Effectiveness of Bar Coded Medication Alerts for Elevated Potassium

Ryan P. Radecki, MD[1]; Allison B. McCoy, PhD[2]; Anwar M. Sirajuddin, MBBS, MS[3], Robert E Murphy, MD[3]; Dean F. Sittig, PhD[2]

[1] Department of Emergency Medicine, The University of Texas Health Science Center at Houston; [2]School of Biomedical Informatics, Center for Healthcare Quality and Safety, The University of Texas Health Science Center at Houston; [3]Memorial Hermann Healthcare System, Houston, TX

Abstract

Bar coded medication administration (BCMA), the automated electronic verification of medications by nurses at the patient bedside, provides an additional layer of safety to the process of medication administration in the hospital setting. We performed a retrospective, descriptive study of BCMA alerts for elevated potassium (>5.5 mg/dL) in place within a multihospital healthcare system. Overall, 642 BCMA alerts were analyzed with a 21.3% acceptance rate. In subgroup analysis, we found that the BCMA acceptance rate was 6.9% for patients aged less than one year, and 85.6% for patients aged greater than one year. The major contributing factor to the low overall acceptance rate was the high frequency of alerts in patients less than 1 year of age. Modifications to rules logic may be necessary for this specific population. While BCMA alerts can beneficial, they should be carefully implemented with periodic post-implementation analysis and refinement.

Introduction

Consider this idealized scenario: a patient is admitted to a medicine ward for an upper respiratory infection. His home medications, which include a daily potassium supplement, are continued at the time of admission. His serum potassium level at the time of admission is normal.

Two days later, due to medication interactions with his antibiotics, his potassium level becomes elevated above the safely normal range. While administering the morning medications at the patient bedside, the nurse uses a handheld bar coded scanning device to verify medications. While scanning the daily potassium supplement ordered during the admission process, the nurse receives an automated alert due to the most recently recorded potassium level. The nurse contacts the ordering physician to clarify the standing order. The potassium supplement is discontinued, and potential life-threatening electrolyte imbalance is averted.

The implementation of additional layers of healthcare safety processes aim to minimize the risk of harms as described by the "Swiss cheese" model of medical error.[1] In medication safety, the final check in preventing error occurs at the patient bedside, during the medication administration phase. Historically, errors in this phase have been reported in 7% to 54% of administrations.[2 3 4 5 6] The severity of medication administration errors ranges from minimal harm to life-threatening.[7 8 9]

To address safety issues at the point of medication administration, bar coded medication administration (BCMA) has been developed as a computerized system designed to reduce these errors by requiring positive patient identification and electronic verification of medications.[10] As shown in Figure 1, BCMA systems are interposed in the final step of the medication ordering and administration process. Their primary goals have been described as to prevent wrong-patient, wrong-dose, wrong-time, and wrong-route errors. Successfully integrated electronic medication administration records (eMAR) and pharmacy systems have been demonstrated to reduce errors of these types by up to 58%.[11]

This study evaluates a BCMA system using a series of novel alerts designed to prevent life-threatening complications of hyperkalemia by generating alerts in the setting of elevated potassium levels, adding an additional layer of clinical decision support for patient safety and going beyond the traditional right-patient, right-dose, right-time, and right-route BCMA alerts. An ideal BCMA system would function as envisioned

in the preceding clinical scenario, preventing dangerous medication administration by prompting follow-up communication. Follow-up evaluation of newly implemented alerts and overrides is critical to determine their clinical relevance and unanticipated consequences.[12]

