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Signed: ___ES* Christy Gorbach______

(Christy Mary Gorbach)

Dated: ___________________________

Evaluating Risk Factors to Commit Medication Errors in Hospital Pharmacy Operations

By

CHRISTY M. GORBACH

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Evaluating Risk Factors to Commit Medication Errors in Hospital Pharmacy Operations

To the Faculty of the University of Houston, College of Pharmacy:

The members of the committee appointed to examine the project of Christy Gorbach find it satisfactory and recommend that it be accepted on April 15, 2013.

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Kevin W. Garey, PharmD, MS

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Alex Varkey, PharmD, MS

____

Linda Blanton, RPh

____

Beverly Lukawski, PharmD

____

Paige Pitman, PharmD

____

Dean, F. Lamar Pritchard, BS, PhD

Abstract

Evaluating Risk Factors to Commit Medication Errors in Hospital Pharmacy Operations

Purpose: Financial constraints and increased awareness of medication errors are two prevailing factors that influence hospital pharmacy operations. Hospital pharmacy increasingly has to do more with less, potentially increasing the pharmacist's risk of committing medication errors. Evaluating and minimizing these risk factors can lead to a safer, more efficient work environment. The purpose of this study is to identify modifiable and non-modifiable risk factors that increase a pharmacists risk to commit errors during the medication order verification process.

Methods: A retrospective, observational study of pharmacist-related medication errors was conducted from July 2011 to June 2012. Medication error data was obtained from the institution's voluntary reporting system. Risk factors that were assessed were workload (average number of orders verified per pharmacist per shift), work environment (type of day, type of shift, and average number of pharmacists per shift), and non-modifiable pharmacist characteristics (type of pharmacy degree obtained, age, number of years practicing, and number of years at the institution). Statistical analysis was conducted using univariate analysis and multivariate logistic regression.

Results: A total of 1,887,751 medication orders, 92 PSN error events and 50 pharmacists were included in the study. The overall error rate identified per 100,000 orders verified was 4.87. The workload stratified analysis demonstrated an increasing rate of error associated with an increasing number of orders verified per pharmacist ($p = 0.007$). The work environment analysis had significant error rate differences for type of shift, type of day, and average number of pharmacists per shift categories ($p = 0.021$, 0.002, 0.001, respectively). The pharmacist demographic variables (degree, number of years practicing, number of years at site, age) did not have statistically significant outcomes.

Conclusions: Type of shift, type of day, average number of pharmacists per shift, and average number of orders verified per pharmacist can be utilized as medication safety benchmarks in hospital pharmacy.

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Acronyms Used

1. Institute of Medicine (IOM)
2. Centers for Medicare and Medicaid Services (CMS)
3. Institute for Safe Medication Practice (ISMP)
4. Adverse drug event (ADE)
5. Computerized physician order entry (CPOE)
6. Patient Safety Net (PSN)
7. University Health System Consortium (UHC)
8. Accreditation Council of Pharmacy Education (ACPE)

Introduction

Hospital's inefficiencies and unsafe environments were first described in the publication of *To Err is Human: Building a Safer Health System* (IOM, 2000) by the Institute of Medicine (IOM) and the Centers for Medicare and Medicaid Services (CMS).[1] This was one of the first, national publications that revealed medical errors occur frequently and are associated with substantial health care costs. They estimated that the total national cost associated with adverse events from medical errors to be between $37.6- $50 billion. The IOM also estimated that between 44,000 and 98,000 Americans die in hospitals each year due to medical errors.[2]

A systematic review conducted by de Vries and colleagues in 2008 attempted to quantify the incidence of in-hospital adverse events. The median overall incidence of adverse events was reported at 9.2%, with the majority of events being related to operation or medicine errors.[3] Along with de Vries and colleagues findings, *To Err is Human* and other IOM publications (*Crossing the Quality Chasm* and *Patient Safety* / *Preventing Medication Errors* (2007)), have all identified that medication errors are a significant contributor to medical errors.[2,4,5,6]

The IOM and the Institute of Safe Medication Practice (ISMP) defines a medication error as "any error occurring in the medication use process".[7] An adverse drug event (ADE) is defined as "any injury due to a medication". Adverse drug events can be non-preventable and preventable. It is estimated that on average a hospital patient is subject to at least one medication error per day. The IOM estimates that in the United States at least 1.5 million preventable ADEs occur each year.[6] Many studies have attempted to quantify the incidence of ADEs, but this number is impossible to identify, as there is too much variability between health care settings and facilities.[7,8,9,10]

Along with medication errors being highly prevalent in the hospital setting, there is a financial burden associated with medication errors. A study conducted in 1997 estimated an extra length of hospital stay attributed to one ADE was 1.74 days, with the associated hospital cost equating to $2013.[11] Applying a percent inflation to this number, it is estimated that in 2010 one ADE is attributed to $2722 in excess hospitalization costs. Based upon 1993 data, the IOM has reported an annual cost due to preventable ADEs to be $3.5 billion in 2006 dollars.[7] Medication errors, including preventable ADEs, are one component of excess health care costs that potentially can be reduced by identifying error-prone processes and human risk factors that place individuals at risk to committing an error.

