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Assessing the Impact of Automated Dispensing Systems on Medication Safety and Workflow Efficiency in Hospital Pharmacies

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Abstract

This study evaluated the impact of Automated Dispensing Systems (ADS) on medication safety and workflow efficiency in hospital pharmacies. A quasi-experimental design was employed, comparing pharmacy operations before and after the implementation of ADS in a tertiary care hospital. Data were collected from 50 pharmacy staff members and secondary data on medication errors and workflow efficiency, with operational metrics such as dispensing time, error rates, and prescription processing rates. The results indicated a 77.1% reduction in medication errors, with significant improvements in the accuracy of drug dispensing, dosage, and labeling. Additionally, workflow efficiency was enhanced, with dispensing times reduced by an average of 7.4 minutes per prescription, and the number of prescriptions processed per hour increased by 60%. Paired t-tests, regression analysis, and ANOVA tests were used to analyze the data, revealing that ADS adoption led to measurable improvements in both safety and efficiency. The study further found that pharmacist training and system readiness were critical factors in maximizing these benefits. These findings suggest that ADS technology can significantly improve medication safety by reducing errors and enhancing workflow, offering valuable insights for hospitals considering the implementation of automated systems. This research fills a gap in existing literature by providing empirical data on the specific impact of ADS on different types of medication errors and by offering a comprehensive analysis of both operational metrics and staff perceptions.

Introduction

Medication safety and effective Pharmacy operation is fundamental to the delivery of healthcare services especially in hospital Pharmacies. Towards this end, WHO states that medicine safety is now a high priority health care agenda since drug related errors are a cause of substantial morbidity and mortality worldwide. It is common these errors result from manual activities, communication threads and human interventions in the course of dispensing of medications within pharmacies. There may be weakness in the operational flow of products in hospital pharmacies; hence, enhancing time in delivery of marketed products, compact workload for healthcare givers, and poor care of patients. Therefore, pressure is mounting on healthcare systems worldwide to finding ways of delivering medicines effectively while containing costs; ADS is one technology that health systems have turned to meet these needs.

Advanced Drug Delivery Systems or Automated Dispensing Systems intended to store, dispense and monitor, has turned into a revolutionary concept in contemporary hospital pharmacy. These systems seek to increase medication safety through decreasing the human element that is often associated with dispensing processes and optimize work processes. Therefore, according to the preliminary investigations, problems of medicinal errors, stock, and personnel can be solved by properly functioning ADS that can reserve much time of workers for clinical work. Nevertheless, as will be exhibited in the various snapshots of how

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implementing ADS has been embraced across different organizations, the efficiency has not been very encouraging and this warrants more research on the actual effects of the ADS on prudent functioning of hospital pharmacy.

The subject of medication safety is as important as the air that we breathe. A medication error involves improper dosing and administration, wrong drugs, and omitted doses bear significant risk that prove unrelenting in healthcare systems. These mistakes not only affect patients' lives, but also have large costs to the health care system (Van et al., 2021; Javaid et al., 2022). Adverse drug events cause more than seven thousand deaths every year in the United States and cost over $40 billion. The same is true in the developing nations where the situations could even be worst due to limited resources to deal with complications that emanate from the mistakes. Ensuring medication safety is, as such, one of the best strategies to enhance patient success besides cutting overall healthcare costs.

Structural efficiency in hospital pharmacy departments is yet another problem area. Dispensing methods previously used entail extensive human effort in matters regarding selection of medicine, labeling of medicine containers and documentation which takes time and is often associated with errors and delays (Ashour et al., 2022; Holden et al., 2021; Bermúdez et al., 2021). Some processes compromise the timely delivery of medication while others increase the cross over time; the effects in terms of staff productivity and morale decreased with resultant bottom-line impacts on patient care quality (Holden et al., 2021). With regard to these weaknesses, ADS provide a possibility to overcome these inefficiencies by freeing up pharmacists' time to contribute more to activities that have greater added-value, such as giving advice to patients and making clinical decisions (Morgan & Zane, 2022).

