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Automation of a tertiary hospital pharmacy drug dispensing system in a lower-middle-income country: A case study and preliminary results

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ABSTRACT

Background: An increase in the use of automated systems has optimised the drug dispensing process in hospitals.
Methods: This case study describes the implementation of automated drug dispensing system and presents the preliminary results of automated pharmaceutical dispensing with robots (PillPick® and BoxPicker®, ©Swisslog Healthcare) at Hospital Sírio-Libanês, a private tertiary hospital in Brazil.
Results: During the study period, between 2013 (pre-automation) and 2017 (post-automation) the number total of medication errors has not changed post-automation, but there was significant reduction in error in the dispensing phase with a relative risk of 0.84 (95% confidence interval: 0.70–0.99) withal a reduction in the numbers of returned items, breakages, and loss of medications, although that delivery times have increased..
Conclusion: The study results suggest that the use of robotic systems in the central pharmacy may improve hospital pharmacy management and generate only a few errors in dispensing pharmaceuticals.

1. Introduction

For the most part, the care setting for hospitalized patients involves the use of medications, and the hospital pharmacy has a large role in this process: it guarantees the supply, dispensing, access, control, traceability, and rational use of drugs and other health technologies; ensures the development of clinical assistance practices that make it possible to monitor the use of drugs and other health technologies; optimizes the relationship between the costs, benefits, and risks of technologies and assistance processes; develops pharmaceutical assistance actions, articulated and synchronized with institutional guidelines; and actively participates in continuously improving health team practices. The medication dispensing process involves stages such as prescription, preparation, distribution, and administration. Failures or errors can occur at any stage.[1]

Errors related to medications can directly impact the health of patients and the institutional processes of care provided, including the occurrence of negative clinical outcomes and an increase in the length of hospital stay.[2] According to estimates, medication errors cause 1 out of every 131 outpatient deaths and 1 out of every 854 inpatient deaths; additionally, inpatient medication error rates are between 4.8% and 5.3%, with annual costs for European healthcare systems of at least €4.5 billion.[3] Identifying errors and their consequences is necessary for strategic planning to reduce them.

Recently, automated drug dispensing systems have been installed in hospitals around the world.[4] The adoption of automated systems in healthcare can minimize the occurrence of errors, increase efficiency, reduce the time required to have validated medication, and facilitate the accessibility of medicines in healthcare units while reducing the costs for health institutions.[5] Some studies have already demonstrated the results of the use of automation in pharmacy systems. Based on a pre-post design study assessing 808 patients and 2087 medications used, Fanning et al. demonstrated a considerable reduction in errors of 64.7% (1.96% before *versus* 0.69% after, *p* value 0.017) in prescription, selection, and preparation when the manual process was compared to the automated process.[6] A recent systematic review showed that all automated and semi-automated drug distribution systems improved medication safety and quality of care and saved more time than a decentralized system.[4] Another systematic review demonstrated that the automation of hospital pharmacies offers benefits over traditional manual dispensing methods in terms of clinical and economic outcomes, with reductions in medication errors, medication administration time and costs.[7]

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Nevertheless, the investment needed for automated systems is extremely high, but it can bring positive results, depending on the context. An economic evaluation carried out in Spanish hospitals shows that for automated systems in hospital pharmacies, using an integrated unit dose process robotic system (PillPick®), the return on investment could take more than 10 years for hospitalized patients, for any number of beds.[8] In a previous study, implementing an automated dispensing system in an intensive care unit had an initial investment of €126,000.00. However, the automation reduced the overall costs of storing expired drugs, and five years after the initial investment, the balance was positive at €148,229.00.[9]

Although the literature indicates that there has been an increase in the use of automated drug dispensing devices in hospitals, most studies were conducted in high-income countries.[7] One study carried out in Brazil presented data on the implementation of an automated drug dispensing system,[10] but data on the ©Swisslog Healthcare robotic pharmacy automation system are still scarce, even though its use has been growing in several countries.[11] Studies in tertiary hospitals from low- to middle-income countries, such as Brazil, remain scarce.

