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Evaluating the Impact of Drug Dispensing Systems on the Safety and Efficiency in a Singapore Outpatient Pharmacy

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Abstract
Purpose: *Automation of pharmacy workflow can reduce medication errors as well as improve efficiency of the medication picking, packing and labeling process. Since September 2012, two drug dispensing systems (DDS) began operations in the Singapore General Hospital Specialist Outpatient Clinic Pharmacy. This study sought to evaluate the impact of the DDS on safety and efficiency in the pharmacy.* ***Methods:*** *The primary outcome was the rate of prevented dispensing incidents contributed by DDS or manual picking of medications defined as the number of prevented dispensing incidents per 1000 medications picked. The secondary outcome was the productivity of each full time equivalent (FTE) when assigned to either the DDS or manual picking stations. Data pertaining to the primary and secondary outcomes between January and December 2013 were collected and analyzed. The rate of prevented dispensing incidents was expressed in median (interquartile range) and compared using Mann-Whitney U test. Other continuous variables were expressed in mean ± standard deviation and compared using independent samples t-test.* ***Results:*** *An average of 59494 medications was picked every month in the pharmacy. DDS accounted for 21.1 percent while manual picking accounted for 78.9 percent of all the medications picked. The median rate of prevented dispensing incidents per month committed by manual picking (2.73) was significantly higher than the DDS (0.00). DDS had greater productivity with each FTE in the DDS having an average of 6175 picks per month which was significantly higher than each FTE in the manual picking stations which had an average of 4867 picks per month.* ***Conclusion:*** *Installation of DDS in an outpatient pharmacy improved safety of the pharmacy workflow by automating the medication picking, packing and labeling process and minimizing human errors. Efficiency of the medication picking, packing and labeling process was also improved by the DDS as there were continuous efforts to boost their productivity as well as being more reliable and better able to handle fluctuations in patient load.*

Introduction

Preventing dispensing errors is one of the fundamental criteria of pharmacy practice. Dispensing errors are defined as "deviations from a written prescription occurring during the dispensing process of selecting and assembling medications (drug/content errors), generating and affixing of dispensing labels (labeling errors) and issue of the dispensed products to patients (issue errors)[1]". Dispensing errors are sub-divided into unprevented and prevented dispensing incidents. Unprevented dispensing incidents (errors) are "dispensing errors detected and reported after medication has left the pharmacy, which may or may not lead to patient harm[1,2]". Prevented dispensing incidents (near-misses) are "dispensing errors detected during dispensing before the medication has left the pharmacy[1-3]".

Automation of the prescription filling process has been shown to reduce dispensing errors as it reduces human involvement during the process[4,5]. In addition, automation can potentially improve labor productivity[6]. Various types of automated options are available in the pharmacy such as automated dispensing cabinets, automated mobile medication carts, automated pharmacy carousel systems, bar-code scanning, computerized prescriber order entry, document management systems, medication packaging systems, narcotic management systems, and robotic picking machines[5].

In 2011, two drug dispensing systems (DDS; Getech, Singapore) were installed in the Singapore General Hospital Specialist Outpatient Pharmacy and began operations in September 2012 after multiple tests and trials. Each DDS contained medication cartridges of two different sizes that housed certain box or blister-packaged medications that fulfilled the criteria for loading inside the cartridges. Medications loaded in the DDS were automatically picked, packed and placed in labeled re-sealable bags when picking jobs were assigned to the DDS. The main aims for installation of the DDS were to reduce occurrences of dispensing errors as well as reduce reliance on manual labor for picking, packing and labeling of medications. This study sought to

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evaluate the impact of the DDS on safety and efficiency in the pharmacy.

Primary Outcome

The primary outcome of this study was the impact of the DDS on the safety of the prescription filling process. Ideally, the rate of unprevented dispensing incidents should be used as an outcome measure. However, occurrences of unprevented dispensing incidents were rare and accurate data was difficult to capture as errors that made it out of the pharmacy may never be discovered. Therefore, the rate of prevented dispensing incidents that occurred during the picking and packing process was used as an outcome measure for safety. The rate of prevented dispensing incidents was defined as the number of prevented dispensing incidents per 1000 medications picked. There were three types of prevented dispensing incidents: wrong quantity, wrong strength and wrong type of medication.