A culture of safety and human error has been heavily studied in other industries such as aviation, aerospace, and oil and gas.[12,13,14] Specifically looking at the airline industry, in the 1990's there were approximately 10 million takeoffs and landings each year with an average of less than 4 crashes per year.[15] There has been a substantial amount of research and work that has been performed in the airline industry to achieve such a safe working environment.

The health care industry, specifically pharmacy operations, resembles a similar high acuity, high stress work environment seen in aviation. A pharmacist has a high risk to commit a medication error due to the intricacies of the medication dispensing process. This process includes the following steps; drug procurement, prescribing, transcribing, dispensing, administering, and monitoring patient's response.[6] Part of the dispensing step includes medication order verification conducted by the pharmacist. This process involves a pharmacist receiving an electronic medication order by the physician or advanced practitioner, assessing for appropriateness and safety, and then verifying the order. Once the medication order is verified, the order is active on the patient's medication profile and the nurse can administer the medication to the patient.

Because the pharmacist functions as a safety net before medications are administered to patients, it is imperative that the pharmacist appropriately performs the order verification step. Due to the pharmacy environment and medication dispensing process resembling other high risk industries, pharmacy can benefit from identifying environmental and human risk factors that place a pharmacist at risk to commit medication errors during the medication dispensing process. The objective of this study is to assess workload, work environment, and non-modifiable characteristics of the pharmacist that increase the likelihood of a pharmacist to commit an error during the medication order verification step in hospital pharmacy.

Methods

Study Design and Data Collection

A retrospective, observational study was conducted to assess the risk factors associated with committing a medication error during the order verification process in hospital pharmacy. The three risk factor categories included in the study were increased workload, work environment, and non-modifiable characteristics of the pharmacist. A medication error was defined as a Patient Safety Net (PSN) error event committed by a pharmacist. The PSN error events were reported through the institution's voluntary reporting system, University Health System Consortium (UHC). The definition of each risk factor category and their associated sub-categories included in the assessment is shown in Table 1.

Table 1: Risk Factor Category and Sub-Category Definitions

Risk Factor	Category	Sub-Category
Workload	Average number of orders verified per shift per pharmacist	Error rate per 100 shifts categorized b y a set integer of average number of orders verified per pharmacist
Work Environment	Type of shift (day, evening, night) Type of day (weekday, weekend) Average number of pharmacists per shift	Average number of pharmacists per shift per type of day
Pharmacist	Age Type of degree (BS, PharmD) Years at site Years practicing	Degree – Years at site Years practicing – Years at site Age – Years at site

Data obtained for the study included inpatient and outpatient medication orders records, pharmacist employee demographic records, and medication error events from the institution's voluntary reporting system, UHC PSN. The medication orders and the PSN error events that occurred from July 1, 2011 to June 30, 2012, the PSN error events that were categorized as order entry/order verification pharmacy process, and the employee demographic records for the pharmacists whose main job responsibility is medication distribution (order verification pharmacists) were included in the study. Medication orders that had the patient name of 'test patient' and the PSN error events that were reported only by a pharmacist were excluded from the study. The pharmacist PSN error events were excluded to help reduce bias in a voluntary reporting system. The study was approved by The Methodist Hospital and University of Houston's Institutional Review Boards.

The medication order records were collected from the institution's pharmacy electronic drug therapy management system, Mediware WORx®. The employee demographic records were collected from the institution's pharmacy human resource database, and were utilized to generate data for the non-modifiable characteristics of pharmacists. The PSN error events were collected from the institution's UHC PSN account. Data collected for medication orders, employee demographic records, and PSN error events were saved in a computerized database (Microsoft Excel and Microsoft Access).

The individual PSN error event was matched with the corresponding medication order. The objective data that was used to match the PSN error event to the medication order included time and date of order verification by the pharmacist, generic name of drug, pharmacist WORx® unique identification number, and patient medical record number. The medication order that was associated with a medication error was assigned a unique number that corresponded to the PSN error event number. The medication orders were then classified into two groups; error event and no error event. The error rates were calculated for each risk factor category by taking the number of medication orders that had an error event and dividing by the number of medication orders that did not have an error event.