Hospital pharmaceutical care in Brazil is very heterogeneous. A study by Santos et al. on the hospital pharmacy workforce in Brazil showed that even though Brazilian law states that all hospital pharmacies must have a pharmacist, approximately half of all hospitals do not have a hospital pharmacist. The hospitals most likely to be in compliance with the law are specialized and of high complexity, owned by non-profit organizations, and located in the richest south-eastern region of Brazil.[12]

In Brazil, the automation of hospital pharmacies is in the earliest stage, and currently, in accordance with ©Swisslog Healthcare, only four hospitals nationwide have the automated pharmaceutical dispensing systems PillPick® and BoxPicker® deployed.

Understanding the advantages of, disadvantages of, barriers to, and facilitators of the implementation of automated hospital pharmacy systems is a key step in guiding the choice of scenarios and assumptions for further studies to be able to assess the impact of these technologies on both patient care and hospital management.

This study was conducted to describe the implementation of the automated pharmaceutical dispensing systems PillPick® and BoxPicker® (©Swisslog Healthcare) in a large tertiary hospital in Brazil and to present the preliminary results of their use.

2. Methods

2.1. Study design, setting, and ethical issues

This case study describes the implementation of automated pharmaceutical dispensing equipment and presents the preliminary results from the implementation of robots (PillPick® and BoxPicker® ©Swisslog Healthcare) at the Hospital Sírio-Libanês, a private tertiary hospital in São Paulo, Brazil. Within the total study period (from 2013 to 2017), the hospital had an increase in bed availability (from 369 to 469 beds) and pharmacist professionals (from 48 to 59). The hospital pharmacy department consists of a central pharmacy, storage units, and satellite pharmacies.

2.2. Data collection

Data collection was performed at the pharmacy department using aggregate data from the Philips Tasy® hospital management system and using business intelligence (BI) indicators.

For notifications of adverse events, we used the Risk Management Module of Actio® software, which promotes the standardization of the risk model through the notification of events in structured templates to generate data for the evaluation and promotion of mitigation plans. The events that occurred during the study period were analysed considering the date, place, type of occurrence, drug involved, process stage, classification, degree, and type of harm resulting by following WHO guidelines[13]: none (failure reached the patient but did not cause damage, and no treatment was required), mild (failure resulted in mild symptoms, no loss of function with minimal damage, no intervention required, or minimal intervention required), moderate (failure resulting in symptoms that required intervention, a prolonged hospital stay, permanent long-term damage or loss of function) and severe (a symptomatic event requiring life-saving intervention or a major surgical/medical intervention, shortened life expectancy, or major permanent or long-term harm or loss of function).

The hospital began the process of its automating drug distribution systems in 2011 with the implementation of the personal digital assistant (PDA) for electronic dispensation. In 2013, the decentralized Pyxis® electronic dispensary was introduced to make medicines available within the hospital units and to speed up the dispensing of urgently prescribed medicines and the admission of patients.[10] In 2014, the central pharmacy implemented the use of equipment with robotic automated dispensing systems, specifically by using the PillPick® (unit dose drug dispensing system) and BoxPicker® (non-unit dose drug dispensing system) robots from ©Swisslog Healthcare. The PillPick® and BoxPicker® robots can reduce human intervention in the dispensing process, have a medication unitization tool, have sequential traceability of each unit of unitized and dispensed medication, have a daily inventory of stocks, prevent the dispensing of expired medication, and promote a centralized process in the hospital pharmacy.

The aggregate data were grouped into two periods: (i) pre-automation (year 2013, 18,830 inpatients, 369 beds, no dispensing robots) and (ii) post-automation (year 2017, 24,491 inpatients, 469 beds, dispensing robots implemented).

