Near-Miss Event Analysis Enhances the Barcode Medication Administration Process

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Near-miss event reporting and analysis is an essential part of a robust patient safety program. Pennsylvania has seen an increase of more than 2,700% in reports of near-miss barcode medication administration (BCMA) events over twelve years, from January 2005 through December 2016. During the same period, events that reached the patient and caused harm (Serious Events) accounted for only 0.5% of reported BCMA-related events. Reporting, but more importantly, the analysis of near-miss events can lead to improvements in processes and reduce the potential for patient harm. Through a case study, the Pennsylvania Patient Safety Authority shares the story of how Blue Mountain Health System reduced its barcode-workflow events by 53% between 2014 and 2016. Through a collaborative effort with the Authority's analysts and patient safety liaison, the health system used near-miss event review and analysis to improve its BCMA process. The Authority shares best practice strategies for BCMA use in the context of near-miss event analysis.

Abstract

Use Near-Miss Event Analysis for Performance Improvement: A Barcode Medication Administration Case Study

Barcode Medication Administration Events (n = 1,309)

Spending time and resources on event analysis is critical.

Near-miss event reports can warn of patient safety hazards before patient harm occurs, similar to a lighthouse.

- Involve frontline staff
- Evaluate current processes
- Conduct direct observations
- Promote event reporting
- Analyze event reports
- Work with the Authority

Note: Data reported through the Pennsylvania Patient Safety Reporting System, January 1, 2005, through December 31, 2016.

Introduction

The Lighthouse of Patient Safety

Much as a lighthouse serves as a navigational aid that warns sailors of hazards and high-risk areas, near-miss event reporting and analysis can warn facilities about patient safety hazards and system weaknesses before patient harm occurs. For this article, a near miss has a Pennsylvania Patient Safety Reporting System (PA-PSRS) harm score of A, B1, or B2. A near miss represents unsafe conditions (i.e., circumstances that could cause an adverse event) or a circumstance that might have caused harm but did not reach the patient because of chance alone or active recovery efforts by caregivers.¹
Near-miss event reporting and analysis is common in industries such as aviation, nuclear energy, and chemical engineering.\textsuperscript{2,6} It identifies precursor situations and trends in order to prevent the occurrence of harmful and fatal events. The Institute of Medicine's 1999 report, \textit{To Err is Human: Building a Safer Health System}, advocated studying near misses "to detect system weaknesses before the occurrence of serious harm."\textsuperscript{9,10} Since then, the Pennsylvania Patient Safety Authority and others have promoted near-miss event reporting and analysis as part of a robust patient safety program.\textsuperscript{10-16} According to an article by Marella, "Near-miss reporting, trending, and data analysis provide an opportunity to take action before someone is injured."\textsuperscript{10} Further, "if your hospital collects only reports of adverse events and ignores near-misses, you are missing out on the most valuable source of data for identifying patient safety priorities and for measuring your progress on the problems you're trying to fix."\textsuperscript{10}

In a recently published article, the Authority profiled the Good Catch ratio, a calculation of the number of near-miss events to the number of Serious Events.\textsuperscript{16} One would expect several near-miss events for each Serious Event. Theoretically, a greater Good Catch ratio may signal a safety culture that values recognition and reporting of hazards before harm occurs.\textsuperscript{16} Merely reporting and counting events, however, is insufficient without analysis of the data. In the case of Blue Mountain Health System, its patient safety liaison (PSL) was cued by an analyst to multiple near-miss events that occurred within the health system and were categorized as an Other/Miscellaneous event type described as "MAK workflow" (Siemens Med Administration Check\textsuperscript{™}). The analyst determined that these events were reported with relative consistency, on a monthly basis, over several months, and appeared to involve the medication administration process.

