Impact of Mobile Dose-Tracking Technology on Medication Distribution at an Academic Medical Center

Matthew Kelm, PharmD, MHA,* and Udobi Campbell, PharmD, MBA†

ABSTRACT

Background: Medication dose-tracking technologies have the potential to improve efficiency and reduce costs associated with re-dispensing doses reported as missing. Data describing this technology and its impact on the medication use process are limited.

Objective: The purpose of this study is to assess the impact of dose-tracking technology on pharmacy workload and drug expense at an academic, acute care medical center.

Methods: Dose-tracking technology was implemented in June 2014. Pre-implementation data were collected from February to April 2014. Post-implementation data were collected from July to September 2014. The primary endpoint was the percent of re-dispensed oral syringe and compounded sterile product (CSP) doses within the pre- and post-implementation periods per 1,000 discharges. Secondary endpoints included pharmaceutical expense generated from re-dispensing doses, labor costs, and staff satisfaction with the medication distribution process.

Results: We observed an average 6% decrease in re-dispensing of oral syringe and CSP doses from pre- to post-implementation (15,440 vs 14,547 doses; $p = .047$). However, when values were adjusted per 1,000 discharges, this trend did not reach statistical significance ($p = .074$). Pharmaceutical expense generated from re-dispensing doses was significantly reduced from pre- to post-implementation (\$834,830 vs \$746,466 [savings of \$88,364]; $p = .047$). We estimated that \$2,563 worth of technician labor was avoided in re-dispensing missing doses. We also saw significant improvement in staff perception of technology assisting in reducing missing doses ($p = .0003$), as well as improvement in effectiveness of resolving or minimizing missing doses ($p = .01$).

Conclusion: The use of mobile dose-tracking technology demonstrated meaningful reductions in both the number of doses re-dispensed and cost of pharmaceuticals dispensed.

Key Words—dose tracking, medication systems, missing doses, nurses, pharmacist, quality assurance, technology

Hosp Pharm—2016;51:382-388

Use of technology at different stages of the medication use process within the health system has been demonstrated to improve safety of medication selection and turnaround times in the inpatient care setting.¹ The 2 most widely studied interventions have been the introduction of computerized physician order entry systems (CPOE) and automated dispensing cabinets (ADCs).^{1,2} Even though these interventions have been effective, timely availability of medications for administration to patients remains a challenge for pharmacy departments, and some track their missing medication request volume

as a metric to gauge their performance. Missing medications are often reported for medications that are known to have been dispensed, and invariably these requests result in re-dispensing activities. Re-dispensing of medications in turn contributes to staff workload and medication waste. Medication dose-tracking technologies have the potential to provide answers about the whereabouts of previously dispensed medications reported as missing, however peer-reviewed literature describing their use is limited.^{3,4} A single study by Calabrese and colleagues investigated the use of an electronic tracking system on pharmacy

*Manager, Unit Dose Distribution, †Associate Chief Pharmacy Officer, Inpatient Operations, Department of Pharmacy, Duke University Hospital, Durham, North Carolina. Corresponding author: Matthew Kelm, PharmD, MHA, Department of Pharmacy, Duke University Hospital, DUMC Box 3089, Durham, NC 27710; phone: 919-681-2414; e-mail: matthew.kelm@duke.edu

turnaround times and organizational structure.⁵ In this article, we describe findings that further this work by understanding the impact of the technology on drug expense and pharmacy workload.

BACKGROUND

Duke University Hospital is 957-bed academic, quaternary, acute care medical center, with 24/7 clinical and operational pharmacy services. The medication distribution model is hybrid in nature, comprised of a 24-hour cart fill process and a heavy reliance on ADCs. Campus-wide pneumatic tube systems and hourly delivery technicians are also used to support medication distribution on a daily basis. In our current medication use process, the pharmacy is able to track time points in the prescribing, pharmacist order verification, label generation, dose preparation, and verification aspects of compounded sterile product and oral syringe preparation. The aforementioned time points are captured using the health system-wide electronic health record (EHR) Epic (Epic Corp., Verona, Wisconsin). With implementation of the comprehensive EHR, the pharmacy department began to utilize a medication administration record (MAR)-based electronic messaging function for nursing users to communicate medication needs, including missing doses. The high volume of medication need requests warrants ongoing monitoring and review by a dedicated staff member on different shifts. Pharmacy staff members have the perception that the ease of use of this messaging system has resulted in an increase in the volume of communication from nursing staff. Until recently, it has not been feasible to determine when medications sent from the pharmacy reach their intended location, how long they took to get there, or their location in real time once outside the pharmacy. Each day, a significant number of missing dose requests are processed at our institution by staff. Missing doses can result in rework by staff, drug waste, and adverse drug events (ADEs) associated with delay in providing a missing dose. Implementation of PharmTrac.PD (Plus Delta Technologies, Durham, NC) mobile dose-tracking technology provides a mechanism to collect the information described above and is a tool for identifying the location of a previously dispensed dose, hence, avoiding re-dispensing doses reported as missing and minimizing delays associated with receipt of medications by the nurse. In this study, we sought to measure the impact of a process involving a pharmacy technician scanning a medication at pick-up from the

pharmacy and at drop-off on the patient care unit. These scanning data are captured in a database and are able to be analyzed for quality improvement purposes. Users are able to determine the location of a drug based on scan data available via an easily accessible web-based portal.