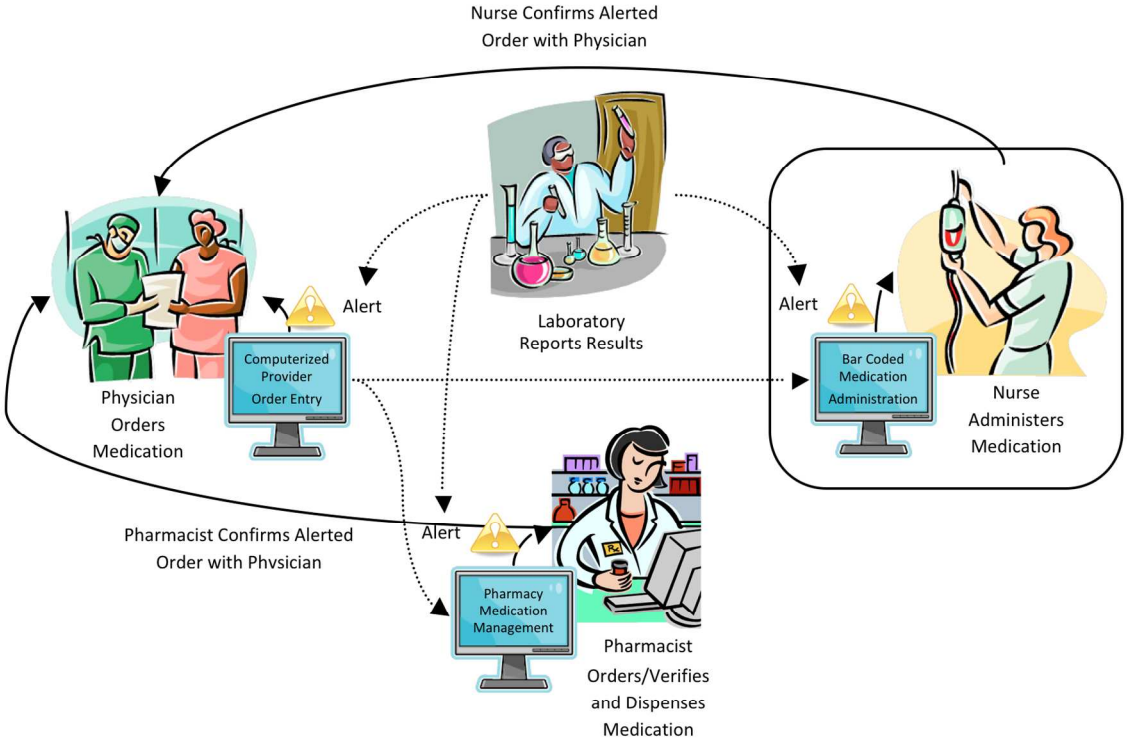

Figure 1: Bar Coded Medication Administration in the Medication Administration Process

Methods

We performed an institutional review board-approved retrospective study developed as a quality improvement review for the organization's Clinical Decision Support Oversight Committee. This study was exempt from informed consent. The study was conducted at Memorial Hermann Healthcare System, which is comprised of 11 hospitals, including a large, academic, tertiary trauma and pediatric center. The healthcare system was recognized as one of the 15 highest performing hospital systems in the USA by Thomson Reuters,[13] is annually recognized as one of the nation's "Most Wired" by Hospitals & Health Networks magazine,[14] and has won several national awards for clinical quality.[15]

BCMA is in use at each facility and consists of a hand-held scanner integrated with eMAR and electronic pharmacy. Nursing staff at a computer workstation access the eMAR just prior to medication administration, then use the scanner to verify bar codes on each dispensed medication. The workstation interface is used to display contextual alerts to nursing staff regarding specific medication administration.

A retrospective, convenience sample consisting of three months of BCMA hyperkalemia alerts was obtained by electronic review of reports generated specifically for quality improvement processes related to clinician decision support. At this institution, the threshold for a BCMA hyperkalemia alert was set at a serum potassium level >5.5 mg/dL. Reviewed fields included potassium level, the response to the BCMA alert (e.g., accept or override), any justification for overriding the alert, the patient age, the ID of the order, and the type of medication ordered. By grouping alerts by the unique ID of the order, it was possible to identify orders that were initially accepted, and then subsequently overridden.

