RESEARCH ARTICLE

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Enhancing Medication Safety: Reducing Administration Errors in Oncology Setting

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Abstract

Purpose: This project aimed to minimize medication errors and improve safe medication administration in an oncology setting in Muscat, Oman. **Methods:** The study, spanning from the second quarter of 2022 to the first quarter of 2023, employed a one-group pretest-posttest quasi-experimental design, assessing key performance indicators (medication error and medication administration errors rates per 1000 patient days) on quarterly basis before and after implementing targeted interventions. Interventions focused on medication management processes and Healthcare Informatics System (HIS), Environment and equipment, and Education The project utilized the FOCUS PDCA (find, organize, clarify, understand, select, plan, do, check and act) methodology. Ethical clearance was obtained from the Institutional Review Board. **Results:** The results showed significant reductions were observed in both medication error and medication administration error rates following the implementation of interventions. Specifically, the medication error rate decreased from 12.59 in the Second Quarter of 2022 (pre-intervention) to 5.26 in the Fourth Quarter of 2023 (post-intervention), with an overall ANOVA F-value of 9.2950 ($p = 0.035$). Similarly, the medication administration error rate declined from 5.39 to 1.29 over the same period, resulting in an ANOVA F-value of 8.2320 ($p = 0.044$). **Conclusion:** The study indicates a significant improvement in patient safety outcomes following the intervention implementation, underscoring the effectiveness of the interventions in reducing medication errors and administration errors.

Keywords: Medication errors- Medication administration- Oncology setting- SQCCRC- Oman- FOCUS PDCA

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Introduction

Medication errors (MEs) represent a significant issue in healthcare, defined as avoidable incidents that can lead to inappropriate medication use or patient harm. MEs can occur at various stages of the medication process, including prescribing, order communication, labelling, packaging, nomenclature, compounding, dispensing, distribution, administration, education, monitoring, and use. These errors are not confined to healthcare professionals alone but can also involve patients or consumers [1-3]. The World Health Organization (WHO) highlights the economic impact of these errors, estimating the annual cost of medical errors to be around 42 billion US dollars [4].

Medication administration errors (MAEs) are a particular subset of medication errors and represent a significant global concern. Research indicates that nearly half of MAEs in clinical practice are preventable, and around 5% of these errors result in fatalities. In critical care units, 19% of MAEs are life-threatening, and 42% require additional life-sustaining therapy [5]. These types of errors are also more likely to cause severe injury or fatalities compared to other medication errors.

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The prevalence of MAEs has been estimated to range between 19-27%, including various mistakes such as dose omission, wrong administration route, incorrect dosage, lack of documentation, incorrect timing, administration to the wrong patient, wrong medicine, and technological issues [1, 2].

To address the challenge of MAEs, researchers and medical experts have established fundamental guidelines for safe medication administration. These guidelines encompass the six rights of medication administration: the right patient, the right drug, the right dose, the right route, the right time, and the right documentation. By rigorously adhering to these six rights, healthcare professionals can significantly reduce the occurrence of drug administration errors. This approach is crucial in ensuring patient safety and effective treatment outcomes [6, 7].

Administering medication in oncology settings is fraught with challenges due to the complexity of cancer treatment regimens and the high toxicity of many cancer drugs. Patients often require intricate treatment plans that include a variety of therapies such as chemotherapy, targeted therapy, and immunotherapy, along with supportive care medications [8, 9]. These plans demand precise administration, timing, and sequencing, significantly raising the risk of errors. Additionally, the narrow therapeutic range of many cancer drugs means that even minor deviations in dosage or administration can have serious adverse effects [8, 9].