Statistical Analysis

The statistical analysis was performed using Stata, version 12 (StataCorp LP, College Station, TX) and Excel (Microsoft Corporation, Redmond, WA). Medication orders were classified as having an error or not. A medication order error was the dependent, categorical variable. The independent variables were the risk factor categories; workload, work environment, and non-modifiable characteristics of the pharmacist.

Depending upon the classification of the independent variable, categorical or continuous, dictated what statistical test was performed for each of the risk factor categories.

1. To assess increased workload, represented by the average number of orders verified per pharmacist per shift, a grouped t-test was performed.
2. To assess type of shift, type of day and average number of pharmacists per shift influenced a pharmacists, a chi square test was performed.
3. To assess degree, a t-test was performed. To assess number of years practicing, number of years at site and age, linear regression analysis was performed.

Multivariate logistic regression and multivariate linear regression analysis was performed for any variable with a p-value of < 0.2 from the univariate risk factor category analysis.

These variables determined independent risk factors for errors. A p-value of less than 0.05 for any specific variable was considered significant.

Results

A total of 1,887,751 medication orders, 92 PSN error events and 50 pharmacists met the study criteria. The top five most common medications associated with a PSN error event was pneumococcal vaccine (13%), piperacillin/tazobactam 3.375 mg vial (4%), influenza virus vaccine (3%), warfarin 5 mg tablet (2%), and dexamethasone 4 mg/mL injection (2%). There was not a significant difference between medication classes and the rate of error per 100 orders verified.

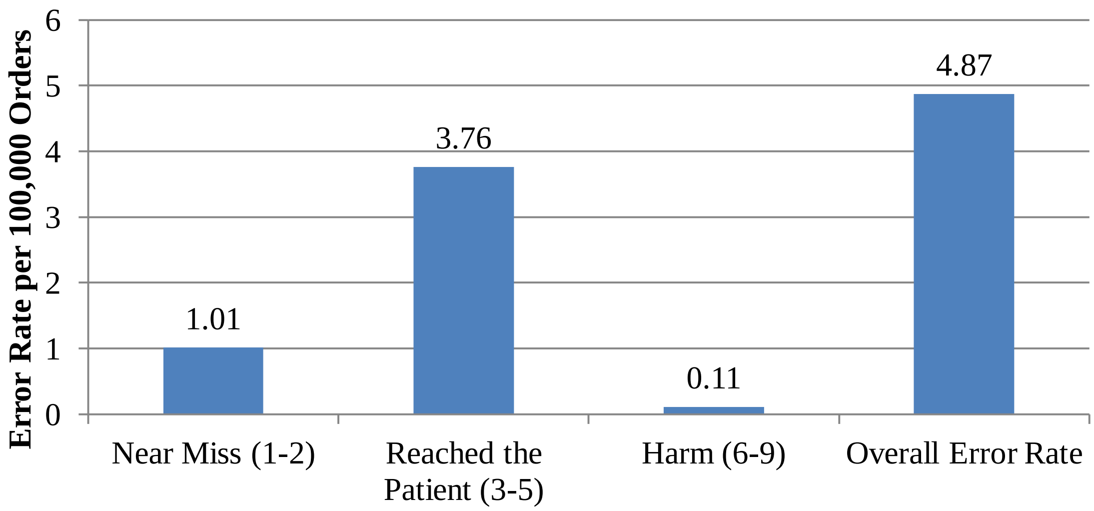
The average age of the pharmacist was 44.82 and the average number of years practicing was 17.92 (Table 2). The majority of pharmacists had a Bachelor of Science degree (64%). A total of 19 pharmacists were not responsible for an error event that was reported in the PSN database.

Table 2: Pharmacist Demographics

Average age, years (min, max)	44.82 (25.31, 71.10)
Average number of years at site, years (min, max)	12.34 (1.12, 29.37)
Average number of years practicing, years (min, max)	17.92 (1, 44)
Degree (%)	
BS	32 (64)
PharmD	18 (36)

The overall error rate per 100,000 orders verified was 4.87 (Figure 1). After categorizing the error events based upon harm score, the highest rate of error fell in the ‘reached the patient’ category (3.76). More importantly, the smallest rate of error (0.11) seen by the pharmacist during order verification harmed the patient. The most common event type reported was wrong dose, with wrong drug or substance being second.

