45/936	15/976	68%	.0001
Error types				
Dose	35/936	12/976	67%	.001
Drug	2/936	0/976	100%	.5
Drug—no order	7/936	2/976	73%	.18
Route	1/936	1/976	4%	1.0

Abbreviation: BCMA, barcode-assisted medication administration.

were excluded from data collection because they are not administered by nurses. Respiratory therapy administers inhaled medications. Nystatin often is self-administered by the patient as part of a patient training program. All other medications were included in the study regardless of where the nurse retrieved the medication.

Medication Administration Error Rate Measurement. Medications documented during observed administrations were compared to the physician's electronic order after all observations were conducted in each time period. The name, dose, route, and time of the medication order were reviewed retrospectively from the patient's EMR and compared to the medication order. Medication administration errors were defined as any discrepancy between the medication that was administered and the medication that was ordered. Errors were classified as wrong drug, route, and dose. Unauthorized medication administrations also were classified as an error. Errors were discovered after medication administration and therefore observers were unable to intervene to prevent any error. The medication administration error rate was calculated as the number of medication administration errors divided by the total number of medication administrations observed in each time period. The error rates by type of error and medication therapeutic class are secondary end points.

The patient medical record number, medication name, dose, route, and time of administration were documented during direct observation of nurses. The drug name, dose, route, and scheduled time of the medication order were recorded from the EMR after all observations had been conducted in each time period. Data were transcribed into an Excel (Microsoft Corporation, Redmond, WA) spreadsheet for analysis. The primary end point, pre- and post-BCMA medication administration error rate, was evaluated using the Fisher exact test. For an estimated baseline error rate of 10% and an estimated error rate reduction of 40%, a total of 951 medication administration observations were required before and after the implementation of BCMA to show an effect at α .05 and 90% power. The Fisher exact test also was used to determine the error rate by type of error. The medication therapeutic category was evaluated using a logistical regression model with a Firth correction.

Results

A total of 936 medication administrations were observed before the implementation of BCMA, and 976 medication administrations were observed after BCMA implementation. Medications from the morning medication pass represented 68% of total observations before BCMA implementation and 75% of observations after BCMA implementation (Table 1).

Medication Administration Errors

In the baseline period prior to BCMA implementation, 45 medication administration errors occurred (4.8% error rate); 15 medication administration errors were discovered after the implementation of BCMA (1.5% error rate; Table 1). This represents a relative rate reduction of more than two thirds in the medication administration error rate. Relative error rate reductions were documented in all error types except wrong route errors. The only error type with a significantly reduced rate was wrong dose errors. The reduction in unauthorized medication administrations also was notable.

Errors by Therapeutic Classification

Medication errors in both time periods were pooled to analyze the impact of AHFS therapeutic category on error occurrence. Only categories with at least 15 medication administrations were included in the analyses. These categories are identified with an asterisk (*) in Table 2. Because of therapeutic categories with no errors and a low error rate, an overall χ^2 test was not the correct statistical test. Instead, a logistic regression model was fit with a Firth correction applied to assess differences in error rates between AHFS categories. The results showed significant differences in error rates between AHFS categories overall ($P < .001$). To identify which categories differed, all

Table 2. Medication Therapeutic Categories Associated with Administration Error.

AHFS Category	AHFS Category Number	Total Administrations	Error Rate
	2	2	0.0%
Antihistamine	4	11	0.0%
Anti-infectives	8*	127	3.9%
Antineoplastic	10	4	0.0%
Autonomic agents	12*	20	5.0%
Blood derivatives	16	1	0.0%
Blood formation and coagulation	20*	120	0.8%
Cardiovascular	24*	361	1.1%
Central nervous system	28*	299	4.0%
Electrolyte, caloric, and water balance	40*	207	2.9%
Antitussive, expectorants, and mucolytics	48	3	0.0%
Eye, ear, nose, and throat preparations	52	7	14.3%
Gastrointestinal drugs	56*	318	2.5%
Hormone and synthetic substitutes	68*	107	12.1%
Topical anesthetics	84	5	0.0%
Smooth muscle relaxants	86	13	0.0%
Vitamins	88*	58	0.0%
Unclassified	92*	249	3.6%

pairwise differences were compared using Fisher exact tests with Holm's adjustment ($k = 45$ tests). Hormones and synthetic substitutes had a significantly greater error rate than cardiovascular drugs (adjusted $P = .0001$), gastrointestinal drugs (adjusted $P = .01$), and blood formation and coagulation drugs (adjusted $P = .02$).