The consequences of medication errors in oncology settings can be profound, given the high toxicity of many cancer treatments and the vulnerable health of these patients. Adverse drug reactions can range from minor side effects to life-threatening conditions. Incorrect medication administration can lead to either under-treatment or over-treatment, affecting the efficacy of the cancer treatment and potentially altering the patient's prognosis. In some cases, such errors may result in prolonged hospital stays, increased healthcare costs, and, in extreme situations, fatalities. The psychological impact on both patients and healthcare providers is also significant, potentially leading to diminished trust in the healthcare system and increased stress and anxiety. Therefore, ensuring accurate and safe medication administration in oncology is critical for patient safety and the effectiveness of cancer treatment [8, 9].

Sultan Qaboos Comprehensive Cancer Care and Research Center (SQCCCRC) is a Joint Commission International (JCI) accredited cancer centre in Muscat, Oman. The centre opened its doors to outpatients in August 2021 and inpatients around December of the same year. As a new centre running for the highest international hospital standards, improving medication safety remains at the heart of quality measures.

Our interventions were therefore selected to target these specific oncology-related challenges. By implementing strategies focused on error prevention and process optimization within high-risk stages such as prescription verification, administration protocols, and monitoring procedures we aimed to reduce the likelihood of medication errors in this critical patient population. This approach underscores our commitment to improving patient safety in oncology, where the consequences of even minor medication errors can be disproportionately severe.

Therefore, this study aims to identify and analyze MAEs in an oncology setting. It delves into the various factors contributing to these errors, ranging from prescription complexities to the challenges in administering highly potent drugs. Moreover, by identifying and addressing the root causes of these errors, this project aims to propose strategies and implement solutions to minimize the rate of MEs. Furthermore, the study contributes to the knowledge in oncology nursing and healthcare administration, providing insights that can be applied to improve clinical practices and develop more effective medication administration protocols.

Materials and Methods

Setting

The project was conducted at the in-patient setting in Sultan Qaboos Comprehensive Cancer Care and Research Centre (SQCCCRC), University Medical City, Muscat, Oman. The timeframe for the study spanned from the second quarter of 2022 through to the first quarter of 2023.

Design and analysis

A one-group pretest-posttest quasi-experimental project was utilized to evaluate the impact of targeted interventions on key performance indicators (KPIs) within the medication administration process, particularly concerning the stages of medication management, including ordering, transcribing, dispensing, administration, monitoring, and reporting.

The goal was to monitor and compare the KPIs before and after the implementation of the interventions to determine their efficacy [10-13] . The study included all medications administered during the project duration for the calculation of these indicators.

The sample cohort was assessed during two timeframes: before the introduction of interventions (pretest) and after their implementation (posttest). This method permitted the observation of changes directly associated with the project's initiatives without the need for a control group. The primary objective was to ascertain if the interventions led to a tangible improvement in the medication administration error and the rate of medication errors.

Focus PDCA approach

Project execution was composed using the FOCUS PDCA (find, organize, clarify, understand, select, plan, do, check and act) framework, illustrated in Table 1 [14-15]. Medication errors and Medication administration error rates per 1000 patient days were used as measures to identify the impact of interventions.

Finding and selecting critical areas for improvement (Find Phase)

During the second quarter of 2022, MEs were found to be the second highest type of errors reported via the SQCCCRC incident reporting (IR) system with 14% of all IRs concerning medications. The calculated rates of MEs and MAEs were 12.59 and 5.39 per 1000 patient

Table 1. FOCUS PDCA Approach Elucidated

Find: Identifying critical areas for enhancement within the medication administration process.
Organize: Composing a team tasked with improving the quality of the medication management and administration process.
Clarify: Analyzing the current process of medication administration to have an objective understanding of the process to recognize the risks and barriers.
Understand: Revealing the process variation and what might be the root cause of medication administration errors and medication errors.
Select: Formulating recommendations for improving the process of medication administration to boost the comprehensive efficacy.
Plan: Planning for the implementation of solutions by developing a "SMART" action plan that stands for specific, measurable, achievable, relevant, and time-bound for enhancing the process of medication administration.
Do: Implementing these action plans within the stages of medication management.
Check: Measuring the efficacy of interventions by collecting data and comparing the actual outcomes against the projected results of the key performance indicators.
Act: Incorporate and implement the adjusted strategies after optimizing the critical results based on the analyzed data and feedback.

days, respectively.