METHODS

Prior to implementing the mobile-scanning technology, a work group of front-line pharmacists, technicians, and managers was formed to develop the configuration and implementation strategies for the use of PharmTrac.PD. The work group determined that the highest impact could be realized by utilizing the system to track parenteral doses prepared in the sterile products cleanroom as well as oral syringes. These target dosage forms were selected due to the expense of the items, time required in their preparation, and unique label configurations that supported individual dose-tracking capability. A very simple unidirectional HL7 interface was established between PharmTrac.PD and the EHR. Deployment required the use of 8 iPod touch handled devices encased in health care grade scanners.

As part of the configuration, all medication pick-up and delivery locations were designated in the system, and unique barcode labels linked to the system configurations were placed at the specific sites. Doses that are distributed via pneumatic tube are able to be documented within the software as well. The system was designed to provide decision support for delivery technicians to ensure medication delivery to the correct patient location. Additionally, the software allows for assignment of acceptable storage conditions based on departmental storage practices; examples include refrigeration requirements, secure storage within an ADC, respiratory therapy-specific storage, or hand delivery to the care nurse. Other features of the technology include the ability to alert the user to patient transfers and dose discontinuation. Employee training was streamlined to a small slide set and on-site support; most staff were able to operate the devices with less than one day of support with training.

The primary objective was to study the percent of re-dispensed oral syringe and compounded sterile product doses prepared within a specified time period pre- and post-technology implementation per 1,000 discharges. Secondary objectives included investigating pharmaceutical expense generated from re-dispensing missing doses pre- and post-technology

implementation, comparison of labor cost associated with compounding re-dispensed doses of compounded sterile products pre- and post-technology implementation, and staff satisfaction with the drug distribution process, as evaluated by a 12-question survey, pre- and post- technology implementation. An important distinguishing characteristic of the data generated within the EHR is that “missing” doses are not able to be consistently and accurately delineated from other re-dispensed doses. For example, supplemental dispenses may be generated when a dose is damaged or additional supply needed, as in the case of a titrated continuous infusion.

Pre-implementation dispense and cost data were collected from February 2014 through April 2014 from electronic reporting within the EHR. The software was implemented on June 16, 2014. The work group developed training documentation and served as super users to train other staff members. The remainder of June was used as a washout period. The baseline data were then compared with identical reports from the EHR to July 2014 through September 2014. Dose re-dispensing data were generated from monthly operational data exports. This report was filtered to contain only dispense types that were being tracked using the PharmTrac.PD system. The financial value of medication re-dispenses that occurred was calculated by determining the current purchase price based on the pricing that was available at the conclusion of the study from the institution’s wholesaler. Doses of hemostatic factor agents as defined by American Hospital Formulary Service Drug Information 2014 (AHFS DI)⁶ were excluded due to their disproportionate effect on this measurement.⁴ These values were assigned and attributed to re-dispenses that occurred during both phases of the study. Statistical significance for comparing continuous variables was determined using a 2-sample *t* test. Survey results were statistically analyzed using a 2-sample *t* test for unequal variances.

RESULTS

The results of this analysis are detailed in **Table 1**. This analysis demonstrated a statistically significant decrease in the number of re-dispenses from the pre-implementation period to the post-implementation period of on average 6% ($p = .047$). When adjusted for re-dispenses per 1,000 discharges, the results trended in the same manner but failed to reach significance ($p = .074$).

The results of this analysis demonstrated a statistically significant ($p = .047$) decrease in the monetary value associated with re-dispenses after the technology implementation. The pharmacy re-dispensed less than \$88,363 worth of product during the 3-month period post-implementation. Based on this figure, a return on investment is rapidly achieved. From a technician labor expense perspective, we projected that \$2,563 worth of labor was avoided during the post-implementation period. This figure was estimated by assigning an average preparation time per dose and multiplying by the median technician salary.

Finally, the study authors wanted to understand if implementation of the technology affected staff satisfaction and attitudes about missing doses. The outcomes of the survey are summarized in **Table 2**. Results from the surveys were similar when comparing number of respondents (56 in pre-implementation survey, 53 in post-implementation survey), role within the facility (pharmacist vs technician), and years of service. The survey was unable to detect significant differences in overall satisfaction, the effect missing doses had on satisfaction, or the perception of pharmacy-nursing collaboration to resolve dose availability. Staff did have significant improvements in their perception of the technology assisting in reducing missing doses ($p = .0003$) as well as improving the effectiveness of resolving or minimizing missing doses ($p = .01$).

