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Describing Medication Administration and Alert Patterns Experienced by New Graduate Nurses During the First Year of Practice

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The aim of this study was to describe medication administration and alert patterns among a cohort of new graduate nurses over the first year of practice. Medical errors related to clinical decision-making, including medication administration errors, may occur more frequently among new graduate nurses. To better understand nursing workflow and documentation workload in today's clinical environment, it is important to understand patterns of medication administration and alert generation during barcode-assisted medication administration. Study objectives were addressed through a descriptive, longitudinal, observational cohort design using secondary data analysis. Set in a large, urban medical center in the United States, the study sample included 132 new graduate nurses who worked on adult, inpatient units and administered medication using barcode-assisted medication administration. Data were collected through electronic health record and administration sources. New graduate nurses in the sample experienced a total of 587 879 alert and medication administration encounters, administering 772 unique medications to 17 388 unique patients. Nurses experienced an average medication workload of 28.09 medications per shift, 3.98% of which were associated with alerts, over their first year of practice. In addition to high volume of medication administration, new graduate nurses administer many different types of medications and are exposed to numerous alerts while using barcode-assisted medication administration.

KEY WORDS: Alerts, Barcode medication administration, Clinical decision-making, Medication errors

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The clinical environment in which nurses work is increasingly complex and ever-changing. Indeed, the COVID-19 pandemic, heavy clinical workloads, and high documentation burden have compounded burnout experienced among clinicians.[1] The pandemic, in particular, prompted health systems to implement crisis documentation standards with the goal to reduce documentation burden experienced by clinicians.[1,2] Although this study predates the pandemic, we examined nurse workflow and documentation during the process of medication administration. Specifically, we described medication administration workload and quantified the number of alerts experienced by a cohort of new graduate nurses over their first year of practice.

BACKGROUND

Spending more time with patients than most other providers,[3] nurses have many responsibilities involving both direct and indirect patient care. In addition to caring for highly acute patients, nurses must quickly integrate new technologies into clinical workflows. A recent study found that nurses spend approximately 35% of their time in patient rooms and another 25% of their time on documentation.[4] Many of these technologies include alarms or alerts; it is estimated that clinicians are exposed to more than 1000 alarms or alerts during each shift.[5]

Medication administration, in particular, is an important clinical activity that contributes to the workload of new graduate nurses and requires the use of what may be unfamiliar technology, namely, barcode-assisted medication administration (BCMA). First iterations of BCMA systems included alerts related to the rights of medication administration (eg, right patient, right drug, right dose). Subsequently, the types of alerts (also known as best practice advisories) that can trigger during BCMA have expanded. In their review, Sloss and Jones[6] found that alert types related to specific medications, such as with warfarin, insulin, and potassium, appeared more frequently in recent literature. This is likely representative of trends in BCMA, in which, in addition to ensuring correct rights of medication administration, expansion of alert types is intended to target other common administration errors.

Documentation is an essential component of nursing; however, researchers are starting to explore connections

between documentation burden and clinician burnout.[7–9] Further compounding documentation burden is the interruptive nature of alerts. Interruptions in workflow due to alerts have been associated with longer times to complete clinical tasks, failure to complete tasks, and increases in errors.[10,11] Although many clinical decision support systems with alerts are effective in reducing medical errors, it is important to understand the impact of unintended consequences, such as interruptions to workflow, on clinician burden, burnout, and patient safety.

Medical errors related to clinical decision-making, including medication administration errors, may occur more frequently among new graduate nurses.[12] Heavy workloads and lack of competence in clinical and technical skills contribute to stress experienced by new graduate nurses.[13] These stressors are compounded today, as new graduate nurses transition to practice in a healthcare delivery system strained by the COVID-19 pandemic.[14]

To better understand new graduate nursing workflow and documentation workload and to improve patient safety, it is important to understand patterns of medication administration and alert generation during BCMA. The primary objective of this study was to describe medication administration and alert patterns among a cohort of new graduate nurses over the first year of practice. Understanding medication administration patterns and alert generation patterns during BCMA use can help to identify areas for improved medication administration safety, as well as to better understand clinical workflows, workload, and documentation burden experienced by nurses in the acute care setting.