Incorporation of ADS has been attributed to vast gains particularly in the aspect of medication safety. Oliveira et al. (2021) showed the benefits of using concentration control in a hospital pharmacy, 60% reduction of dispensed errors evidenced that ADS can significantly reduce human error. According to Glide et al. (2021), ADS contributed to optimal implementation of safe practices of medication handling as a prerequisite to improve overall safety. The current study is complemented by meta-analyses, proving that ADS are characterized by decreased error rates compared to conventional methods of manual documentation (Cummings et al., 2022).

Apart from improving safety, researchers have recorded that the use of ADS has a positive impact on workflow. A study done by Zheng et al. (2021) showed that implementation of ADS made dispensing of medications 30% faster so that more time is available for the other tasks including the direct interface with patients and clients. In another study done by Penny et al. (2021), they too opined that ADS helped in proper stock control; less stock-out and minimized wastage of medication. These operational advantages do not only enhance the working processes in the facilities of pharmacy; they save costs of various health facilities (Svoboda et al., 2021).

This paper also identifies certain challenges that are associating with the implementation of ADS. Some Integrated Management of Surgical Artifacts include implementing high initial costs, difficultly in affecting employee change, and technical problems that slow down efficiency of the integrated systems (Ahmad et al., 2021). The study done by Yoon & Kim (2024) revealed that the effect of ADS on pharmacy operations may be conditionality by the size of the hospital, the degree of development of the pharmacy's drug stock, and the provided level of staff training. These contextual factors explain the rationale for performing an evaluation of ADS implementation results in different healthcare organizations.

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This research proposes to add to the literature on ADS by analysing its effect on medication safety and pharmacy productivity in hospitals. In line with the objectives of this study, it is therefore important to use quantitative research approach with a view of establishing the degree to which ADS can enhance efficient solutions to the challenges of medication errors as well as the inefficiency of work flows. In light of these assumptions, the knowledge generated in this study should advance understanding of the factors influencing the acceptance of automated medication dispensing systems amongst hospital pharmacists, and contribute to decision-making by hospital administrators, policymakers, and pharmacy practitioners toward deploying best practices in healthcare settings.

Method

This research work adopted a post-operation survey quantitative research approach in order to assess the effect of ADS on safety of medications and health care staffs' productivity within the hospital pharmacy environment. Carried out in a tertiary health facility setting, the study targeted Pharmacy and the processes in place both before and after ADS. This design allowed a formal assessment of changes in operational performance which made it easier to identify variables related to manual and automated dispensing. While assuming a quasi-experimental research design, the study offered valuable information about ADS in enhancing the flow of work in pharmacies.

Participants of this study were hospital pharmacy employees, specifically pharmacists, pharmacy technicians, support staff, as well as secondary data on the functioning of the pharmacy and medication error rates. Convenience sampling was used in this study because an attempt was made to only select participants who frequently engage in dispensing duties. The sample comprised 50 respondents with 25 of them employing manual dispensing before the use of ADS and the other 25 who used the system after its integration. This approach allowed for coverage of both phases to determine the level of ADS impact adequately.

The two main activities used in data collection were cross-sectional questionnaires and contrast questionnaires. Firstly, self-completed, validated questionnaires were used to gather the pharmacy staff's perceptions of ADS when optimising the role in increasing efficiency and/or decreasing error rates. The questionnaire consisted of closed-ended questions, that were answered on a 5-point Likert scale from Strongly Disagree to Strongly Agree. Second, related operational data, medication errors, time required to dispense the prescription and number of prescriptions filled per hour were obtained from the records of the hospitals. These data were collected for six months both before and after the implementation of the program to ensure both phases were well represented.

Survey and Operational data collection instrumentations used were standardized. The survey instrument was developed based on previous frameworks that have been utilised in other research on opera tions of the pharmacy (Baysari et al., 2016; Chapuis et al., 2016). A pilot test of the questionnaire was conducted with 10 participants to assess the reliability a of the questionnaire was found to have a Cronbach's alpha value of 0.87 thus depicting high internal reliability. Measures of operation were obtained from the hospital pharmacy management information system since it offered reliable details in relation to dispensing time and error frequency. The written records of these measures were then cross-checked with the logs created using the automated system, thereby confirming the result.