\section*{Barcode Medication Administration}

With the advent and adoption of health information technology (Health IT), such as the electronic health record (EHR), pharmacy computer systems, automated dispensing cabinets, and barcode medication administration (BCMA) systems, complexities are believed to be better managed, albeit not free from workarounds or error.\textsuperscript{17-20} BCMA, an inventory control system, uses barcodes to help prevent medication-administration errors.\textsuperscript{21-23} The technology is designed to improve the likelihood that the right patient will receive the right medication in the right dose at the right time.\textsuperscript{22}

BCMA systems started with U.S. Department of Veterans Affairs (VA) hospitals in the late 1990s and were mostly stand-alone systems that did not integrate with other medication-management technologies.\textsuperscript{24,25} In 2004, the U.S. Food and Drug Administration (FDA) published its final rule on barcode labels, and manufacturers had until 2006 to comply with the medication-labeling standards.\textsuperscript{26}

Excluding specialty, federal, and VA hospitals, 86\% to 93\% of U.S. hospitals have adopted BCMA.\textsuperscript{27,28} In its most recent survey published in 2015, the American Society of Health-System Pharmacists reported that "significant increases [in the number of hospitals using BCMA] were seen in the last five years" and reported a more than 6,000\% increase in adoption of BCMA since its 2002 survey.\textsuperscript{28}

Blue Mountain Health System, located in northeastern Pennsylvania, includes Gnaden Huetten and Palmerton hospitals.\textsuperscript{29} In 2007, the health system's leadership committed to system-level organizational changes to become a high-reliability organization. The strategies included establishing a culture of safety that prioritized goals that would achieve the biggest impact on patient safety. High-risk functions and processes, such as medication management, were chosen as a high priority.\textsuperscript{30} Health system leadership identified BCMA improvement opportunities and engaged Authority staff to help improve aspects of the hospitals' BCMA process. Near-miss event review and analysis proved critical to understanding BCMA workflow at the health system and ultimately led to improvements in medication-administration safety.
Leaders at Blue Mountain Health System noticed a lack of internal near-miss event reporting prior to 2010 and modified their internal medication-error reports to capture contributing factors. Leadership’s commitment to be "obsessed with failure" included focusing on identifying hazards and increasing near-miss event reporting. In 2012, the health system upgraded its automated dispensing cabinets to include barcode scan on medication removal for all inpatient nursing units and barcode scan on refill by pharmacy. The bedside barcode scanning application software provided the capability of running medication administration–related reports.

**Methods**

Authority analysts queried the PA-PSRS database for BCMA events occurring in Pennsylvania healthcare facilities from January 1, 2005, through December 31, 2016—a twelve-year period adequate to capture a sufficient number of events for analysis and spanning the progressive adoption of BCMA implementation in healthcare facilities.

The query included all facility types, event types, and care areas. The reporting facilities provided the following information regarding the event: event type, harm score, and event description. Analysts searched free-text data fields for the following key words and phrases, including their variations: barcode, BCMA, and MAK Workflow. The query yielded 2,220 events. Analysts manually reviewed all events. Included for analysis were events caught at the point of administering the medication to the patient and excluded were 841 events that were not medication barcode events, as well as 70 events that were not applicable (e.g., barcode description did not involve the medication administration node). This resulted in 1,309 events as the final sample for analysis. Preliminary analysis demonstrated a relatively large number of reports submitted during 2007; further analysis was conducted to identify whether one or multiple facilities contributed to this increase.

A simple percentage-change formula was used to calculate the percentage increase of PA-PSRS BCMA near-miss events from 2005 to 2016 and the percentage decrease of Blue Mountain Health System's barcode scanning events from 2014 to 2016.

**Good Catch Ratio**

The Good Catch ratio (good catch-to-Serious Event) was calculated by comparing the number of good catch reports (i.e., events submitted with harm scores, A, B1, or B2) to the number of Serious Event reports (i.e., harm scores E, F, G, H, or I), creating a proportion that can be expressed as $x:1$, or simply $x$. 