METHODS

Study Design

This was a retrospective, longitudinal, descriptive cohort study. This study was part of a broader study that examined factors influencing nurse cognition and decision-making in response to alert generation during BCMA.

Setting and Participants

Set in a large, urban academic medical center in the United States, the study sample included 132 new graduate RNs hired into a nurse residency program between January 1, 2018, and December 31, 2018. During this time, four cohorts of new graduate nurses emerged distinguished by residency start date. Inclusion criteria included new graduate nurses hired to work on adult inpatient care units and used BCMA to document medication administration. New graduate nurses were excluded if their employment tenure was less than 1 year, if they transferred units within the study period, or if they had more than 2 weeks off between any two shifts. No exclusions were made based on age, gender, or race.

Study Variables

Variables for this study included demographics (age, gender, and education), residency cohort (determined by start date), unit (unit type), patient workload, medication workload, medication encounter characteristics (date, time, drug name, and drug category), and alert characteristics (date, time, type, category, drug, and drug category). Differing from prior studies that examined efficacy of early BCMA implementation, patient mismatch and drug mismatch alerts did not appear in the data file of alert encounters because of advances in clinical workflow; nurses could not proceed with medication administration if not first establishing patient and drug match. In addition, this study did not capture alerts that occurred outside of the electronic health record, such as those displayed by IV pumps.

In some instances, raw data were recoded to facilitate analysis and interpretation. Specifically, unit was recoded as unit type and included general care unit, intermediate care unit, and ICU, representing differences in patient acuity and other environmental factors (eg, nurse-to-patient ratio). In addition, drugs were categorized by mechanism of action and targeted system including but not limited to cardiovascular agents, analgesics, respiratory agents, and vitamins/supplements. Alerts were categorized as "display only" or "action required," depending on the action required by the nurse in response to the alert. An example of an "action required" alert is "Patch Removal," because the nurse is prompted to verify completion of a task, in this case, removal of an existing medication patch from a patient.

Patient and medication workload variables were derived from the data. Patient workload refers to the number of unique patients to which an individual nurse administered medications during a 12-hour shift. Nurse-to-patient ratio can be intuited; however, we did not determine the number of patients assigned to a nurse during each shift but rather how many unique patients a nurse administered medication to over their shift. Medication workload was derived from and refers to the total number of alert or medication administration encounters (also referred to as medication encounters) that a nurse experienced on a given shift.

Procedures

Data were collected retrospectively from clinical (electronic health record) and administrative (eg, nurse residency) data sources, beginning at date of hire and spanning the first year of employment. An honest broker, a neutral intermediary between the health system and research team,[15] deidentified and provided linkage across data files using a unique nurse identifier. Demographic information was received for 249 new graduate nurses hired during the recruitment window and the raw electronic health record data file contained a total of 784 237 medication encounters. After applying inclusion and exclusion criteria, the final sample for this study consisted of 132 nurse participants. During data cleaning and preparation, 41 nurses were not linked to any medication encounter. Further, 76 nurses were removed for the following reasons: missing or ineligible unit of hire (n = 41),

employment tenure less than 1 year (n = 30), and long gaps of time (>22 days) in between medication encounters (n = 5).

Analysis

Descriptive analyses were conducted using the statistical software JMP Pro 15 (SAS Institute Inc., Cary, NC, USA).[16] Descriptive statistics included calculation of means, SDs, ranges, and frequencies of medication and alert encounter characteristics. During data analysis, we discovered that, because of a reconfiguration of the alert, the Acetaminophen Max Dose alert type was not captured in the data after a specific date, even though the alert continued to be generated during BCMA. Although the results describe Acetaminophen Max Dose alerts as they appeared in the data file, we inferred that there were an estimated 10 000 additional Acetaminophen Max Dose alerts that were not captured or included in analysis.

Ethics

Institutional review board approval was obtained prior to study implementation. Because this was a retrospective study using secondary data analysis, and all data were deidentified prior to receipt by the investigators, consent was not obtained from nurse participants.