DISCUSSION

Implementation of mobile dose-tracking technology created a mechanism for a complete chain of data from the time of provider ordering through administration. In our experience, the use of this tool has demonstrated operational improvements in terms of the volume and cost associated with products re-dispensed from the sterile products cleanroom and oral syringes. The addition of decision support for pharmacy technicians in their daily distributive activities, which allows for appropriate storage of medications as well as access to information describing when pick-ups and deliveries have occurred, are greatly enhanced by this technology. Moreover the reduction in pharmaceutical expense and technician labor make the return on investment for this system readily quantifiable. Within our institution, the cost avoided during the study period covered the cost of technology and implementation. Although the implementation of a dose-tracking

Table 1. Pharmacy operational data pre- and post-implementation of PharamTrac.PD

Variable	Pre-implementation		Post-implementation		<i>p</i> value
Discharges	Discharges				
	Feb	3,172	July	3,629	
	Mar	3,561	Aug	3,669	
	Apr	3,532	Sept	3,498	.261
Discharges total	10,265		10,796		
No. of dispenses ^a	Dispenses				
	Feb	59,963	July	60,331	
	Mar	62,877	Aug	57,948	
	Apr	59,342	Sept	57,676	.206
Total dispenses	182,182		175,955		
Total dispenses per 1,000 discharges	17,747.88		16,298.17		
No. of redispenses ^a	Redispenses				
	Feb	5,075	July	4,810	
	Mar	5,198	Aug	4,702	
	Apr	5,167	Sept	5,035	.047
Total redispenses	15,440		14,547		
No. of redispenses ^a per 1,000 discharges	Redispenses per 1,000 discharges				
	Feb	1,599.94	July	1,325.43	
	Mar	1,459.70	Aug	1,281.55	
	Apr	1,462.91	Sept	1,439.39	.074
Value of redispenses, controlled for blood factor	Value of redispenses				
	Feb	\$287,087	July	\$241,035	
	Mar	\$271,496	Aug	\$238,055	
	Apr	\$276,246	Sept	\$267,376	.047
Total value of redispenses, controlled for blood factor	\$834,830		\$746,466		

^a SPC and oral syringes.

technology has been beneficial, it has come at the cost of more time spent in the investigation of doses reported as missing and scanning of products on pick-up and delivery. Time is now required to query the online portal to determine a dose's status in the system. Despite this incremental increase to

cycle time, no additional technician resources were required to implement this technology and hourly run cycles have been preserved.

Another appreciated effect of this technology implementation has been the improved access to information when quality improvement projects are

Table 2. Survey data pre- and post-implementation of PharmTrac.PD

	Pre-implementation	Post-implementation	Pre-implementation Mean (SD)	Post-implementation Mean (SD)	<i>p</i> value
1. What best describes your role?	<i>n</i> = 55	<i>n</i> = 53			
Pharmacist	<i>n</i> = 19	<i>n</i> = 17			
Technician	<i>n</i> = 36	<i>n</i> = 36			
2. How long have you worked at Duke?			3.36 (1.54)	3.38 (1.48)	
<1 year	11	6			
1-3 years	7	14			
3-5 years	8	6			
5-10 years	10	8			
>10 years	19	19			
3. How would you rate your job satisfaction?			3.44 (1.08)	3.45 (1.1)	.94
Very dissatisfied (1)	4	5			
Dissatisfied (2)	7	3			
Neutral (3)	11	15			
Satisfied (4)	27	23			
Very satisfied (5)	6	7			
4. How big of a problem do you perceive missing doses to be?			4.34 (0.69)	4.19 (0.71)	.72
Insignificant (1)	0	0			
Of minor significance (2)	1	1			
Neither insignificant or significant (3)	5	6			
Significant (4)	29	28			
Very significant (5)	20	18			
5. How do missing doses make you feel about your job?			2.25 (0.62)	2.28 (0.63)	.01
Very dissatisfied (1)	4	5			
Dissatisfied (2)	34	28			
Neutral (3)	16	20			
Satisfied (4)	1	0			
Very satisfied (5)	0	0			

(continued)

Table 2. Survey data pre- and post-implementation of PharmTrac.PD (CONT.)