Results

During the three month study period, 642 BCMA alerts for hyperkalemia were generated. Overall, 137 BCMA alerts were accepted resulting in stoppage of the current medication administration, a rate of 21.3%.

Three general types of medication orders containing potassium were identified. 403 BCMA alerts were generated for the administration of potassium supplementing medications, 119 alerts were generated for nutritional fluids containing potassium (e.g., total parenteral nutrition), and 120 alerts were generated for medications and fluids that had potassium as an additive to a primary IV solution. Of these BCMA alerts, 130 (20.2%) were subject to override at the time of the initial alert. An additional 9.1% of these alerts were subject to override after the nurse temporarily accepted the computer-generated suggestion and stopped the medication administration. This data is described in Table 1. The acceptance rate was significantly greater for potassium supplements than other medication administrations ($p < 0.01$ for both comparisons).

Table 1: BCMA Alert Acceptance by Order Type

Medication Order Type	Total	Alert Accepted (%)	Subsequently Overridden
Potassium Supplement	403	115 (28.5)	35
Potassium-Containing Nutrition	119	5 (4.2)	5
Primary IV solution with potassium additive	120	10 (8.3)	6

A clear difference in rate of alert acceptance was noted in neonatal and infant patients, as compared to the adult population. To illustrate this difference, a dichotomized cut-off of one year was selected in order to capture the greatest extent of neonatal and small infant patients. Of the 642 BCMA alerts obtained by electronic record review, 524 occurred in patients who were less than one year of age. The acceptance rate of medication administrations in this age group was 6.9%, compared to an acceptance rate of 85.6% in patients aged one year or greater. This difference is statistically significant ($p < 0.001$). This data is shown in Table 2.

Table 2: BCMA Alert Acceptance by Age

Age	Total	Alert Accepted (%)	Subsequently Overridden
Less than 1 year of age	524	36 (6.9)	25
Greater than 1 year of age	118	101 (85.6)	13

Logistic regression with potassium level as the independent variable showed a weak trend towards decreasing likelihood of alert acceptance as potassium levels increased (OR 0.64, 95% CI 0.38 – 1.09). Summary data for acceptance rate by potassium level is shown in Table 3.

Table 3: BCMA Alert Acceptance Rate by Serum Potassium Level

Serum K+ (mg/dL)	*n*	Acceptance Rate
5.6	124	20.7%
5.7	84	35.7%
5.8	96	25.6%
5.9	50	18.8%
6.0	49	3.1%
6.1	70	5.6%
6.2	20	16.7%

6.3	41	5.6%
6.4	12	4.3%
6.5	4	0.0%
6.6	13	30.0%
6.7	1	0.0%
6.8	8	0.0%
6.9	7	53.8%
7.1	3	0.0%
7.4	6	33.3%
8.4	2	0.0%

When overriding a BCMA alert, the nursing staff may choose from four template explanations, followed by an optional free-text addendum. Overall, there were 505 overrides, and 114 had additional free-text justification entered. Detailed data, dichotomized by age, describing the justification for overriding the BCMA alert is shown in Table 4.

Table 4: BCMA Alert Override Justification and Free-Text Addenda

Override Justification	Total Overrides	Free-text Addenda (%)
Dosing interval appropriately adjusted	108	52 (48.1)
Potential benefit outweighs risk	62	7 (11.2)
This is not clinically significant	92	19 (20.6)
Will monitor labs for patient changes	243	38 (15.6)

Considering the age of the patient, a significant difference was observed between the rates of free-text justification given when overriding a BCMA alert. For patients aged less than 1 year, this rate was 21.5%, compared to 52.9% in patients greater than 1 year of age ($p = 0.03$). The data describing this difference is shown in Table 5.