**Medication Management**

The medication management process is a series of interdisciplinary, complex tasks that can be divided into five to eight stages or nodes, from selecting a medication through monitoring medication effects on patients. For this analysis, analysts assigned each event to one or more of four applicable nodes:

- Prescribing
- Transcribing
- Dispensing
- Administering

**Literature Review**
Analysts conducted a review of the literature and an internet search to obtain data and information on BCMA, barcode implementation, near-miss event reporting in healthcare and other industries, and workarounds. A medical librarian assisted with a search for published articles indexed between January 1, 2011, and December 13, 2016, in the Association for Computing Machinery, CINAHL, Embase, Google Scholar, Medline, PubMed, and Scopus databases. Search terms included the following: automatic data processing, barcodes, BCMA, hospital medication systems, implementation, installed, medication errors, workflow, safety management, hazards, and workarounds.

**Event Details* and Facility-Level Data**

The health system's co-authors analyzed data captured in the bedside barcode scanning software application for medication administration,35 and provided the facility-level data that represents the actual number of reports submitted to their quality improvement and patient safety committees.

The health system's director of pharmacy/medication safety officer reviewed and analyzed this report data and compiled the results according to the PA-PSRS harm score taxonomy.

**Blue Mountain Health System's Bedside Barcode**

To assess whether nursing staff was performing barcode scanning at the patients' bedsides, the team analyzed the bedside barcode scanning application system's data from the medication administration node that correlated with the right-patient/right-medication scanning step. After standardizing the medication management practices at both campuses, the health system team validated that the medication-management processes were improving.

* The details of the PA-PSRS event narratives in this article were modified and de-identified to preserve confidentiality. Unless otherwise noted, none of the event narratives came from Blue Mountain Health System reports.

**Results**

**Barcode Medication Administration Event Trend**

Figure 1 illustrates an increase in the number of BCMA events reported through PA-PSRS from 2005 through 2016. The increase in 2007 is attributable to a single facility (not a Blue Mountain Health System facility), which accounted for 86.5% (n = 270) of the 312 reports that year. The most recent trend began in 2012, and a spike in reporting occurred in 2015.
Nodes, Harm, and Near-Misses

BCMA events occurred during each node of the medication-management process; 9.9% (n = 130 of 1,309) of reports involved more than one node, and therefore, the following percentages will equate to more than 100%. The majority of events, 81.3% (n = 1,064) involved the administering node. The remaining events involved these nodes:

- Dispensing, 27% (n = 354)
- Prescribing, 1.6% (n = 21)
- Transcribing, 0.8% (n = 11)

Although all of the events in the sample were identified as BCMA events, 245 did not involve the administering node, as seen in the following example in which the dispensing node was involved and the error was caught during administration:

_The patient was ordered an extended release oral diabetes medication [and the] pharmacy sent [the immediate release version]. The error was caught in scanning the barcode._

The majority of events, 65.5% (n = 857), reached the patient (harm scores C through I; Figure 2). However, only seven (0.5%) Serious Events occurred (i.e., resulted in patient harm; harm scores E through I). All of the patient harm events involved only the administering node.
Near-miss events accounted for 34.6% (n = 453) of the 1,309 BCMA events and 34.8% of the 1,302 Incidents, as seen in these examples attributed to successful barcode scanning:

*The pharmacy dispensed the wrong dose of a [dopamine promoter] medication. The error was caught upon barcode scanning. The intended process functioned as designed. Pharmacy re-dispensed the medication and the patient received the correct dose.*

*The nurse scanned the barcode for the [antibiotic], and the system alerted to wrong medication. Nurse verified with pharmacy that the wrong medication was dispensed. The patient received the correct medication.*

The Good Catch ratio for BCMA events in this study is 65:1. Interestingly, the Good Catch ratio for the subset of Blue Mountain Health System’s BCMA events is incalculable because no Serious Events were reported in this study period, compared with the 122 reported near misses.