Organizing the team (Organize Phase)

The project was executed by huddling a multidisciplinary team encompassing experts from diverse departments, which comprised the pharmacy, nursing, informatics and cyber security, quality and accreditation, and physicians.

Clarifying the situation (Clarify Phase)

This study delineated a comprehensive process diagram, depicting the cyclic nature of medication management in five distinct stages. Initially, the cycle commences with a healthcare provider ordering and prescribing the medication. The subsequent stage involves transcribing and verifying the prescribed medication, ensuring accuracy and appropriateness. In the third stage, the medication is dispensed and delivered to the appropriate department, ready for administration. The fourth stage is the actual administration of the medication to the patient, a critical step in this cycle. The final stage entails monitoring the administered medication and vigilantly reporting any drug reactions or adverse effects that might occur (Figure 1).

Additionally, a detailed flow chart outlining the current medication use process at SQCCCRC was developed. This process begins with obtaining the best possible medication history upon patient admission in inpatient settings. Concurrently, examination results are reviewed to address any concerns. Following this, a privileged healthcare provider places a medication order. This order then undergoes a reconciliation process where home medications are compared with newly ordered medications, identifying and resolving any discrepancies. The validation step, performed by a pharmacist, is pivotal, ensuring the drug's appropriateness in terms of dose, frequency, route of administration, and checking for therapeutic duplication, allergies, potential interactions, and other contraindications.

The process continues with a check for medication availability in the center, either from the floor's automated dispensing cabinet (ADC) or via the Cartfill process from the pharmacy. Cartfill refers to the process of filling medication carts with the prescribed doses for patients, usually done in a centralized pharmacy setting. This process involves preparing and organizing individual patient medications in advance, often on a daily or weekly basis, to ensure accurate and timely delivery to each patient care area [1-2].

After dispensing and accurate labeling, the medication undergoes a verification process, especially for high-alert medications, which require an independent double check. Only after completing the six medication administration rights will the staff administer the medication to the patient.

In instances where required home medication is unavailable at the healthcare center, a pharmacist collects it as the patient's own medication, ensuring proper storage conditions and correct labeling, including auxiliary labels. This medication, particularly if classified as a narcotic or high-alert drug, undergoes rigorous storage protocols and additional independent double checks before administration. Narcotics are stored in a secured drugs cabinet, while non-narcotics are kept in a special medical computer cart, Capsa. This meticulous approach underscores the importance of accuracy and safety in medication administration within the healthcare setting.

However, the team identified critical barriers present in the medication administration process. Table 2 outlines the critical barriers.

Table 2. Critical Barriers in the Medication Administration Process

Theme	Critical barriers
Ordering	·* High number of prescribing errors.
Validation	·* Medications administered before validation.
Patient own medication	·* Lack of patient awareness of own medication process, so patients refused to hand in home meds upon admission.
Dispensing from Automated dispensing Cabinet 'ADC' (out)	·* ADC fridge items are taken directly without logging to Omnicell and barcode-scanning of the medication.
	·* ADC opened without any action carried out on the ADC.
	·* Not completing the return process on the ADC
Preparation- patient care unit	·* Not using alcohol swabs to wipe vial top or ampoule neck.
	·* No visual inspection of preparation after mixing.
	·* Not wearing gloves
	·* No double-checking for high-alert medication during preparation (narcotic)
	·* No reference checking for compatibility of reconstitution fluid
	·* Wrong dose calculation (e.g.; dexamethasone)
	·* Stainless Steel trolleys not used for preparation

Understanding the root causes (Understand Phase)

To gain a comprehensive understanding of the reasons behind the challenges and obstacles faced within the medication administration process, the "Understand Phase" was initiated. During this phase, a systematic approach was employed, leveraging the Fishbone (Ishikawa) diagram tool as a central method to identify the underlying causes contributing to the identified issues as illustrated in Figure 2.