Table 1. Nurse Demographics and Workload Characteristics

	Residency Cohort				Unit Type			
	1	2	3	4	ICU	Intermediate	General	All
Age, y								
Mean	27.32	26.59	24.57	25.43	26.79	26.22	26.06	26.31
SD	6.08	7.46	2.37	3.88	6.74	4.04	6.45	6.08
Min	21.00	21.00	22.00	22.00	21.00	22.00	21.00	21.00
Max	49.00	58.00	29.00	35.00	43.00	37.00	58.00	58.00
Median	25.00	24.00	24.00	24.00	24.00	25.00	24.00	24.00
Gender								
Female								
Total no.	31.00	37.00	34.00	11.00	27.00	24.00	62.00	113.00
Percent	83.78	84.09	89.47	84.62	72.97	85.71	92.54	85.61
Male								
Total no.	6.00	7.00	4.00	2.00	10.00	4.00	5.00	19.00
Percent	16.22	15.91	10.53	15.38	27.03	14.29	7.46	14.39
Highest education								
ADN								
Total no.	8.00	17.00	7.00	8.00	7.00	13.00	20.00	40.00
Percent	21.62	38.64	18.42	61.54	18.92	46.43	29.85	30.30
BSN								
Total no.	29.00	26.00	30.00	5.00	29.00	15.00	46.00	90.00
Percent	78.38	59.09	78.95	38.46	78.38	53.57	68.66	68.18
MSN/clinical nurse leader								
Total no.	0.00	1.00	1.00	0.00	1.00	0.00	1.00	2.00
Percent	0.00	2.27	2.63	0.00	2.70	0.00	1.49	1.52
Patient workload								
Mean	3.12	3.48	3.60	3.50	2.23	3.84	3.90	3.41
SD	1.21	1.22	1.09	1.15	0.81	0.86	1.02	1.19
Min	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Max	9.00	9.00	9.00	9.00	8.00	9.00	9.00	9.00
Median	3.00	4.00	4.00	4.00	2.00	4.00	4.00	4.00
Medication workload								
Mean	25.40	28.15	30.85	28.03	20.84	30.22	31.36	28.09
SD	12.49	13.39	14.78	12.92	10.08	13.25	14.07	13.65
Min	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Max	79.00	109.00	96.00	98.00	98.00	109.00	96.00	109.00
Median	24.00	27.00	28.00	27.00	20.00	28.00	29.00	26.00

RESULTS

Sample Characteristics

Table 1 displays nurse demographics and workload characteristics of the sample. Nurse participants were hired across a variety of adult inpatient units. Units were categorized by level of acuity. Most nurse participants were hired to units categorized as general (n = 67), followed by ICU (n = 37) and intermediate (n = 28).

Workload Characteristics

Patient and medication workload characteristics varied by type of unit where nurse participants worked. Nurse participants who worked on ICUs had the lowest average patient workload at 2.23 patients per shift. Intermediate and general unit nurses had slightly higher workloads on average at 3.84 and 3.90 patients per shift, respectively. Medication workload followed a similar pattern, with ICU nurses having the lowest average at 20.84 medication encounters per shift, followed by intermediate and general unit nurse participants with 30.21 and 31.36 medication encounters per shift, respectively.

Medication Encounter Characteristics

Nurses in the sample experienced a total of 587 879 medication encounters, administering 772 unique medications to 17 388 unique patients. Individual nurses experienced, on average, 4453.63 medication encounters over their first year of practice. The number of medication encounters varied by unit of hire. Nurses working on ICUs experienced the fewest number of medication encounters on average (μ = 3349.57), whereas nurses working on general units experienced the most (μ = 4923.39) (Table 2).

Individual new graduate nurses administered an average of 277.67 unique medications over the study period. The number of unique medications administered by nurses also varied by unit type. Nurses working on ICUs administered the fewest number of unique medications, on average, whereas nurses working on intermediate units administered the highest number of unique medications. Table 2 displays descriptive statistics for total medication administration encounters and unique medication administrations experienced by new graduate nurses over their first year of practice.