Figure 3 illustrates a 2,725% increase in number of near-miss BCMA events reported through PA-PSRS from 2005 to 2016. The increased trend began in 2014 and a spike in reporting occurred in 2015. The percentage increase from the start of the trend (2014) is 105.5%.
The Blue Mountain Health System's bedside barcode scanning software application allowed for increased data capture and internal reporting capability. Using these reports, the health system noticed a 172.7% increase in overall medication-administration error reports (n = 77 in 2011 to n = 210 in 2012) at the first campus and a 36.4% increase (n = 77 in 2011 to n = 105 in 2012) at the second campus. In addition, the team determined that the proportion of near-miss event reports had increased more than 280% at both campuses, from 20.5% of total reports in 2011 to 78.6% in 2012.

Figure 4 illustrates Blue Mountain Health System's downward trend (improvement) in near-miss BCMA events. The overall improvement is 52.9% from January 2014 to December 2016.

* Data reported through the Pennsylvania Patient Safety Reporting System, January 1, 2005, through December 31, 2016.
Workflow and Workarounds

Failure to follow a policy or procedure or employing workarounds was identified in 40.3% (n = 527) of the BCMA events reported through PA-PSRS. Of those 527 events, 83.1% (n = 438) reached the patient but only 0.9% (n = 5) involved serious harm including death, as seen in these examples:

The nurse selected the wrong patient in the computer and administered the medication without checking the patient's ID. The patient was subsequently transferred to a higher level of care for more frequent monitoring.

An RN mistakenly administered an [opioid at four times] the ordered dose. The [construct of the electronic order contained both] the ordered dosage and the high-alert dose range. A second RN verified the higher dose with the administering RN before handing over two syringes. A syringe was scanned after the medication was administered. The patient later died.

Of BCMA events, 25.7% (n = 337) involved a problem related to equipment, including unreadable patient identification bracelets, uncharged scanners, missing or smudged barcode labels on medication, and lack of wireless connectivity. Fourteen of these equipment-related events also involved staff bypassing policy or procedure.

Blue Mountain Health System's Bedside Barcode

At the health system, the initial percentage of nurses using BCMA for patients at bedside on the inpatient units was 97.7%, which increased to 99.6% after one year. Initially 94.1% of the barcode errors occurred during the right-patient/right-medication step of the administration node; this increased to 97.5% after one year. Examples of the types of administration errors included missed doses, delays in medication administration, and wrong-patient scans, including what appeared to be intentional barcode scans of the wrong patient.

Discussion

The number of reports of overall BCMA events reported through PA-PSRS, specifically near-miss BCMA events, is trending higher. The sharp increase in reporting seen in 2007 is likely special cause variation and, as mentioned, is attributable to a single facility. The Authority reached out to the facility responsible for that increase, but as of press
time had not received a response. In comparing Figures 1 and 3, the majority of the 2007 reporting spike seen in
Figure 1 is attributable to events with a harm score of C or D, meaning the "event reached the patient but did not
cause harm or required monitoring to confirm that it resulted in no harm, and/or required intervention to prevent
harm."\(^1\)

The 2015 spike in reporting seen in both figures is attributable, in part, to Blue Mountain Health System's event-
identification initiative and reporting. Additionally in 2015, the Authority updated PA-PSRS to collect information
regarding health IT–related contributions to events, as applicable.\(^36\)

The low number of Serious Events compared to Incidents is encouraging. Near-miss events are increasingly being
identified and reported. Analysis of these "lighthouse" events can alert staff to patient safety hazards and system
weaknesses and, similar to the work shared by the health system, can help identify opportunities to measure
progress on existing initiatives and improve patient safety.

**Workflow and Workarounds**

A death was reported in which staff bypassed the BMCA procedure. Although the Authority cannot say for certain that
this death could have been prevented, recognizing when and identifying why staff use workarounds or modify
procedures to "get the work done" enables leaders to identify hazards and at-risk behavior and potentially redesign
the work.\(^37\)

**Blue Mountain Health System and the Authority's Collaboration for Improvement**

Simultaneous to the health system's team's tracking and trending of the bedside barcode scanning reports, an
Authority analyst detected and notified the Authority PSL of a pattern of "MAK workflow"-related near-miss reports
submitted by the health system. The PSL was invited to observe the facility's BCMA workflow and identified system
and process opportunities.