Discussion

This study adds to the solid organ transplant medication safety literature by measuring a baseline medication administration error rate and the error rate reduction of transplant medication administration errors with BCMA. To the authors' knowledge, there are no other observational studies evaluating medication administration errors on a transplant unit of an academic medical center. The results of the study demonstrate that BCMA is an effective tool to reduce medication errors associated with the complicated medication regimens of transplant patients and to identify specific error types and medications associated with error so that mitigation strategies can be implemented to reduce error.

As a result of these observations, a lower baseline error rate was found on the transplant unit compared to previous reports on inpatient units.[2,5-8] This difference in reported and observed error rates may be attributed to the use of an EMR with clinical decision support on the transplant unit in the baseline period. The orders populated an electronic medication administration record (MAR) that allowed nurses to print out a work list. The work list was used to assist with removing medications from the ADC and at the bedside to verify orders before medication administration. This practice possibly promoted fewer mistakes in medication administration compared to a traditional MAR because the work list was more portable than the MAR.

BCMA implementation on the transplant unit resulted in a relative rate reduction of medication administration errors by 68%, which is consistent with other BCMA studies using a similar observation technique when wrong time errors are excluded.

BCMA reduced wrong dose errors by 67%, which was the only error type to reach a significant rate reduction. The rate reduction of unauthorized medication administrations was greater than wrong dose errors but it did not reach significance because of a low baseline error rate. These errors were the result of medication administrations that were substantially off schedule (a morning medication given in the evening or vice versa). Before BCMA implementation nurses did not always have medication information with them after medication retrieval. Doses or schedules may have changed from the time they printed their medication list in the morning to the time they administered the medication. After implementation of the integrated EMR and BCMA, nurses interacted with the electronic MAR on a workstation while distributing medications. The electronic MAR displayed the most up-to-date dosing information, which assisted the nurse to administer medications accurately.

Corticosteroids, classified as Hormones and Synthetic Substances by AHFS, were associated with the highest rate of medication administration error. Corticosteroids are

commonly adjusted as part of the patient's antirejection regimen. Prednisone, the oral corticosteroid used on the transplant unit, is dispensed in 5 mg tablets from the ADC; that dosage strength is used to minimize gastrointestinal side effects from the steroid. Nurses remove as many 5 mg tablets as required for the ordered dose. The intravenous formulations of corticosteroids, methylprednisolone, and hydrocortisone often are ordered in doses not equal to the available package sizes, requiring nurse calculation to draw up the appropriate dose. Providing nurses with package sizes equal to ordered doses would minimize nurse manipulation of the dose and potentially reduce errors. The transplant service is working to standardize practice not only for the ordering of corticosteroids but also the tapering of these drugs. Standardization of steroid prescribing likely will lead to reduced errors of every type.

Although the authors are the first to report a medication administration accuracy in transplant patients using an observational technique, a 10-day systematic evaluation of medications administered on an inpatient renal transplant unit revealed 103 clinically significant medication errors, 68 of which reached the patient.[11] Medication administration errors in this study represented 33% of the errors that reached the patient, which is similar to previous reports of potential and preventable adverse drug events for general hospital inpatients.[12] To the authors' knowledge, there are no observational studies that evaluate the incidence and severity of medication errors on an inpatient transplant unit prior to the present analysis.

Limitations

Any observational study is limited by the Hawthorne effect, or the bias of subjects changing behavior as a result of being observed.[10] Adherence to the observational technique minimized its impact, but IRB requirements for verbal informed consent before each nursing medication administration observation may have made nurses more aware of the observer's presence. Additionally, nurses were required to introduce the observer to the patient to make the patient feel more comfortable. The study design assumes that the physician order is correct even though prior studies have demonstrated that medication ordering has the highest rate of error.[12] A nurse may have made a clinically appropriate deviation from the physician order at the time of medication administration, but this would have been counted as an error. The study design did not allow evaluation of errors of omission, or of a patient not receiving an ordered medication. Errors of omission accounted for the highest proportion of observed errors in another observational study.[13] The implementation of an integrated EMR may have contributed to the decreased medication error rate because of advanced clinical decision-support tools not available in the previous system and new processes for nurse communication with other members of the patient care team. Nurse demographics in each time period were not controlled for in the statistical analysis. Although turnover is historically low, there is potential that improvements in medication error rates could be biased by improvements in nursing quality. Last, observations were scheduled during the morning and evening medication passes. As-needed medications throughout the rest of the day and the noon medication pass were not represented in the observational data.

Conclusions

The implementation of BCMA reduced the rate of all medication administration error types on an academic medical center transplant unit. The most common error observed on the transplant unit was wrong dose errors, followed by unauthorized medication administrations. Considering the complexity of care issues involving transplant patients, technology was shown to improve at least one aspect of it—medication administration. With a multitude of new medications and potential associated complications, transplant patients may benefit from the implementation of BCMA; BCMA may reduce the potential for errors that could affect their outcome.

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Declaration of Conflicting Interests

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