The most common medication appearing across medication encounters was acetaminophen (n = 29 475), accounting for 5.01% of all potential administrations. When grouped by category, cardiovascular agents were the most frequently administered medications, followed by gastrointestinal/genitourinary agents and analgesics. Nurses working on ICUs, intermediate units, and general units experienced varied numbers of administration across medication categories. For instance, based on descriptive statistics and as a percent of total encounters, nurses working on intermediate units administered cardiovascular agents at higher rates compared with ICU and general unit nurses. Nurses working on ICUs administered higher rates of respiratory agents and anti-infectives compared with general and intermediate unit nurses. Most medication encounters occurred between 9 AM and 11 AM followed by the hours between 9 PM and 11 PM. The lowest number of encounters occurred around 7:15 AM and 7:15 PM, times commonly associated with change of shift.

Alert Type

Types and frequencies of alert encounters are displayed in Table 3. The most common alert encounter was "Acetaminophen Max Dose," a display-only message that prompted nurses to

Table 2. Medication Encounters and Unique Medications Administered

	Residency Cohort				Unit Type			
	1	2	3	4	ICU	Intermediate	General	All
Medication administration encounters								
Mean	4036.81	4507.82	4835.74	4339.62	3349.57	4788.5	4923.39	4453.63
SD	904.36	1007.54	948.26	912.25	622.17	696.49	764.41	990.89
Min	2794.00	2674.00	3141.00	2984.00	2674.00	3564.00	2885.00	2674.00
Max	6219.00	6069.00	6439.00	6477.00	6477.00	6439.00	6226.00	6477.00
Median	3824.00	4649.50	4944.00	4334.00	3264.00	4685.00	5064.00	4498.00
Unique medications administered								
Mean	261.60	277.86	295.05	271.92	247.62	291.27	288.49	277.67
SD	37.97	33.97	28.26	30.83	29.77	18.59	34.34	35.38
Min	183.00	194.00	224.00	220.00	183.00	248.00	194.00	183.00
Max	339.00	336.00	348.00	318.00	323.00	329.00	348.00	348.00
Median	262.00	283.00	296.00	269.00	252.00	288.00	291.00	281.50

By nurse, over 1 year.

Table 3. Frequency of Alerts by Type

Alert Type	Alert Text/Description	Alert Category	n	% of Total
Acetaminophen Max Dose	"Acetaminophen Dose Verification: If this dose is given, the 24 hr Acetaminophen dose will be []"	Display only	17 975	89.79
Patch Removal	"Remember to remove the previous [name of drug] patch."	Action required	1690	8.44
Vancomycin Trough Task Check	"The task to draw the vancomycin trough has not been completed. Has the Vancomycin trough level been drawn? If not, please choose 'Cancel,' draw the sample, and mark the task complete before administering this dose of vancomycin."	Action required	105	0.52
Neuroblock Vent	"Your patient MUST BE ON A VENTILATOR when receiving this medication!"	Action required	79	0.39
Diabetes Task	*Triggers when insulin orders are placed. The purpose of the task is to make sure clinicians teach patients to self-inject insulin.*	Action required	71	0.35
BCMA_ Factors	*BCMA Factors is unique and not used often. This alert is triggered when the nurse will scan and document the dose from the multiple containers.*	Action required	37	0.18
BCMA_Routes	"[name of drug] - FOR INTRAVENOUS (IV) INJECTION ONLY! Fatal if given intrathecally!"	Action required	23	0.11
Dilution Required	"MUST BE DILUTED prior to administration."	Action required	10	0.05
Reassess Pain	*This alert is triggered when one of the pain medications listed in the specification document is charted as administered.*	Action required	10	0.05
Med Allergy Drug	*This alert is triggered when there is a possible allergy.*	Display only	6	0.03
Buprenorphine Total Dose	*Notifies nurse of the cumulative dose of buprenorphine.*	Action required	4	0.02
Drug-Drug Interaction	*This alert is triggered when there is a drug-drug interaction.*	Action required	4	0.02
Kinetic Consult	"Pharmacokinetic consult service recommends pharmacy pharmacokinetic consultation for all adult orders for systemic gentamicin, tobramycin and amikacin for expected duration >24 hours."	Display only	2	0.01
Pharm Dose Range Checking	"Dose Range Alert for: [Drug]. The following violation was found: []"	Action required	1	0.00
Pharm Height Weight	"This patient has not had their height and/or weight documented."	Display only	1	0.00