Secondary Outcome

The secondary outcome was the impact of the DDS on the efficiency of the medication picking, packing and labeling process. Operationally, this meant the time taken for the medications to be picked, packed, labeled and ready to be dispensed. However, the time taken to pick, pack and label medications at the manual picking stations was not available. Therefore, the productivity of each full time equivalent (FTE) when assigned to either the DDS or manual picking stations was used as a surrogate marker to measure the efficiency of the medication picking, packing and labeling process. Productivity was calculated by dividing the total quantity of medications picked over the total number of FTEs working in the DDS or the manual picking stations.

Methods

Study Design and Setting

This was a cross-sectional, retrospective study analyzing data in the pharmacy after installation of the DDS. Each DDS measured 1.25 meters (width) by 3.85 meters (length) by 2.2 meters (height) and weighed 1400kg without medications inside. One DDS had 70 small cartridges and 45 large cartridges while the other DDS had 50 small cartridges and 56 large cartridges. There were also buffer cartridges preloaded with medications ready to be loaded into the DDS when necessary. The different sizes of the cartridges allowed for flexibility in loading medications of different packaging dimensions. Three different sizes of re-sealable bags were utilized in each DDS to accommodate different quantities of medications. The expected throughput of each DDS was 360 picks per hour (assuming four items per bag inclusive of printing and bagging). When an order for a medication inside the DDS was received, the medication was automatically picked by the DDS using robotic arms with an air suction mechanism and packed into a re-sealable bag with the dosing instructions and particulars of the patient printed on the bag (Figure 1). Barcode technology was utilized during the preloading of cartridges as well as inside the DDS. Each medication cartridge in the DDS had a medication barcode attached in which the robotic arm must scan and match the barcode input into the DDS during the preloading process by the pharmacy staff. If the scanned barcode did not match the input in the DDS, the robotic arm would not pick the medication. Medications not found in the DDS or those unsuitable to be picked by the DDS such as loose tablets and capsules, solutions, suspensions, vials, enemas and suppositories were picked, packed and labeled manually by pharmacy technicians at their assigned picking stations.

Prior to November 2012, there were two separate pharmacies catering to 14 specialist outpatient clinics. One pharmacy had the DDS installed and the other did not. Merger of these two pharmacies took place in November 2012 and it took approximately two months to iron out administrative issues, familiarizing staff with the new pharmacy, redistribution of workload and stabilizing the workflow as the prescription load and pharmacy staff increased significantly. Therefore, we analyzed data from January 2013 onwards. The merged pharmacy had approximately 100 staff at any one time consisting of pharmacists, pharmacy technicians, pharmacy assistants, pre-registration pharmacy graduates and university and polytechnic interns serving 14 specialist outpatient clinics. An average of 1200 prescriptions which include single or multiple medication orders per prescription was handled each day. The pharmacy operates five and a half days a week, from 8:00am to 7:00pm on weekdays and 8:00am to 1:00pm on Saturday. The DDS operates only on weekdays from 8:00am to 6:00pm.

Polytechnic and university interns and pre-registration pharmacy graduates were responsible for the picking, packing and labeling of medications but these were carried out under supervision until they passed the competency tests. Polytechnic and university interns and pre-registration pharmacy graduates also dispensed medications under supervision. Pre-registration pharmacy graduates performed clinical checks on prescriptions under supervision. Pharmacy assistants were involved in the picking, packing and labeling of medications. Pharmacy technicians were responsible for receiving prescriptions, validating patient information, performing a technical and legal check of prescriptions, keying in medication orders electronically, generating medication labels and picking, packing and labeling of medications. Dispensing of medications was performed by pharmacists and pharmacy technicians. Pharmacy technicians can only dispense to patients with three or less medications while the rest must be dispensed by pharmacists. All prescriptions were clinically checked by a pharmacist before dispensing. Pharmacists and pharmacy technicians performed an accuracy check before dispensing the medications.