	Pre-implementation	Post-implementation	Pre-implementation Mean (SD)	Post-implementation Mean (SD)	<i>p</i> value
6. How satisfied are you with your ability to resolve medication requests?			3.67 (0.34)	3.85 (0.89)	.92
Very dissatisfied (1)	1	0			
Dissatisfied (2)	5	4			
Neutral (3)	15	13			
Satisfied (4)	24	23			
Very satisfied (5)	10	13			
7. How well do you feel the pharmacy and nurses work together to resolve medication issues?			2.67 (1.11)	2.74 (1.26)	.78
Poorly (1)	8	13			
(2)	18	8			
Neutral (3)	16	15			
(4)	10	14			
Very well (5)	3	3			
8. How well do you find technology, current resources, and logs assist you in identifying and reducing missed doses?			2.91 (0.87)	5.53 (0.85)	.0003
Very dissatisfied (1)	2	1			
Dissatisfied (2)	16	5			
Neutral (3)	22	16			
Satisfied (4)	13	27			
Very satisfied (5)	1	4			
9. How effectively do you feel the institution resolves or minimizes missing doses?			2.73 (1.04)	3.23 (1.03)	.01
Very ineffective (1)	7	4			
Ineffective (2)	18	9			
Neither ineffective or effective (3)	13	13			
Effective (4)	17	25			
Very effective (5)	0	2			

designed or during the investigation of after-the-fact events. Access to reliable, time-stamped information allows managers to clearly understand the chain of events in medication delivery as well as provide actionable staff feedback for development. Additionally, the technology enhances the institution's compliance with The Joint Commission Medication Management Standard 03.01.01 to safely store medications.⁷

Limitations noted in this study are based in part on EHR design and configuration. Re-dispensed doses are not reliably able to be classified as missing, damaged, or as replacement for continuous use. This resulted in the inability to investigate doses of missing source exclusively. Additional limitations to the survey data could include the Hawthorne effect where respondents are biased by knowing the process is being studied.⁸ While not all survey responses support this trend, the possibility cannot be ruled out. Additionally, although not constructed in a manner to induce bias, there is not a validated survey tool available that specifically met the needs of this project. Finally, the study was able to detect a statistically significant decrease in both re-dispenses and expense; when adjusted for discharge volume, the decreases noted in re-dispense volume no longer met the confidence level of 95%.

Future directions for further study on this topic would be an investigation of the ability of this technology to impact the percentage of doses that arrive on the unit by their due time and by whether improvements in overall cycle time could be achieved. Additionally we have interest in understanding the effect this technology has on nursing pharmacy communication. A future area of study is likely to include providing nurse access to the web portal and describing the effect this has on both interaction and behavior.

CONCLUSION

The use of mobile dose-tracking technology demonstrated meaningful reductions in both the number of doses re-dispensed and cost of pharmaceuticals dispensed. Use of the technology decision support system for pharmacy technicians and increased access to delivery information were key components

of this impact. As results from the staff survey demonstrated, the introduction of a technology solution enhanced perceptions about effectiveness in performing a core job function.

ACKNOWLEDGMENTS

The authors would like to acknowledge the statistical support provided by Yulia Likhnygina, PhD. The study was funded by the Duke University Hospital Department of Pharmacy. The authors have no conflicts of interest to disclose.

REFERENCES

1. Agency for Health Care Research and Quality. Medication turnaround time in the inpatient setting. AHRQ publication no. 09-0045. May 2009. <https://healthit.ahrq.gov/sites/default/files/docs/page/medication-turnaround-time-quick-reference-guide.pdf>. Accessed March 12, 2016.
2. Chou J, Peaty N, Strickland JM. Measuring, evaluating, and improving medication distribution process and performance metrics in an inpatient pharmacy: The value of medication tracking, on-time delivery, and pharmacy analytics. <http://www.plusdeltatech.com/d/PharmTrac%20Performance%20Monitoring%20White%20Paper%202013%203.1.2013.pdf>. Accessed August 5, 2014.
3. Wolters Kluwer Health |Pharmacy OneSource®. Medication tracking systems. Website-case study. <http://www.wolterskluwerhealth.com/News/Documents/Case%20Studies/Riverside%20Methodist%20Hospital.pdf>. Accessed October 15, 2015.
4. Aethon. Streamlining your hospital pharmacy operations: How a real-time advanced medication tracking system increases productivity and improves patient care. <http://www.aethon.com/wp-content/uploads/2014/07/MedEx-Whitepaper-Real-Time-Medication-Delivery-Tracking-Web.pdf>. Accessed October 15, 2015.
5. Calabrese SV, Williams JP. Implementation of a web-based medication tracking system in a large academic medical center. *Am J Health Syst Pharm*. 2012;69:1651-1658.
6. McEvoy GK, Snow ED, eds. *AHFS: Drug Information*. Bethesda, MD: American Society of Health-System Pharmacists; 2014:1550-1678.
7. The Joint Commission. Medication Management Chapter. July 1, 2014.
8. Roethlisberger FJ, Dickson WJ. *Management and the Worker*. Cambridge, MA: Harvard University Press; 1939. ■