consider the total amount of acetaminophen administered to the patient in a 24-hour period. The Acetaminophen Max Dose alert accounted for 89.79% (n = 17 975) of all alerts generated over the study period, followed by an alert to verify prior "Patch Removal" before applying a new patch at 8.44% (n = 1690). Notably, the number and percent of Acetaminophen Max Dose alerts would likely have been higher if it were not for the loss of the alert type after a specific point in time during the study period.

Alert Frequency

Table 4 displays descriptive statistics for medication encounters, alert encounters, and alert frequencies by unit type. There were 20 018 alert encounters generated by nurse participants over the first year of practice. The number of alert encounters experienced by nurses varied by unit type (Figure 1). ICU nurses experienced, on average, the lowest frequency of alerts across medication encounters (μ = 99, 3.05%), whereas nurses on general units reported the highest frequency of alerts

Table 4. Mean Encounters and Alert Frequencies by Unit Type Over 1 Year of Practice

	ICU			Intermediate			General			Total		
	Med Count	Alert Count	Alert %	Med Count	Alert Count	Alert %	Med Count	Alert Count	Alert %	MedCount	Alert Count	Alert %
Mean	3349.57	99.00	3.05	4788.50	123.71	2.54	4923.39	192.40	3.98	4453.63	151.65	3.41
SD	622.17	58.46	0.02	696.49	76.678	0.01	764.41	109.77	0.02	990.89	100.10	0.02
Min	2674.00	14.00	0.47	3564.00	25.00	0.54	2885.00	10.00	0.29	2674.00	10.00	0.29
Max	6477.00	241.00	7.16	6439.00	338.00	6.72	6226.00	445.00	10.556	6477.00	445.00	10.56
Median	3264.00	73.00	2.52	4685.00	107.50	2.29	5064.00	182.00	3.62	4498.00	122.50	2.72

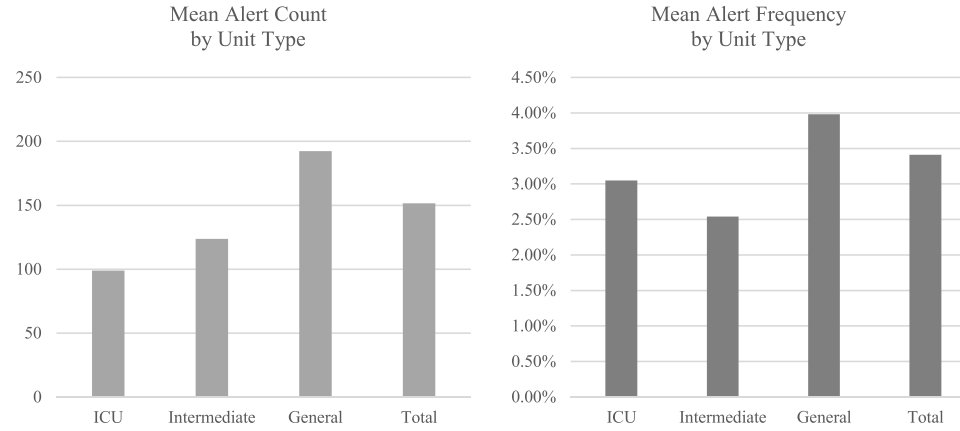

FIGURE 1. Mean alert counts and frequencies by unit type over 1 year of practice.

(μ = 192.4, 3.98%). Nurses on intermediate units experienced more alerts than ICU nurses (μ = 123.71), on average, although because intermediate unit nurses had higher numbers of medication administration encounters, the frequency of alerts was only 2.54%.