Data Collection

Data between January and December 2013 were collected. Prevented dispensing incidents were reported by dispensing staff. These were recorded on data collection forms placed at every dispensing counter. Assigned pharmacy technicians would collate these data at the end of every week. The number of medications picked per month was retrieved electronically and sorted according to DDS-picked or non-DDS-picked.

Statistical Analysis

The rate of prevented dispensing incidents was expressed in median (interquartile range) and compared using Mann-Whitney U test. Other continuous variables were expressed in mean ± standard deviation and compared using independent samples t-test. Data analysis was performed with Statistical Package for the Social Sciences (SPSS) version 18.0.1 with the level of statistical significance set at $\alpha = 0.05$ for all the analyses.

Results

In the one year of data collected, an average of 59494 ± 11363 medications were picked every month in the pharmacy. The mean number of medications picked per month by manual picking (48670 ± 11819) was significantly higher ($p < 0.05$) than by the DDS (12350 ± 2012). The DDS accounted for 21.1 ± 3.1 percent while manual picking accounted for 78.9 ± 3.1 percent of all the medications picked.

Primary Outcome

A total of 1565 prevented dispensing incidents were committed during the study period in which 1132 involved wrong quantity of medication, 64 involved wrong strength of medication and 369 involved wrong type of medication. An average of 141 (79 - 162) prevented dispensing incidents per month were committed by manual picking while 0 (0 - 6) were committed by the DDS. The median rate of prevented dispensing incidents per month committed by manual picking [2.73 (1.88 - 3.57)] was significantly higher ($p < 0.05$) than the DDS [0 (0.00 - 0.46)]. For each type of prevented dispensing incident, manual picking also contributed a significantly higher ($p < 0.05$) median percentage per month as compared to the DDS. These results are summarized in table 1.

Secondary Outcome

Since installation of the DDS, two FTEs were assigned to attend to the DDS while ten FTEs were assigned to manual picking stations. Each FTE in the DDS had an average of 6175 ± 1006 picks per month which was significantly higher ($p < 0.05$) than each FTE in the manual picking stations which had an average of 4867 ± 1182 picks per month. These results are summarized in table 2.

Discussion

Safety of the Prescription Filling Process

The DDS was shown to improve safety of the prescription filling process by committing a lower rate of prevented dispensing incidents compared to manual picking during the study period. The use of barcode technology during the preloading process as well as cartridge recognition inside the DDS minimized the likelihood of wrong strength and wrong drug being picked. This was reflected by the zero error rates for these two categories committed by the DDS (Table 1). Medication packaging which had perforations or were prone to warpage were susceptible to having the wrong quantity picked by the DDS. However, occurrences of wrong quantity of medication being picked by the DDS were rare compared to manual picking (Table 1). Errors in picking by the DDS can also happen during the preloading stage whereby the pharmacy staff loaded the wrong quantity, strength or type of medication into the cartridge. To prevent such errors, all medication cartridges undergo two stages of checking and verification by a pharmacy technician before loading into the DDS. In addition, only trained pharmacy technicians who passed a competency assessment were allowed to preload and load medication cartridges in the DDS.

Manual picking of medications at picking stations involved long hours doing repetitive work. Many factors can contribute to picking errors at these stations such as distractions, fatigue, memorizing medication bin locations as well as during hours of high workload where staff at the picking stations were usually pressured to complete picking jobs faster. A previous study had shown that prevented dispensing incidents usually occur during prolonged periods of high workload where pharmacy staff become more complacent and less careful as well as after busy periods where pharmacy staff became tired[7]. These problems were not encountered by the DDS as the pharmacy staff were not directly involved in the picking and packing of medications. Therefore, the DDS helped to minimize human errors during the picking process and improved medication safety of the pharmacy workflow.