Selecting area improvement strategy and developing the plans and implementing them (Select, Plan, Do phases)

Evidence-based improvement strategies were selected based on previous studies (Cottel et al, 2020; [12, 16-20, 21-26], followed by the development of operational plans. Please refer to the table below (Table 3).

To operationalize medication safety improvements, specific actions were implemented across key areas in the oncology setting. For Processes and Staff, physicians are tasked with daily medication chart reviews to prevent issues like double orders and to re-evaluate held medications. Consultation teams make real-time adjustments to medication orders as needed, and both physicians and nurses are directed to regularly check pharmacists' notes and intervention messages to stay updated on any changes. Nurses are required to

Table 3. Improvement Areas and Operational Plans for Quality Improvement

Area	Implemented action Plan
Processes and Staff	*Perform a daily review of medication charts by physicians to improve prescribing practices (particular attention to avoiding double orders, re-assessment of held orders …etc.) * Consultation/referral teams to make changes to medication orders as per their plan. * Physicians should read pharmacists' notes and pharmacists' intervention messages regularly * Nurses should receive and finalize events in the HIS (mandatory for supply/re-supply and availability of medications). * Review available and functioning templates on HIS and delete wrong templates. * Revise nurses' workflow on the preparation of high-alert medications as the witness cannot be identified.
Healthcare Informatics System (HIS)	*Revise the default end date for certain medications, e.g. antibiotics, and IV electrolytes. * Make medication administration charts accessible to physicians. * Add a search filter/tool on medication orders. * Change HIS logic for continuous infusions to appear daily in the nursing chart. * Combine medication administration and finalization processes in one click (especially for oral medications).
Environment and equipment	*Follow up on new (bigger) fridges purchased by the center with the biomedical department. * Re-organize the medication room and refrigerator
Education	* Educate physicians and nurses on common errors and incidents. * Educate physicians on the appropriate use of available medication templates. * Educate physicians and nurses on SMAT (standardized medication administration time) policy to optimize administration times. * Conduct multidisciplinary team education with the HIS * Organize medication management and safety courses for nurses periodically. * Emphasis on patient and family education