Figure 1: Harm Score and Overall Rate of Error per 100,000 Orders Verified



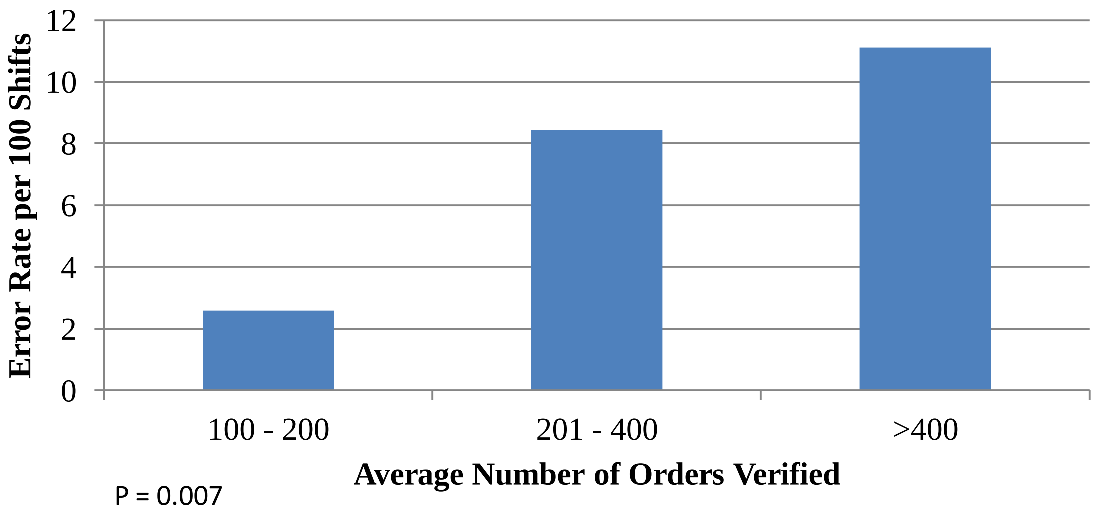
Specific Aim 1 – Workload

There was no difference in the average number of orders verified per pharmacist by the presence or absence of an error event (Table 3). Categorizing the average number of orders verified per pharmacist into three distinct ranges, demonstrated an increasing rate of error with an increasing number of orders verified per pharmacist (p = 0.007). Figure 2 illustrates a linear increase in error rate per 100 shifts, with the average number of orders verified greater than 400 being associated with the highest rate of error.

Table 3: Workload - Average Number of Orders Verified per Pharmacist

	Variable	Average Number of Orders Verified	P - value
Error Event	Yes	274.42	0.14
	No	264.40	

Figure 2: Average Number of Orders Verified Rate of Error per 100 Shifts



Specific Aim 2 – Work Environment

The work environment variables; type of shift, type of day, and average number of pharmacists per shift, all had significant outcomes (Table 4). The evening shift had the highest rate of error per 100 orders verified, day had second to highest, and night had the lowest, 10.57, 7.33, 4.55, respectively(p=0.021). In the type of day variable, weekday had a significantly higher rate of error than weekend at 9.17 and 3.29, respectively (p=0.002). The average number of pharmacists working per shift was significantly different (p=0.001), but was not associated with an identifiable trend in error rate. The highest rate of error was seen with an average of 8 pharmacists working during one shift and the lowest rate of error was with an average of 6 pharmacists per shift. The average number of pharmacists per shift was then stratified to type of day, which produced a significant difference in rate of error (p=0.0018). Once again, there was not an identifiable trend in error rate, but 8 pharmacists on evening shift during the weekday did have the highest rate of error at 13.91.

Table 4: Work Environment Variable Error Rate per 100 Shifts

	Variable	Error Rate	Average Number of Orders per Shift	P - value
Type of Shift	Day	7.33	2204	0.021
	Evening	10.57	1801	
	Night	4.55	961	
	Variable	**Error Rate**	**Total Number of Orders Verified**	**P-value**
Type of Day	Weekday	9.17	1491723	0.0015
	Weekend	3.29	328184	
	Variable	**Error Rate**	**Average Number of Orders per Pharmacist**	**P-value**
Average Number of Pharmacist per Shift	10 (Day, WD)	8.71	255	0.001
	8 (Evening, WD)	13.91	168	
	3 (Night, WD)	5.22	698	
	7 (Day, WE)	4.00	152	
	6 (Evening, WE)	2.97	175	
	3 (Night, WE)	2.91	246	
Weekday; WD, Weekend; WE				

Specific Aim 3 – Pharmacist Demographics

The pharmacist demographic variables (degree, number of years practicing, number of years at site, age) did not have statistically significant outcomes in each of the univariate analyses (Table 5). The number of years at site variable was stratified to type of degree, number of years practicing, and age. When years at site variable was stratified to type of degree, there was a trend of lower error rate the longer the pharmacist practiced at the site (p=0.077). There was also a lower error rate seen in the pharmacists who held a Doctor of Pharmacy degree compared to the pharmacists who had a Bachelor of Science degree in the stratified analysis. The stratified analysis of years at site and age, and years at site and years practicing did not produce significant results, and were therefore not reported.