The study adopted descriptive along with inferential analysis to understand the gathered data. Analysis of numerical data involved descriptions about average and standard deviation and frequency distribution tables. The medication error rates and dispensing time data analysis used weighted paired t-tests between pre-ADS and post-ADS periods. The researchers conducted

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regression analysis to understand ADS's impact on workflow productivity at the same time ANOVA analyzed survey participant groups consisting of pharmacists and technicians to check their response patterns. The combination approach between qualitative and quantitative work delivered a complete understanding of ADS consequences on performance and safety achievements.

Result and Discussion

Medical institutions increasingly embrace Automated Dispensing Systems (ADS) which proves itself as an accurate method to enhance both medication safety and delivery system performance in hospital pharmacies. The primary benefit ADS provides to extensive healthcare systems stems from its ability to reduce manual workflow tasks and enable better error prevention in medicine dispensary procedures. The study investigated the ADS impacts on medication safety together with operational efficiency after it was installed at a tertiary care hospital. This research section details how medication errors responded alongside work flow analysis and staff perceptions and hospital operational workflow effects following ADS deployment.

Table 1. Summary of Medication Errors Before and After ADS Implementation

Medication Error Type	Pre-Implementation (Manual)	Post-Implementation (ADS)	Percentage Reduction (%)
Wrong Drug Dispensed	25	5	80%
Incorrect Dosage	30	8	73.3%
Wrong Patient Labeling	15	3	80%
Total Medication Errors	70	16	77.1%

Table 1 summarizes the types and frequencies of medication errors before and after the implementation of ADS. The findings show a substantial reduction across all error types, with an overall 77.1% decrease in total medication errors.

Table 2. Dispensing Time per Prescription (in Minutes)

Phase	Mean Dispensing Time (SD)
Pre-Implementation	15.2 (±3.4)
Post-Implementation	7.8 (±2.1)
Difference	7.4

Table 2 highlights the average dispensing time per prescription before and after ADS implementation. The data indicate a significant improvement, with the mean dispensing time reduced by 7.4 minutes, suggesting enhanced workflow efficiency.

Table 3. Number of Prescriptions Processed per Hour

Phase	Average Prescriptions Processed
Pre-Implementation	25
Post-Implementation	40
Percentage Increase	60%

Table 3 displays the average number of prescriptions processed per hour in each phase. ADS implementation led to a 60% increase in processing capacity, reflecting its positive impact on operational efficiency.

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Table 4. Survey Responses on Workflow Efficiency

Survey Item	Mean Score (Pre)	Mean Score (Post)	Difference
Reduced time per prescription	2.3	4.5	+2.2
Improved task coordination	2.8	4.4	+1.6
Decreased workload stress	3.0	4.2	+1.2
Enhanced overall workflow	2.7	4.6	+1.9

The changes in workflow efficiency were investigated by pharmacy staff who provided their mean survey responses as shown in Table 4. Organizational staff members recorded substantial rises in their evaluations for all assessment elements which demonstrated better operational effectiveness.

Table 5. Regression Analysis of ADS on Workflow Efficiency

Variable	β Coefficient	Standard Error	p-value
ADS Implementation	0.65	0.08	0.0001
Staff Training Level	0.35	0.12	0.002
Pre-existing Technology Use	0.12	0.10	0.07

The research analysis in Table 5 illustrates ADS implementation together with other variables as predictors that affect workflow efficiency. Analysis showed that ADS implementation served as the main efficiency factor with a β coefficient of 0.65 and a p-value at 0.0001.

Table 6. ANOVA Results for Survey Responses Among Staff Groups

Group	Mean Score	F-Value	p-value
Pharmacists	4.5	5.12	0.01
Pharmacy Technicians	4.2		
Support Staff	3.8		

Table 6 shows the ANOVA results that evaluate survey feedback between different staff groups. Pharmacists demonstrated the highest levels of workflow efficiency according to the data analysis findings which yielded statistically significant group distinctions ($p = 0.01$). Staff members hold diverse opinions regarding how ADS affects their workflows according to their respective duties.

This study observed a 77.1% overall reduction in medication errors, which underscores the significant role of Automated Dispensing Systems (ADS) in enhancing patient safety. By breaking down error reductions into specific categories such as wrong drug dispensing (80%), incorrect dosages (73.3%), and patient labeling errors (80%) this research provides granular insights into how ADS addresses vulnerabilities in manual dispensing. Previous studies have highlighted the generic role of automation in reducing errors. Documented a general decrease in medication errors post-automation but did not delve into error subtypes. This study bridges this gap by showing that barcode verification and double-check systems integrated within ADS are particularly effective in reducing labeling and dosage errors, areas prone to human oversight (Chu et al., 2024).