2.3. Outcomes of interest and data analysis

The following outcomes were considered when comparing the pre- and post-automation periods:

1. Delays in drug delivery: the number and frequency of deliveries beyond the limit of 2 h after administration time.
2. Returns of delivered drugs: the number and frequency of deliveries that returned from the care units to the central pharmacy due to non-use, which occurred when the dispensing process was very early in relation to the administration time.
3. Breakages and losses in the drug batches dispensed: the number and frequency of medications lost due to breakage, spillage, damage, or expiration.
4. Adverse events: the number and frequency of patient injuries resulting from medication, either because of a pharmacological reaction to a normal dose or because of a preventable adverse reaction to a drug resulting from an error. Data were presented for each phase of pharmaceutical care (prescription, request, distribution, preparation, or administration).[13]
5. Errors: the number and frequency of an error that could result in an adverse event. Data were presented for each severity category of failure (none, mild, moderate, and severe): Thus, as previously described, the measurement of the outcome considered the classification of adverse events by following WHO guidelines.[13]
6. Involvement of pharmacy professionals: the number of pharmacy assistants at the central pharmacy involved in the dispensing process.
7. Total overtime paid/year: the estimated value including overtime paid to pharmacy professionals from the central pharmacy.

For statistical analysis, the risk ratio (RR) was used to measure the association, and the significance level of 0.05 was adopted for all analyses. The chi-square statistic was obtained using Microsoft Excel 2016® software.

3. Results

The main results related to the outcomes and presented by study period are depicted in Table 1.

The hospital reported 637 medication errors in 2013 (pre-automation) and 871 in 2017 (post-automation), with the same proportion of errors occurring between the periods.

Table 1
Characteristics and outcome results by study period.

Outcome/characteristic	Study period: Pre-automation (2013) N (%)	Study period: Post-automation (2017) N (%)	RR (95% CI)
Hospital beds, *N*	369	469	–
Medications dispensed, *N*	3,245,051	4,796,341	–
Medication errors, *N (%)* *	637 (0.019)	871 (0.018)	0.92 (0.83–1.02)
Medication errors by phase, *N (%)* *			
Prescription	168 (26)#	135 (15) #	**0.54 (0.43–0.68)**
Request	14 (2) #	22 (3) #	1.06 (0.54–2.08)
Distribution	230 (36) #	284 (33) #	**0.84 (0.70–0.99)**
Preparation	48 (8) #	86 (10) #	1.2 (0.85–1.73)
Administration	177 (28) #	344 (39) #	**1.31 (1.1–1.6)**
Severity of errors in the distribution phase, *N (%)* *			
None	557 (87) #	800 (92) #	**1,05 (1.01–1.09)**
Mild	60 (9) #	56 (6) #	**0.68 (0.48–0.97)**
Moderate	10 (2) #	14 (2) #	1.02 (0.46–2.29)
Severe	10 (2) #	1 (0.1) #	**0.07 (0.01–0.57)**
Delays in drug delivery/month *N (%)* *	195 (0.36) *	283 (0.62) *	0.98 (0.82–1.18)
Returns of delivered drugs/month	45,146	41,548	**–**
Breakages and losses in the drug batches dispensed	15,085 (0.46)	4624 (0.10)	**0.21 (0.20–0.21)**
Pharmacy professionals involved in the dispensing process	48	59	–
Total overtime paid/year	R$ 26,798.82; USD 16,281.18&	R$ 4327.35; USD 2183.32&	–

CI- confidence interval; R$- Brazilian reais; RR: risk ratio; USD- United States dollars. *Frequency based on the total medications dispensed; #Frequency based on the total medication errors; &Converted to USD by using purchasing power parity, as estimated by the Organization for Economic Co-operation and Development (OECD), allowing comparisons across different periods [https://eppi.ioe.ac.uk/costconversion/default.aspx].