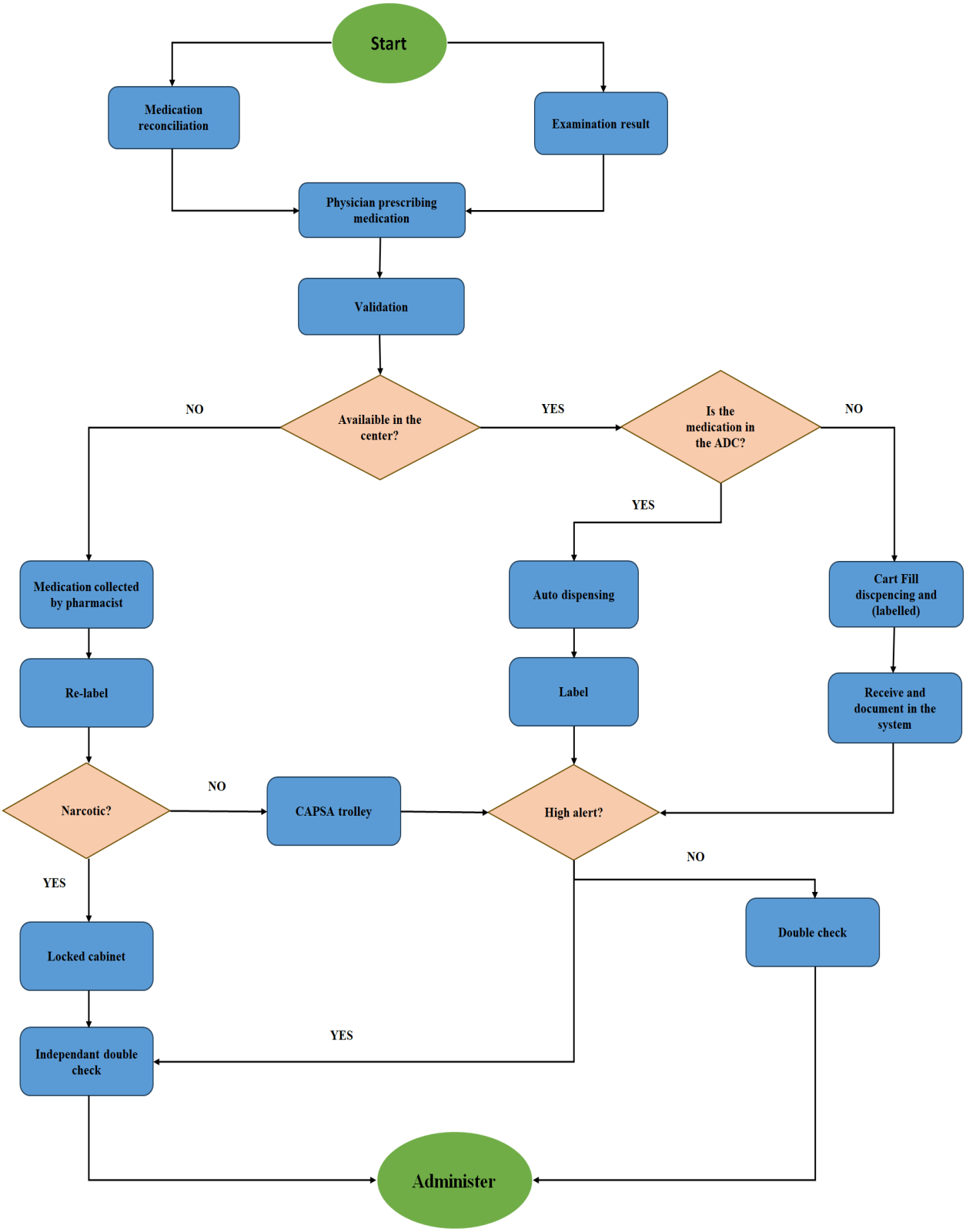

Figure 1. Process Flow Chart of Medication Administration

acknowledge and complete tasks in the Health Information System (HIS) to ensure medication supply and availability, with a review process for templates in the HIS to remove any incorrect or outdated options. Additionally, the nursing workflow for preparing high-alert medications was revised to ensure accountability and verification, especially where witness identification might be challenging.

In the Healthcare Informatics System (HIS), several functionality enhancements were made. The default end dates for critical medications like antibiotics and IV electrolytes were adjusted to align with clinical best practices. Physicians now have direct access to medication administration charts, and a search filter was added to streamline order retrieval. HIS logic was modified so