Efficiency of the Medication Picking, Packing and Labeling Process

The DDS improved the efficiency of the medication picking, packing and labeling process with each FTE having a higher productivity than those in the manual picking stations. This was due to efforts to boost the productivity of the DDS. First, there was emphasis on streamlining the DDS workflow, increasing the pool of trained and competent staff to manage the DDS and minimizing DDS mechanical and software errors. Other initiatives included periodical review of consumption patterns in the pharmacy to optimize usage of medication cartridges in the DDS, rounding up of medication quantities as the DDS can only pick medications in complete blister packs, strips or boxes as well as identifying and improving bottlenecks in the DDS workflow. Altogether, these initiatives contributed to a steadily increasing trend in the percentage of all medications picked by the DDS (Figure 2) while the number of FTEs being utilized remained the same. Drops in percentage medication picks by the DDS in November and December 2013 were attributed to a few reasons. First, alfacalcidol was removed from the DDS at the start of November due to photosensitivity issues. Second, rounding up of furosemide quantities was stopped at the start of November because it was frequently prescribed for short durations thus it was deemed to be unsuitable for rounding up as patients may end up with oversupply of furosemide. However, the percentage medication picks by the DDS during these two months were still higher than the months in the first half of the year.

Productivity of the DDS was less likely to be affected by fluctuations in manpower and patient load. The DDS could maintain continuous output as long as the medication cartridges were topped up. In contrast, manual picking relied heavily on manpower and the productivity were more easily affected by shortage of manpower. The pharmacy faced fluctuations in patient load throughout the day as shown in figure 3. Peak patient load occurred around 11:00am to 12:30pm and 3:30pm to 5:00pm. Peak patient load at 11:00am to 12:30 coincided with lunch timings and the manpower shortage during this time may impair the efficiency of the manual picking, picking and labeling of medications. Manpower requirements for the DDS remained the same despite a surge in patient load as buffer cartridges were present to cope with these situations. Buffer cartridges were selected to be preloaded with medications with high turnover rate during periods of low patient load. Therefore, the DDS were better able to maintain productivity despite fluctuations in manpower and patient load as compared to manual picking.

Limitations of the Study

There were limitations to this study. First, the retrospective nature indicated that missing data could not be reconciled. However, all the data with the exception of prevented dispensing incidents were retrieved electronically from databases thus it was unlikely that there were much missing information. Second, capturing data on prevented dispensing incidents relied on self-reporting by pharmacy staff which may have led to underestimation of the incidences. Capturing accurate data on prevented dispensing incidents had always been a challenge as no method was available to ensure that all prevented dispensing incidents were reported. There were other methods of capturing prevented dispensing incidents such as the direct observation method[8] but this was not adopted in the pharmacy. Therefore, we relied on self-reporting to collect such data.

Conclusion

In summary, installation of DDS in an outpatient pharmacy improved safety of the pharmacy workflow by automating the medication picking, packing and labeling process thus minimizing human errors. The efficiency of the medication picking, packing and labeling process was also improved by the DDS as there were continuous efforts to boost their productivity as well as being more reliable and better able to handle fluctuations in patient load.

References

1. James KL, Barlow D, McArtney R et al. Incidence, type and causes of dispensing errors: a review of the literature. Int J Pharm Pract. 2009; 17: 9–30.
2. James KL et al. A study of unprevented dispensing incidents in Welsh NHS hospitals. Int J Pharm Pract. 2008; 16: 175–188.
3. James KL, Barlow D, Burfield R et al. Unprevented or prevented dispensing incidents: which outcome to use in dispensing error research? Int J Pharm Pract. 2011; 19: 36–50.
4. Carmenates J, Keith MR. Impact of automation on pharmacist interventions and medication errors in a correctional health care system. Am J Health Syst Pharm. 2001 May 1; 58(9):779-83.
5. Oswald S, Caldwell R. Dispensing error rate after implementation of an automated pharmacy carousel system. Am J Health Syst Pharm. 2007 Jul 1; 64(13):1427-31.
6. Lin AC, Huang YC, Punches G, Chen Y. Effect of a robotic prescription-filling system on pharmacy staff activities and prescription-filling time. Am J Health Syst Pharm. 2007 Sep 1; 64(17):1832-9.
7. James KL, Barlow D, Bithell A et al. The impact of automation on workload and dispensing errors in a hospital pharmacy. Int J Pharm Pract. 2013 Apr; 21(2):92-104.
8. Flynn EA, Pearson RE, Barker KN. Observational study of accuracy in compounding i.v. admixtures at five hospitals. Am J Health Syst Pharm. 1997; 54:904-12.