Table 5: Pharmacist Demographic - Error Rate per 100,000 Shifts

	Variable	**Error Rate**	**P - value**
Degree	BS	5.19 ± 6.11	0.28
	PharmD	3.54 ± 4.55	
Years Practicing (years)	1 - 10	2.92 ± 3.60	0.95
	11 - 20	6.44 ± 6.42	
	> 20	3.77 ± 5.44	
Years at Site (years)	1 - 10	5.63 ± 6.27	0.17
	11 - 25	3.87 ± 4.65	
	> 25	2.60 ± 5.46	
Age (years)	20 - 35	2.47 ± 3.16	0.96
	36 - 49	6.32 ± 5.98	
	≥ 50	3.46 ± 5.64	
Degree - Years at Site Stratified	BS, 1 - 10	7.52 ± 7.42	0.077
	BS, 11 - 25	4.52 ± 5.00	
	BS, > 25	2.60 ± 5.46	
	PharmD, 1 - 10	4.14 ± 4.97	
	PharmD, 11 - 25	1.42 ± 1.67	
	PharmD, > 25	N/A	

*The following stratified analysis were conducted; Years practicing - Years at site and Age - Years at site. The results of these analyses were not significant. BS; Bachelor of Science, PharmD; Doctor of Pharmacy

Discussion

The health care industry, like other high risk industries, is expected to operate efficiently and at the same time safely. This vulnerable environment can lead to both preventable and non-preventable medical errors, as demonstrated in the publication *To Err is Human* (IOM, 2000). The medication dispensing process is an example of a high risk process that pharmacists perform in hospital pharmacy. The objective of this study was to evaluate suspected risk factors that influence the pharmacist to commit a medication error during the order verification step in the medication dispensing process. The results of this study can be utilized for medication safety benchmarking and can also help guide pharmacy leadership when assessing for areas of safety risks within hospital pharmacy operations.

The workload univariate analysis did not result in a statistically significant difference in the average number of orders verified per pharmacist per shift. When workload was categorized into an increasing integer of average number of orders verified, there was a significant difference in rate of error (Figure 2). There was an increase in error rate per 100 shifts as the average number of orders verified per pharmacist increased. This finding indicates that there is a safety risk associated with the more orders a pharmacist is expected to verify during a shift when all other influencing factors are controlled for. Additional studies are required to validate this finding and also identify a max number of orders verified per hour that maintain safe practices.

Of the three risk factor categories (workload, work environment, and pharmacist) the work environment had the most significant influence on medication error events during order verification. Type of shift, type of day, and average number of pharmacists per shift included in the work environment category, all significantly influenced the rate at which an error occurred. The weekday evening shift displayed the highest error rate in this category, as well as in the stratified analysis. This finding could be institutional specific and requires validation among other hospitals.

There was not an association between increased workload and increased error rate in the average number of pharmacists per shift stratified analysis. This finding differs from the finding in Figure 2. A higher error rate, as seen on the weekday evening shift, may not have been due to increased workload, but rather a combination of risk factors that are influencing a pharmacist medication error during a specific shift.

The type of degree and number of years at site were the two most influential variables in the non-modifiable pharmacist characteristics studied. Although, not statistically significant, the Bachelor of Science degree had a higher error rate per 100,000 orders verified when compared to the Doctor of Pharmacy degree in the univariate analysis. This finding was validated when type of degree was stratified to years at site. The highest rate of error per 100,000 orders verified was seen in the pharmacist who had been at the site for 1 to 10 years. As the pharmacist spent more time at the site, the error rate decreased.

A limitation to this study was utilizing a voluntary reporting system database to identify medication error events. This limited the number of medication error events included in this study, and introduced bias to the type of events included. The risk of bias was mitigated by only including medication error events that were reported by non-pharmacist health care professionals. Utilizing a voluntary reporting system to collect medical errors is standard to most institutions in the United States. Another limitation identified was conducting a single-site study, and therefore does not account for other types of pharmacy operations workflows and practice models. This can limit generalization of results to different types of hospital pharmacies.

Conclusion

Work environment and workload significantly influence the risk of a pharmacist committing a medication error during order verification. Increased workload is associated with an increased rate of error during order verification. Type of shift, type of day, average number of pharmacists per shift, and average number of orders verified per pharmacist can be utilized as medication safety benchmarks in hospital pharmacy.

Appendix

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