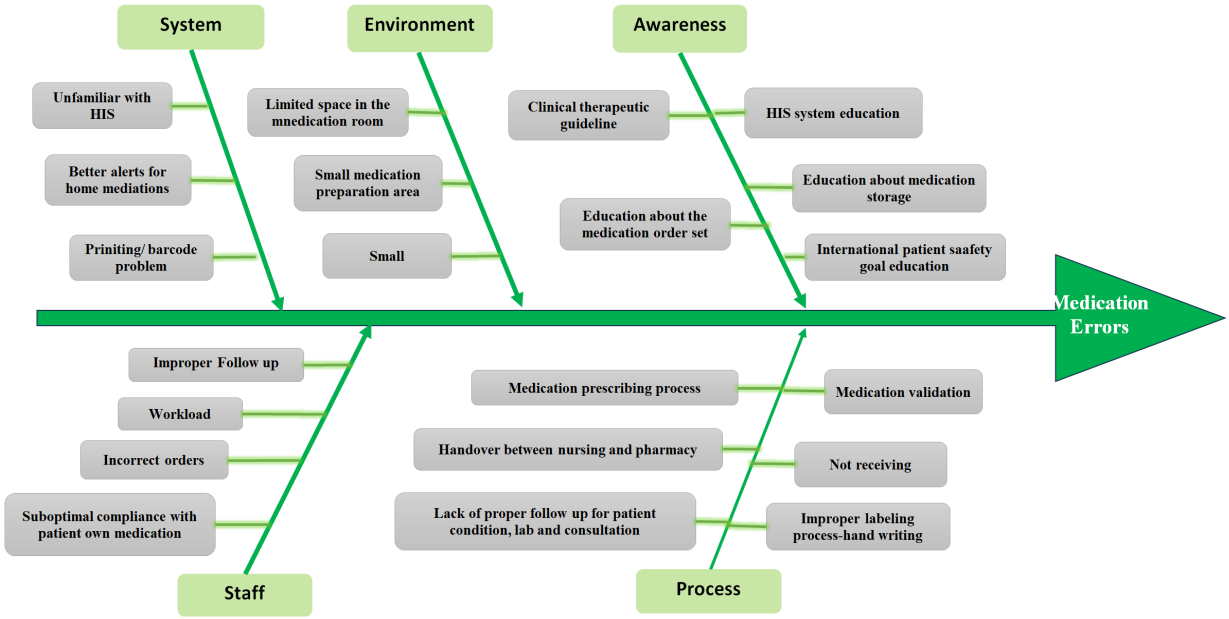

Figure 2. Fish Bone Diagram for Medication Errors for Root Cause Analysis

Table 4. Pre- and Post-Intervention Medication Administration Rates

	Rate of medication error per 1000 Patient Days	Rate of medication administration errors per 1000 Patient Days
Second Quarter 2022 (pre-intervention)	12.59	5.39
Third Quarter 2023 (post-intervention)	7.26	1.81
Fourth Quarter 2023 (post-intervention)	5.26	3.04
First Quarter 2023 (post-intervention)	5.69	1.29
F (P value)	9.2950(0.035)	8.2320(0.044)

that continuous infusions appear daily on the nursing chart, and the process for administering and finalizing oral medications was combined into a single-click action to reduce processing time and potential errors. For Environment and Equipment, the medication room and refrigerators were reorganized to improve accessibility, and new, larger fridges were installed with the support of the biomedical department.

To sustain these changes, a robust Education Program was implemented. Physicians and nurses received targeted training on common errors, SMAT (Standardized Medication Administration Time) policies, and proper use of HIS medication templates. Multidisciplinary team sessions were conducted to reinforce teamwork and safe practices in medication administration. Regular medication safety courses for nursing staff and dedicated patient and family education sessions were introduced to ensure that everyone involved understands and actively participates in medication safety processes.

Data Analysis

SPSS version 23 was used. Average mean was used to measure the pre and post intervention data. ANOVA and p value were conducted to measure the differences in the results and show the effectiveness of intervention.

Ethical Considerations

Institutional review board approval was obtained from the Research Office at Sultan Qaboos Comprehensive Cancer Care and Research Centre (SQCCCRC), Muscat, Oman (CCCRC-55-2023) for the improvement projects. The project adhered to all relevant ethical guidelines and standards set forth by the institution, including maintaining confidentiality, and protecting the rights and welfare of all staff and patients. The guidelines emphasize the importance of conducting research with integrity, transparency, and respect for human dignity.

Results

The study investigated the impact of an intervention on medication errors and medication administration errors in a healthcare setting, as depicted in Table 4.

Prior to the intervention, during the second quarter of 2022, the rate of medication errors per 1000 patient days was recorded at 12.59, with a rate of medication administration errors at 5.39 per 1000 patient days. Following the implementation of the intervention, notable reductions were observed in both types of errors. In the third quarter of 2023, the rate of medication errors decreased to 7.26 per 1000 patient days, while medication administration errors decreased to 1.81 per 1000 patient days.