The health system's near-miss reporting results appeared to indicate an intentional barcode scan of the wrong
patient. For example, patient A should have been scanned, but Patient B was scanned instead. The error report was
generated because the nurse had the wrong patient on the bedside barcode scanning application computer screen.
The barcode scanning report caught this discrepancy, and when the Authority's PSL observed medication-
administration workflows, she found that nursing staff was not clearing the previous patient from the barcode
scanning system before scanning the next patient, because staff found this procedure modification more efficient
(fewer mouse clicks).

As is common with BCMA and other health information technologies, a given task may be performed multiple ways
within the system; therefore, more opportunities exist for errors to occur.\(^17,18,22,34\) When the health system conducted a
failure modes and effects analysis on failure points identified through the on-site observations, frontline staff identified
challenges related to the system design of the BCMA workflow practices. The BCMA system allowed for variations in
access to patient medication administration records and charting. This variation created increased risk of near-miss
events associated with barcode scanning workflow, such as potential wrong-patient selections. Limitations of the
system (e.g., lack of internet connectivity) led to staff employing workarounds that they believed were the safest
alternatives, yet posed additional opportunities for error. For example, the health system noted certain patient rooms
had greater numbers of barcode scanning events than others, which was associated with limited or no internet
connectivity. Internet connectivity was expanded to include those areas.

In reviewing all of the 2015 barcode scanning events, the team found some correlation to specific users (i.e., nurses)
and the number of events per user. The unit director conducted individual staff interviews and provided education.
Staff development provided formal education on an *as needed* basis.
To understand the nurses' barcode scanning workflow better, the team surveyed nursing staff about their scanning process, including whether they scan the medication or the patient first. The existing policy set an expectation that the patient is scanned first, then the medication. However, nurses would engage a workaround in certain circumstances (e.g., when the same medication was ordered for multiple patients [e.g., acetaminophen], nurses would first scan the medication). This workaround contributed to some of the wrong-patient scan totals. In addition to policy re-education, nursing directors affixed a STOP sign visual reminder to the mobile computers (Figure 5), which reinforced the proper scanning sequence. This reminder helped reduce the number of wrong-patient scan errors.

Figure 5. Stop Sign on Mobile Computer

Scan = Scan the patient, scan the medication
Close = Close the screen to
Advance = Advance to the
Next = Next patient profile

The health system team continues to focus on all medication events as well as sustaining the progress made in the bedside barcode scanning workflow and wrong-patient-scan events. The health system hospitals are implementing a new EHR and plan to use the system's reporting capabilities to identify processes that need improvement and make those improvements.

**Strategies for Success**

Research supports near-miss event reporting and analysis with the successful implementation of BCMA. Highlights of best practices and strategies for success are featured below.

**Prior to bringing on new processes/systems**
• Promote event reporting. Collect and analyze all reports, and specifically near-misses, to help identify patient safety hazards and detect existing system weaknesses.\(^6,13,16\) Establish a baseline of performance before implementation to provide a means of comparison for like events during and after implementation.\(^23,38\)

• Secure administrative support. Support from leadership and the creation of an implementation team are keys to successful implementation.\(^17,21\) Both help keep the project on track, and leaders can help remove roadblocks. Blue Mountain Health System continued to dedicate resources well after the initial "go-live," which led to continued improvements.