Drug Categories Associated With Alert Encounters

The most common medication associated with alert generation was acetaminophen (n = 15 994) at 79.90%, followed by nicotine (n = 1586) and acetaminophen-oxycodone (n = 1586) at 7.92% and 4.23%, respectively. By category, analgesics accounted for the most frequent medication category appearing across 87.85% of alert encounters (Supplemental Digital Content 1, http://links.lww.com/CIN/A260). This was followed by neuro/neuromuscular agents, accounting for an additional 7.93% of alert encounters. Medication categories with the lowest frequencies of alert generation included psychiatric/mental health agents, skin and wound care agents, and vitamins/supplements. Medications categorized as "other" did not appear in any alert encounters.

There was some variation of the medication category associated with alert encounters by unit type. Nurses working in intermediate care settings more frequently experienced alerts when administering neuro/neuromuscular agents compared with nurses on other units. Alert encounters with medications categorized as anesthetics/paralytics/sedatives were more frequently experienced by nurses working in ICUs.

DISCUSSION

We believe that this is the first study to explore patterns of medication administration and alert generation patterns among a cohort of new graduate nurses. Results from this study describe the number of medication administration and alert encounters experienced by a cohort of new graduate nurses, as well as the number of unique medications administered over the course of 1 year of practice. Notably, we found that new graduate nurses experienced alerts in 3.40% of all medication encounters during BCMA. Differing from early studies on BCMA, patient mismatch and drug mismatch alerts were not captured in this study because of hard stops in BCMA workflow. Specifically, nurses did not have the option to proceed with administration by accepting or overriding an alert if a patient or drug mismatch existed. Adding to existing literature on BCMA, this study found that nurses are exposed to many other types of alerts beyond the five rights of medication administration.

Study Sample

When comparing the study sample to the national nursing workforce, the percentage of BSN-prepared nurses (68.2%) hired into the nurse residency program over 1 year was higher than the national average of nurses who reported a BSN as the degree that qualified them for practice (41.8%).[17] Only two (1.52%) of the new graduate nurses were MSN–clinical nurse leaders, which is slightly lower than the national average of nurses who reported an MSN as the degree that qualified them for practice (3.9%).[17] The remaining 30.3% of the sample earned an associate's degree, which is lower than the national average (36.4%).[17] Numerous studies show that baccalaureate-prepared nurses are associated with improved patient outcomes including lower mortality rates.[18–21] Although we did not examine medication-related safety outcomes as part of this study, it is important to consider findings including alert frequency in the context of the study sample where baccalaureate-prepared nurses comprised a higher percentage of new graduate nurses compared with the national mean.

Medication Workload

New graduate nurses experienced an average medication workload of 28.09 medication encounters per shift over their first year of practice. As expected, this average varied by unit type where nurses working on general and intermediate units

experienced more encounters on average than nurses working on ICUs. This may reflect the nature of medication administration in the ICU setting, where high-risk medications are often administered intravenously or dosages are adjusted on an IV pump. Regardless, all new graduate nurses experienced higher numbers of medication encounters than what has been previously reported in the literature.[22,23] In one case, a nurse experienced 109 medication encounters during a 12-hour shift.

Medication workload from this study differed from previous studies that found nurses administer an average of 19.70 to 25.00 medications per 12-hour shift.[22,23] The average number of medication administration encounters reported in this study may be higher than those previously reported because all alert and medication administrations were included in medication workload, even in cases when an alert was triggered and the nurse did not proceed with administration. Specifically, this study included all encounters where a nurse initiated the medication administration process by scanning the barcode of a medication even if the encounter did not result in an administration. In addition, the types of medications administered by nurses using BCMA might differ from other facilities. In this study, alert and administration encounters included not only prescribed medications, but also prescribed supplements such as vitamin D and topical medications including chlorhexidine. The inclusion of these types of medications, particularly antiseptic topical administrations, may have differed from previous studies. Still, this is a significant finding in that antiseptics and supplements represent additional BCMA workload and thus has implications for new graduate nurses' clinical workflow, workload, and documentation burden. Given this, it is essential to consider the amount of time required of nurses to use BCMA during medication administration, considering nurses spend an average of 33% of their shifts interacting with various technologies including the electronic health record.[24]