This trend of decline persisted in the fourth quarter of 2023, where the rate of medication errors further decreased to 5.26 per 1000 patient days, although there was a slight increase in medication administration errors to 3.04 per 1000 patient days.Similarly, during the first quarter of 2023, the rate of medication errors continued to decrease to 5.69 per 1000 patient days, with medication administration errors decreasing to 1.29 per 1000 patient days.Statistical analysis revealed significant differences in both the rate of medication errors ($F = 9.2950$, $p = 0.035$) and the rate of medication administration errors ($F = 8.2320$, $p = 0.044$) pre- and post-intervention.

Discussion

This study employed the FOCUS PDCA framework to systematically address medication errors (MEs) within the SQCCCRC. By utilizing a one-group pretest-posttest quasi-experimental design, we provided a structured approach to evaluate the interventions' effectiveness. The design allowed for a detailed analysis of key performance indicators (KPIs) before and after implementation, revealing a significant reduction in error rates. This outcome highlights not only the effectiveness of the quality improvement strategy but also its clinical relevance, as reducing MEs directly translates into fewer adverse events and improved patient outcomes in oncology care [1-3].

Our study revealed a high prevalence of pharmaceutical prescription errors, often due to difficulties in navigating the recently implemented Health Information System (HIS). In an oncology setting, where patients bring non-cancer medications upon admission for monitored administration, such errors pose significant clinical risks [1-3].

One particular issue identified was the premature administration of medications without adequate validation. This mirrors findings in other studies, where inadequate validation contributes to medication administration errors and adverse drug interactions [1, 3]. By implementing a modified validation process and improving patient education on medication transfer protocols, we strengthened medication safety procedures, creating a more reliable process that aligns with real-world challenges in oncology [1-3].

We introduced an Incident Reporting (IR) system to address the regulatory gaps and reinforce best practices. This system proved instrumental in capturing error patterns and enforcing compliance, a critical factor in oncology where medication accuracy is paramount. Additionally, to address the HIS challenges, we made modifications to enhance its usability such as adjusting preset drug expiration dates, optimizing continuous infusion handling, and simplifying the medication delivery process. These changes are aligned with recommendations in existing literature and have a practical impact on reducing human error, improving the system's compatibility with oncology workflows, and supporting a safer administration process [22-25].

The study also focused on challenges related to Automated Dispensing Cabinets (ADCs), where skipped log entries and incomplete return operations posed significant risks. Our intervention included strict adherence to ADC standards and comprehensive staff training, in line with best practices in healthcare settings. This approach is critical in oncology, where even minor errors in dispensing can have severe consequences due to the potency of the drugs involved. Ensuring precise and effective ADC usage aligns with broader healthcare safety practices and addresses real-world issues in medication management [16-18].

Issues in medication preparation methods were also identified, such as failures to use alcohol swabs, inconsistent visual inspections, and inaccurate dose estimations for high-alert drugs, particularly opioids. In response, we implemented a double-check system and standardized preparation protocols, ensuring that preparation adhered to safety standards. These measures not only enhance medication accuracy but also provide a practical safeguard against potential overdoses or underdoses, which are particularly critical in high-risk oncology treatments [16, 18].

We recognized the importance of infrastructure on medication safety, leading us to propose improvements in medication storage facilities. Effective storage and refrigeration technologies are essential for maintaining medication efficacy, especially in oncology where drug potency can impact treatment outcomes. By enhancing storage and accessibility, we reduced the risk of administering expired or improperly stored drugs, an improvement with direct clinical implications in reducing adverse reactions [19].

Education was a cornerstone of our intervention strategy, with continuous training for healthcare staff on common errors, HIS use, and adherence to prescription administration standards. Additionally, patient and family education was emphasized to foster a comprehensive approach to medication safety. This focus on education not only reduces immediate errors but also instills a culture of safety, empowering patients to engage actively in their care. In oncology settings, where treatment regimens are complex and patient compliance is crucial, this educational component has a long-term impact on both patient safety and treatment efficacy [16, 27].