• Communicate with and involve frontline staff. Facilities adopting medication management–related technologies, whether stand-alone or integrated, can consider the technologies’ interconnectedness and functionality for the end user.\(^18,21,34,37\)

• Evaluate current workflows, procedures, and processes. Understanding "work as done" will assist facility staff in selecting the appropriate product or service.\(^23,34,37\)

• Conduct failure mode and effects analysis. Proactively assessing potential failures will inform team leaders and help them select and design successful implementation strategies.\(^21,38,39\)

During the initial phases of implementation

Facility and team leadership can build upon the previous strategies with these enhancements:

• Conduct direct observations of staff workflows. Observing processes currently and soon after implementation allows team leaders to engage with patients and staff about the system and how it is working, compared to how it was imagined during planning, and determine necessary adaptations to workflow.\(^18,34,37,38,40\) These observations will afford leaders the opportunity to identify and manage equipment failures. Incorporate these observations into existing processes, such as Joint Commission's Tracers™.\(^41,42\)

• Conduct simulation exercises. Simulating certain scenarios or key tasks can identify new or unforeseen tasks or steps that emerge during a new or revised process and allows staff to practice the redesigned or newly created procedures.\(^43,44\)

• Analyze event reports. Encouraging reporting and analyzing events ensures staff have a venue to inform leadership about the processes and workflows and, as mentioned previously, ensures a means of comparison for like events.\(^8,13,16,23,38\)

After implementation

• Perform root cause analyses. Exploring the root causes of factors that contribute to near misses and events that reach the patient, regardless of harm, helps workers understand whether and why (or why not) steps or tasks followed the plan, laying the ground work for solution identification.\(^34\)

• Seek assistance from the Authority. Inviting Authority staff, such as the PSL, on-site to conduct observations allows for objective evaluation and feedback of part or all of the processes. Authority staff can help with PA-PSRS data analysis and the calculation of the Good Catch ratio.

Limitations
Some data presented here are from the PA-PSRS database. Despite mandatory reporting laws, the data are subject to the limitations of self-reporting, including the complexities of selecting the appropriate event type, harm level, and harm score. Over time, the Authority has collaborated with facilities, organizations, and the Department of Health to clarify definitions and reporting standards, which the Authority believes has helped standardize and facilitate reporting.

In-depth analysis by the Authority is limited by the information provided by the facility on the event report submitted through PA-PSRS, including the event descriptions. BCMA is not a structured data field in the PA-PSRS report; therefore, a keyword search of the event detail and other free-text data fields was applied. However, facilities may have submitted reports using different terminology.

**Conclusion**

Near-miss event analysis provides an organization the opportunity to uncover real and potential hazards in a process before an event reaches a patient and causes harm. Healthcare is catching up to other industries, such as aviation and nuclear energy, with regard to near-miss event reporting and analysis. Pennsylvania healthcare facilities can use their own aggregated PA-PSRS data as a resource to trend near-miss reporting. The Good Catch ratio may be a useful tool to assess BCMA reporting practices in addition to the overall near miss-to-Serious Event ratio.

As seen in the Blue Mountain Health System example, the facility and the Authority independently tracked and trended PA-PSRS reports and as a result, the Authority assisted the health system in improving aspects of its BCMA process. Pennsylvania facilities are strongly encouraged to reach out to the Authority for assistance.

Preventing patient harm is a healthcare priority, and the importance of near-miss event analysis to this end cannot be overstated. Near-miss analysis provides a valuable source of information about patient safety hazards and system weaknesses, identifies patient safety priorities, and measures progress on safety and quality-improvement initiatives. Using the lighthouse analogy, near-miss event reporting and analysis helps organizations keep patients safe as they navigate through the healthcare system.

**Acknowledgment**

The Blue Mountain Health System co-authors were willing to share their medication-administration quality improvement story for altruistic purposes in the hope that other facilities may learn from their journey. The Authority is grateful to Blue Mountain Health System employees for their transparency and willingness to co-author this article.

**Notes**


30. Patzek D. (Vice president of Nursing/Chief Nursing Officer, Blue Mountain Health System). Interview with Mary C. Magee. 2015 Feb 16.


http://patientsafety.pa.gov/ADVISORIES/Pages/201712_BCMA.aspx 12/19/2017