It appeared that new graduate nurses quickly achieved their average medication workload, per shift, within their first month of hire. When considering previous studies that show medical error rates are notably high among new graduate nurses,[12] this is significant. New graduate nurses very quickly gave the same number of medications on average at approximately 1 month of experience that they gave at the end of their first year. Heavy workloads, as well as use of unfamiliar technology, contribute to higher levels of stress among new graduate nurses.[13] This finding highlights the need to support new graduate nurses as they transition to practice and assume patient care responsibilities as an RN.

Patient Workload

Similar to medication workload, patient workload also varied by unit type and across individual nurses. As expected, nurses who worked on general units experienced the highest patient workload, administering medications to an average of 3.90 patients per 12-hour shift, whereas nurses in ICUs administered medications to an average of 2.23 patients during a 12-hour shift. Workload for individual nurses ranged from one to nine patients. Variations in workload may be attributable to shift, for example, day shift versus night shift, as well as occupancy rates and staffing levels.

Medication Encounter Characteristics

This study found that new graduate nurses included in the sample administered 772 unique medications, and similar to medication workload, the number of unique medications appearing across encounters varied by unit type. Although slightly lower for new graduate nurses working on ICUs, new graduate nurses working on general or intermediate units administered nearly 300 unique medications over their first year of practice. Again, this is important to consider in the context of clinical knowledge and experience, particularly when studies have shown new graduate nurses may experience higher rates of medical error compared with experienced nurses.[12]

Patterns of Alert Generation

This study found that the percentage of alerts resulting from potential administration encounters varied widely by nurse. However, these findings are similar to frequencies reported by previous studies, where alert generation was found to have occurred in 1.22% to 42% of all administration encounters.[25,26] The number of daily alert encounters decreased over time, attributable to the lack of capture of the Acetaminophen Max Dose alert throughout the entirety of the study period. Of note, this change took place approximately day 300 for the first residency cohort and approximately day 35 for the fourth residency cohort, which is important to keep in mind when interpreting alert generation frequency by cohort. Including all types, alerts most frequently occurred between 9 AM and 11 AM, followed by between 5 PM and 7 PM, which mirrors peak medication administration encounter times.

Including Acetaminophen Max Dose alerts, the majority of alerts generated were categorized as display only. Upon exclusion of the Acetaminophen Max Dose alerts, the majority of alerts remaining were categorized as action required. As noted, there were no patient or drug mismatch alerts included in the sample because of the hard-stop nature of patient or drug mismatch alerts during BCMA clinical workflow. Rather, this study included alerts that were generated during BCMA that required the nurse to make a decision about whether to proceed with administration or stop administration. In general, this differs from previous findings that reviewed alert types, where alerts related to rights of administration were commonly reported in the literature.[6] However, many of these studies date back to original BCMA

efficacy studies where the rights of medication administration were the only types of alerts generated during BCMA. Because nurses developed workarounds in response to alert generation during BCMA,[27,28] the implementation of these hard stops are likely intended to make it harder for nurses to bypass the BCMA alerts and prevent inappropriate override.

Findings from this study show the prevalence of alert types that are related to patient situation or specific medication. In this study, alert type was largely driven by the type of medication given or route of administration. For instance, any medication containing acetaminophen triggered an Acetaminophen Max Dose alert. Similarly, any medication administered as a patch resulted in generation of the Patch Removal alert. Of the hundreds of alert types that exist in the BCMA system, those that were not associated with alert encounters among nurses in the study sample included (but were not limited) to pregnancy lactation and other medication task–specific alerts (vincristine, diphenhydramine, others).