The proportion of errors changed over each delivery phase (prescription, request, preparation, distribution, or administration), and in 2013, 230 (36%) adverse events occurred during the drug distribution phase, 177 (28%) in drug administration, and 168 (26%) in prescription. In 2017, the number of adverse events was 284 (33%) in distribution, 344 (39%) during drug administration, and 135 (15%) in prescription; the other errors occurred in the preparation or request phase. After the use of ©Swisslog, there was an observed reduction in errors in the prescription and distribution phases, whereas the errors in the administration and preparation stages increased (Table 1). More than 80% of errors were classified as no damage, 554 (87%) in 2013 and 800 (92%) in 2017, and in the distribution phase, no event was classified as a moderate or severe error. The number of errors related to the distribution phase increased in the periods analysed, with 230 notifications in 2013 and 284 notifications in 2017. However, as the hospital had an increase in the number of beds and the number of medications dispensed, regarding the number of errors in the distribution stage and the occurrence of events, the ©Swisslog (2017) post-automation period actually had a significant reduction in the occurrence of errors in the distribution phase, with a lower rate of dispensing errors in the post-automation period than in the pre-automation period (RR 0.84; 95% CI 0.70 to 0.99). Additional impacts included greater control and reductions in losses and breakages of medicines, in expired drugs and products, and in the need for overtime by the central pharmacy team. However, there was an increase in the frequency of batches being delivered late.

4. Discussion

The present study shows that the implementation of the PillPick® and BoxPicker® robots in the central pharmacy had an impact on inventory management, reducing the frequency of breakages and losses of medicines and the number of expired medicines and products. Moreover, in the period after the introduction of the robots, there was a reduction in overtime pay for the central pharmacy team.

Another important result of our study was the reduction in the frequency of errors in the prescription and distribution phases after automation was introduced in the central pharmacy.

The proportion of total errors that occurred during the two periods of our study did not change, but a higher proportion of no-harm and a lower proportion of severe errors were observed in the distribution phase during the automation phase.

In the dispensing phase of our study, there was a reduction in the number of medications returned or reversed. However, there was an increase in the frequency of batches being delivered late. This result includes the time until arrival at the patient's bed, and therefore, this increase may be related to the increase in the number of beds, the lack of definition of rules and the lack of training in the medication administration scheduling process.

The review by Batson et al. on the automation of hospital pharmacies[7] included 46 primary studies conducted in Europe (14 studies), the USA (17 studies), Australia (4 studies), Brazil (one study),[10] Thailand (one study)[14] and Lebanon (one study).[15] Regarding the technology assessed in these studies, 21 of them did not report the system used, and the others did not use ©Swisslog Healthcare robotic systems. Our results corroborate the data from this review, which reported that the benefits following the implementation of automatization in pharmacies included reductions in medication errors, medication administration time, and costs.[7]

Concerning medication errors, a French study carried out in a prison unit using the same systems (PillPick®, ©Swisslog) reported potential medication errors, *i.e.*, detected and corrected, of only 0.5% relative to the total number of error opportunities, mainly due to wrong delivery orders.[15,16] In our study among the 4,796,341 medication dispensed, we observed confirmed medication errors amounting to 0.018%.

This study has limitations because it is retrospective, and analyses secondary data obtained from the hospital information system.

Despite these limitations, the preliminary results of this study contribute to the body of evidence indicating that the use of the PillPick® and BoxPicker® robots centralizes the dispensing process, brings benefits in reducing losses, prevents the distribution of expired medicines, offers greater safety in the process and reduces the time that the pharmacy dedicate to inventory management.

5. Conclusion

This study reported the implementation of an automated system in the central pharmacy of a private hospital in Latin America. The preliminary results suggest that the use of robotic systems in this setting may improve hospital pharmacy management and generate fewer errors in dispensing pharmaceuticals to patients.

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Ethical approval

We submitted the project to Research Ethics Committee. The protocol was approved by the Research Ethics Committee of the Sociedade Beneficente de Senhoras Hospital Sírio-Libanês (CEPesq/HSL, registration number: 3.641.612).

Authors' contribution statement

Conception and design: AMB, DC, JLAB

Data curation/collection: DCMFC, AMB

Formal analysis: AMB, RR Funding acquisisition/ Investigation: JLAB Methodology: AMB, RR Project administration: AMB, JLAB, DCMFC Resources/ Software: DCMFC writing original draft: AMB, RR, JLAB

Writing-review editing: AMB, DCMFC, JLAB, RR.

Final approval: all authors.

All authors approved the version to be submitted for publication.

Declaration of Competing Interest

The authors declare no competing financial interests related to this manuscript.