Table 1: Comparison between DDS and manual picking on the rate of prevented dispensing incidents.

	Median (IQR*) per month	DDS	Manual Picking	p value
Rate of prevented dispensing incidents		0 (0.00 - 0.46)	2.73 (1.88 - 3.57)	< 0.05
Wrong quantity of medication		0.00 (0.00 - 0.46)	2.01 (1.40 - 2.65)	< 0.05
Wrong strength of medication		0.00 (0.00 - 0.00)	0.08 (0.06 - 0.14)	< 0.05
Wrong type of medication		0.00 (0.00 - 0.00)	0.67 (0.38 - 0.98)	< 0.05

*IQR = interquartile range

Table 2: Comparison between DDS and manual picking on the percentage of medications picked per month and the productivity per FTE.

		DDS	Manual Picking	p value
Number of medications picked	Mean ± SD* per month	12350 ± 2012	48670 ± 11819	< 0.05
Percentage of medications picked		21.1 ± 3.1	78.9 ± 3.1	< 0.05
Productivity per FTE		6175 ± 1006	4867 ± 1182	< 0.05

*SD = standard deviation

Figure 1: From top left clockwise: a) Drug Dispensing System (DDS); b) re-sealable bags and printing system; c) drug cartridges in the DDS; d) side view of the robotic arm picking medications

Figure 2: Mean percentage of all medications picked per month by the DDS in 2013.

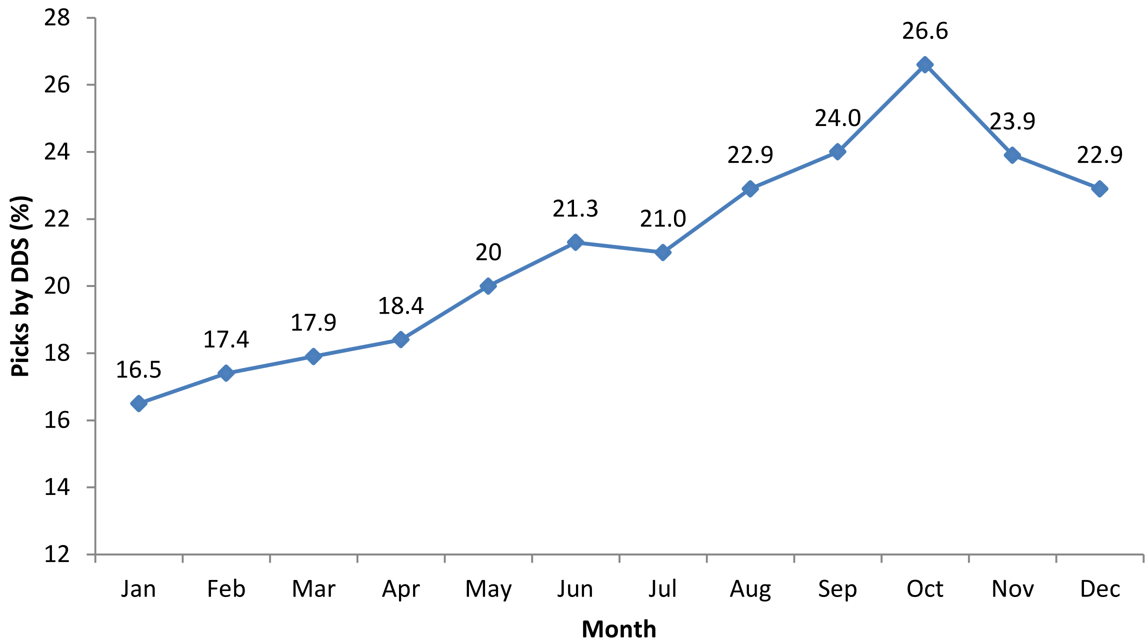

Figure 3: Mean number of patients each day in the pharmacy at different time intervals in 2013.