Further, it is important to ensure that nurses receive alerts that are actionable within their scope of practice rather than alerts that are designed for provider or pharmacist response. This, among other factors, pertains to the meaningfulness of alerts. Although not specific to alerts, it is estimated that 80% to 99% of alarms are not clinically meaningful or do not require action on the part of the clinician.[5,29] Alarm and/or alert fatigue can develop when clinicians are repeatedly exposed to alarms or alerts of low clinical meaningfulness.[5]

When looking at common medications associated with alerts, acetaminophen and nicotine were the two most frequent medications associated with alert encounters. Other common medications associated with alert generation included insulin and paralytic agents. As insulin and paralytic agents are considered high-risk medications, it seems appropriate that alert generation occurs with these medication encounters. This echoes findings from another study that found higher alert frequencies were associated with administrations of high-risk medications.[30]

Including all alert types, nurses working on general units had the highest raw and adjusted alert frequencies compared with nurses working on intermediate care and ICU units. The average number of alerts generated by new graduate nurses working on general units over the first year of practice changed from 192.40 to 17.31 when Acetaminophen Max Dose alerts were excluded, representing a change in frequency from 3.98% to 0.34%. In the context of alert fatigue, this decrease is likely significant. Ancker et al[31] tested cognitive overload and desensitization hypotheses on alert acceptance rates among primary care clinicians. The study showed that alert acceptance decreased as alert complexity and the number of repeated alerts increased, indicating alert fatigue.[31] Although our study did not evaluate alert complexity, specifically, the removal of the Acetaminophen Max Dose alert, a display-only alert, would significantly reduce the number of alerts experienced by new graduate nurses and would likely mitigate the risk of developing desensitization to the alert stimulus among nurses.

Limitations

There were several limitations to this study, both to study design and scope. First, the study sample included new graduate nurses from one acute care setting in the mid-Atlantic region of the United States. Therefore, findings from this study may not be generalizable nationally or internationally. Additional limitations to this study arose from the use of retrospective, secondary data for analysis. Although merged data files and calculated variables were validated, it is possible that errors occurred during data cleaning, linkages, and calculations. Further, the reconfiguration of the Acetaminophen Max Dose alert during the study period resulted in incomplete alert encounter data. Despite this, data from this study elucidate medication workload and workflow among a cohort of new graduate nurses over their first year of practice.

Implications for Clinical Practice

This study found that new graduate nurses in their first year of practice are not only administering high numbers of medications each shift but are also giving many different medications. In today's work environment, new graduate nurses care for acutely ill patients while balancing stressors such as heavy workloads and fluctuating staffing levels. These stressors, as well as documentation burden, contribute to burnout and lead to less time for patient care and increased medical error rates.[2] Educational systems need to ensure adequate preparation for and support of new graduate nurses as they transition to practice. Nurse residency programs should include robust training on the use of technology, such as BCMA, to promote appropriate use and with experienced nurse preceptors providing mentorship and guidance as new nurses navigate the complex and technologically oriented clinical environment.

Studies consistently show the effectiveness of BCMA in the reduction of medication administration errors.[32] However, there is also evidence that clinicians can develop alarm/alert fatigue when there is repeated exposure to alarms/alerts of low clinical meaningfulness.[5] Indeed, this study found that new graduate nurses were exposed to large numbers of alerts during BCMA. Considering the interruptive nature of alerts and impact on clinical workflow, we must ensure that alerts are appropriate and effective. It is imperative that nurses working at the point of care collaborate with clinical informaticians, pharmacists, and other stakeholders to carefully evaluate alert deployment, modification, or discontinuation. Most importantly, it is imperative to consider the impact of alarms and alerts on clinical workflow, documentation

burden, and clinician burnout. Future studies can build on these findings to optimize BCMA alerts to promote medication administration safety while minimizing the development of alert fatigue. Although we know that BCMA improves medication administration safety, it remains necessary to carefully evaluate alert implementation and continually assess alert efficacy.[33]

CONCLUSION

Our study found that new graduate nurses using BCMA administer nearly 30 medications per 12-hour shift. In addition to describing medication workload, we also found that new graduate nurses administer many different types of medications and are exposed to numerous alerts during the process. This study highlights the need to adequately support new graduate nurses as they transition to practice, as well as to continually evaluate the appropriateness and effectiveness of alerts during BCMA.

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