References

1. Aldhwaihi K, Schifano F, Pezzolesi C, Umaru N. A systematic review of the nature of dispensing errors in hospital pharmacies. Integr Pharm Res Pract 2016;5:1-10. https://doi.org/10.2147/IPRP.S95733.
2. Baker GR, Norton PG, Flintoft V, et al. The Canadian adverse events study: the incidence of adverse events among hospital patients in Canada. CMAJ 2004;170:1678–1686. https://doi.org/10.1503/cmaj.1040498.
3. Wittich CM, Burkle CM, Lanier WL. Medication errors: an overview for clinicians. Mayo Clin Proc 2014;89:1116–1125. https://doi.org/10.1016/j.mayocp.2014.05.007.
4. Ahtiainen HK, Kallio MM, Airaksinen M, Holmström A-R. Safety, time and cost evaluation of automated and semi-automated drug distribution systems in hospitals: a systematic review. Eur J Hosp Pharm 2020;27. https://doi.org/10.1136/ejhpharm-2018-001791.253 LP – 262.
5. Cousein E, Mareville J, Lerooy A, et al. Effect of automated drug distribution systems on medication error rates in a short-stay geriatric unit. J Eval Clin Pract 2014;20:678–684. https://doi.org/10.1111/jep.12202.
6. Fanning L, Jones N, Manias E. Impact of automated dispensing cabinets on medication selection and preparation error rates in an emergency department: a prospective and direct observational before-and-after study. J Eval Clin Pract 2016;22:156–163. https://doi.org/10.1111/jep.12445.
7. Batson S, Herranz A, Rohrbach N, Canobbio M, Mitchell SA, Bonnabry P. Automation of in-hospital pharmacy dispensing: a systematic review. Eur J Hosp Pharm Sci Pract 2021;28:58–64. https://doi.org/10.1136/ejhpharm-2019-002081.
8. Giménez E, Reynold S, Espallargues M. Evaluación del impacto económico, organizativo y de la seguridad de la dispensación robotizada de fármacos en hospitales en España. Catalunya: Agència de Qualitat i Avaluació Sanitàries de Catalunya. Ministerio de Sanidad, Consumo y Bienestar Social; 2019.
9. Chapuis C, Bedouch P, Detavernier M, et al. Automated drug dispensing systems in the intensive care unit: a financial analysis. Crit Care 2015;19:2011–2015. https://doi.org/10.1186/s13054-015-1041-3.
10. De-Carvalho D, Alvim-Borges J, Toscano C. Impact assessment of an automated drug-dispensing system in a tertiary hospital. Clinics 2017;72:629–636. https://doi.org/10.6061/clinics/2017(10)07.
11. Swisslog. Swisslog Healthcare. https://www.swisslog-healthcare.com/ 2022. (accessed March 3, 2022).
12. Santos TR, Penm J, Baldoni AO, Ayres LR, Moles R, Sanches C. Hospital pharmacy workforce in Brazil. Hum Resour Health 2018;16:1. https://doi.org/10.1186/s12960-017-0265-5.
13. World Health Organization (WHO). The Conceptual Framework for the International Classification for Patient Safety (ICPS)Final Technical Report January 2009. 2010. https://doi.org/10.1109/AERO.2013.6496891. 1.1:154.
14. Noparatayaporn P, Sakulbumrungsil R, Thaweethamcharoen T, Sangseenil W. Comparison on human resource requirement between manual and automated dispensing systems. Value Heal Reg Issues 2017;12:107–111. https://doi.org/10.1016/j.vhri.2017.03.007.
15. Hitti EA, Lewin 3rd JJ, Lopez J, et al. Improving door-to-antibiotic time in severely septic emergency department patients. J Emerg Med 2012;42:462–469. https://doi.org/10.1016/j.jemermed.2011.05.015.
16. Le Gonidec P, Diallo ML, Djoussa-Kambou S, Guizard M. Performances d'une solution associant l'automate de délivrance Pillpick® au logiciel de prescription Pharma® utilisée pour une activité de dispensation à délivrance nominative dans une unité de consultation et de soins ambulatoire. Ann Pharm Fr 2009;67:84–90. https://doi.org/10.1016/j.pharma.2008.12.004.