Table 5: BCMA Alert Override Free-Text Addenda per Patient Age

Age	Total Overrides	Free-text Addenda (%)
Less than 1 year of age	488	105 (21.5)
Greater than 1 year of age	17	9 (52.9)

Discussion

This study describes the response patterns to BCMA alerts for potentially hazardous medication administration in the setting of hyperkalemia. Overall, measured compliance with alerts was poor. However, nearly half of recorded BCMA alerts for hyperkalemia were generated for administrations of medications or additives to a primary IV solution, which may indicate a physiologic maintenance fluid. When the BCMA alerts are evaluated for potassium supplementation, performance is improved to a 28.5% acceptance rate. However, this performance is still considered low.

The most salient explanation for this low rate is apparent when the data is dichotomized by patient age. Of the 118 BCMA alerts generated on patients aged one year or greater, there was an 85.6% acceptance rate. Of the remaining 17 BCMA alerts that were overridden in this population, 11 (64%) followed an initial acceptance. Of the remaining 6 BCMA alerts that did not follow a back-out, 4 of them have additional free-text justifications. This leaves a mere 2 single-click overrides out of 118 BCMA alerts that did not prompt additional free-text justification addenda or initial acceptance; this may be viewed as a 98.3% effective reconsider rate, which is excellent by any measure.

Conversely, the 6.9% acceptance rate present in the BCMA alerts generated for patients aged less than one year does not improve to a clinically effective rate, even when a similarly conjectured effective reconsider rate is estimated. There are several reasons possible for this clinically, and in the data. Nearly all of the BCMA alerts for potassium-containing nutritional supplements and intravenous fluids with potassium additives occurred in the less than one year old group. As the potassium content of these medication administrations is unlikely to be harmful, these alerts may not be clinically significant. There are also physiologic differences in young patients, particularly neonates, in which the normal serum potassium level ranges up to a high value of 6.0 mg/dL.[16] Blood draws in neonates are also frequently performed by heel-stick, which has a higher incidence of hemolysis, which results in spuriously elevated serum potassium levels. Finally, fluid and electrolyte supplementation in the neonatal period is more aggressive than in adults due to ongoing losses. The combination of all these elements likely contributes to the apparent ineffectiveness of the currently implemented BCMA alerts in this patient population.

Considering the template justifications provided for the overrides, the terminology in the provided response may not give a complete picture of the decision-making process by the nurse and/or physician for their action. The override justification for 163 BCMA alerts was provided as "This is not clinically significant." However, it is not clear from this response if the nurse spoke directly to a physician to make this determination. This may have been documented in other aspects of the electronic medical record not evaluated as part of this research. The need for improved template options is also suggested by the frequency of included free-text addenda. These may represent instances in which nursing staff feel the need to provide additional documentation to supplement the structured template options. Improved override justification options may have the effect of increasing acceptance of the alerting system in general, increasing consultation, and appropriate documentation of pertinent decision-making.

Even though a trend towards decreased acceptance of alerts was noted with increasing potassium level, there was no apparent clinically relevant effect. For the small number of grossly elevated potassium levels (>7.0 mg/dL), however, the nurses frequently supplied free-text addenda to the override justification template. While the retrospective nature of this study precludes comprehensive knowledge of individual clinical situations, the representative sample of free-text addenda suggests that values in this range were thought to be erroneous due to hemolysis, or the treatment is based on a newer laboratory result that has is not available in the electronic health record (e.g., bedside laboratory analyzers). A possible effective modification to the alert may involve incorporating the source of the blood draw (e.g., heel stick), as falsely elevated potassium levels due to hemolysis represents the preponderance of alert overrides observed in this cohort.

Conclusion

As the final line of defense in preventing errors in medication administration, bar coded medication administration as implemented in this study was frequently overridden. These frequent overrides were localized to a specific population subset of patients less than 1 year of age whose elevated potassium levels were likely due to hemolysis, and should prompt revision of these BCMA alerts to account for differences in clinical care for this population. Periodically analyzing alert response rates should be done to revise alert logic to improve performance in preventing potential medication errors at the time of administration.

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