However, the study had limitations. Variability in implementing the operational strategies across different oncology settings due to diverse resources, staff expertise, and patient demographics was a concern. Reliance on self-reported data from healthcare providers could introduce biases. The study also didn't monitor the long-term sustainability of the changes, though this is now managed through a drug-related incident reporting mechanism.

The study's applicability was limited to a specific cancer setting, and it lacked a thorough exploration of the patient perspective, essential for a complete understanding of medication safety and administration. Despite these limitations, the study has significant implications for future research and practice in healthcare, particularly in cancer medication management. It underscores the importance of a comprehensive approach that includes process optimization, technology improvements, environmental changes, and ongoing education.

Future research should focus on longitudinal studies to assess the sustainability of the changes and expand to various healthcare settings to evaluate the generalizability of the findings. Exploring the patient perspective in medication safety is another vital area for future research, as patient involvement is crucial for the success of any healthcare intervention. The study also highlights the potential of healthcare informatics systems in enhancing medication safety, suggesting further technological advancements and integrations as a promising area for research.

In conclusionm, this study demonstrates that implementing a structured quality improvement framework significantly reduces medication errors in an oncology setting. For future research, we recommend exploring the scalability of the FOCUS PDCA approach across other high-risk departments, such as intensive care, to assess its broader impact. Additionally, studies examining long-term outcomes of Incident Reporting (IR) systems could offer insights into the sustainability of error reduction strategies. Further research could also investigate advanced HIS enhancements, such as AI-driven predictive analytics, to proactively identify and address potential error points.

Practically, healthcare facilities could benefit from optimizing HIS functionalities related to drug tracking, enforcing strict ADC protocols, and mandating double-check systems for high-alert medications. Enhancing storage infrastructure and developing ongoing education programs for both healthcare providers and patients are essential for fostering a culture of safety. These targeted measures provide a clear pathway for sustaining medication safety improvements and reducing adverse events in high-risk oncology environments.

Author Contribution Statement

Supervision of the Whole Project: Bushra Mustafa Salman, Omar Ayaad, Khalid AlBaimani. Department Supervision: Amna Khamis AlHashar, Huda Shinoon AlAwaisi. Implementing the FOCUS PDCA Approach and Interventions: Bushra Mustafa Salman, Omar Ayaad, Rawan Ibrahim, Manal Salim AlHatrushi, Rawan Ibrahim, Razzan Al Zadjali, Zainab Abdullah AlTobi, Sara Ali AlSheidi, Ghalia Mubarak AlHasani, Mohamad Hussein Majed, Sara Ali AlSheidi, Abier Atabani, Nabiha Said AlHasni, Malouk Nasser AlMusheifri. Data Collection and Curation: Bushra Mustafa Salman, Mohamed Ibrahim El Kholy, Omar Ayaad, Rawan Ibrahim. Manuscript Preparation and Review: Bushra Mustafa Salman, Omar Ayaad, Rawan Ibrahim. Project Administration: Bushra Mustafa Salman, Omar Ayaad. Investigation and Visualization: Bushra Mustafa Salman, Omar Ayaad.

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Data Availability Statement

The datasets generated and analyzed during this study are available from the corresponding author on reasonable request.

Scientific Approval

The study proposal underwent review and approval by the research committee at the Sultan Qaboos Comprehensive Cancer Care and Research Centre (SQCCCRC) in Muscat, Oman.

Ethical Declaration

Institutional Review Board (IRB) approval for conducting and publishing the project was obtained from the research office at the Sultan Qaboos Comprehensive Cancer Care and Research Centre (SQCCCRC) in Muscat, Oman.

Conflict of Interest

The authors declare no conflicts of interest regarding the publication of this manuscript.

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