Moreover, while studies such as those by Ng et al. (2021) suggested that automation could occasionally introduce system-based errors, this study found no evidence of such issues during the observation period. This finding is significant as it highlights the importance of a robust implementation strategy, including thorough system testing and staff training, to mitigate risks.

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These results reinforce the need for technology-driven workflows in high-volume hospital settings, where the risk of human errors escalates under pressure (Pappas et al., 2022; Ammu, 2023).

The study's findings reveal a substantial improvement in workflow efficiency, with dispensing time per prescription reduced by 7.4 minutes and prescription processing rates increasing by 60%. These results reflect a transformational shift in pharmacy operations, echoing conclusions drawn in earlier studies such as Pundir et al. (2024), which highlighted ADS as a catalyst for enhancing operational throughput. However, unlike prior research, this study integrated survey data with operational metrics, offering a comprehensive perspective on efficiency improvements. Pharmacists perceived the most significant gains in task coordination (mean score: 4.5 on a 5-point Likert scale), emphasizing their critical role in overseeing and optimizing workflows.

This dual approach of combining quantitative metrics with subjective insights strengthens the argument for ADS adoption, particularly in facilities struggling with high workloads and staff burnout. Similar findings were reported by El Baraka et al. (2024) where ADS significantly improved task alignment among pharmacy staff. Integrating ADS allows pharmacies to reallocate human resources to more value-added activities, such as patient counseling and clinical decision-making (Yussof et al., 2022). These secondary benefits, though less quantifiable, underscore the holistic impact of automation on workflow dynamics.

Existing literature often provides qualitative insights into the benefits of ADS but lacks the robust statistical analysis needed to quantify its effects. This study addressed this gap by employing paired t-tests, regression analysis, and ANOVA to provide a rigorous evaluation of ADS outcomes. For instance, while Rhodes et al. (2022) acknowledged that automation improves dispensing accuracy, they did not quantify error reductions or explore variations across error types. This study advances the field by offering precise statistical data on error reductions and associating these improvements with specific ADS features, such as real-time alerts and integrated verification protocols.

Additionally, the role of staff training as a critical factor in successful ADS implementation has been recognized but rarely quantified. By identifying training level as a significant predictor of workflow efficiency ($\beta = 0.35$, $p = 0.002$), this study provides empirical support for the need to prioritize training during ADS deployment. Who emphasized that effective staff education reduces resistance to technological change and enhances system adoption. However, this study extends their conclusions by quantifying the impact of training on operational outcomes, making a stronger case for comprehensive, role-specific training programs.

From a theoretical standpoint, the findings validate technology acceptance models (TAM) within healthcare settings, demonstrating that perceived ease of use and usefulness of ADS correlate with tangible improvements in safety and efficiency. This extends the work of Bryan & Zuva (2021), who proposed TAM as a framework for understanding technology adoption, by providing empirical evidence specific to hospital pharmacies. Assertion that successful technology adoption depends not only on system features but also on user engagement and institutional readiness.

The significant reductions in dispensing times and error rates offer actionable insights for healthcare administrators and policymakers. With operational metrics demonstrating a 60% increase in prescription processing rates, ADS adoption could serve as a scalable solution to address inefficiencies in high-volume hospital pharmacies. This study underscores the importance of addressing human factors, such as user training and staff perceptions, to maximize the benefits of automation.

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Conclusion

The study demonstrated ADS systems in hospital pharmacies produce merits for both medication safety and operational efficiency. The newly installed ADS system cut down healthcare risks and delivered improved operational outcomes because the system facilitated faster medication dispensing and reduced dispensing errors. Our evidence shows that the implementation of ADS systems successfully addressed operational issues and created a safer medication setting because it eliminated human mistakes. The data confirms both the significance of technological applications in pharmacy practice today and demonstrates the requirement for staff training in combination with ongoing optimization of hospital ADS to fulfill automation objectives in healthcare.

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