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(REVIEW ARTICLE)

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Assessing ward system changes to mitigate medication administration errors: A comprehensive systematic review of interventional studies

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Abstract

Background and aim: Medication administration errors are any deviation from the medication order specified by the prescriber on the patient's chart, specifically relating to the process of administering the medication to the patient. It is estimated that between 18.7% and 56% of all adverse events in hospitalised patients are attributable to preventable medication errors. The aim of this review was to assess the efficacy of nursing staff based ward system change interventions to reduce MAEs in in-patient settings.

Methods: This review adhered to PRISMA guidelines and conducted an electronic search across PubMed, Scopus, Embase, and Cochrane Library using keywords related to nursing interventions and medication administration errors. The search, limited to English-language records, excluded commentaries, editorials, and non-research articles. After screening titles and abstracts, we included randomised and non-randomized clinical trials and other interventional studies focused on ward-based system changes for reducing medication administration errors. Studies involving educational or technology-based interventions, simulations, or observational methods were excluded, as were those with incomplete data on Medication administration errors. Data extraction covered study details, intervention types, and impacts on Medication administration errors reduction.

Results: Out of 655 initial records, 46 were screened, and nine studies were included in the review. Most studies (five) were from the USA, with durations from 2 to 47 months, and focused mainly on single institutions. Key findings include: reduction in IV infusion errors through standardisation of doses and training; improved medication accuracy via safety processes and leadership training; a 52% reduction in Adverse Drug Events with quality improvements; however, mixed results with a "Safe Zone" protocol; decreased MAEs by 56.4% with comprehensive bundles of interventions; no significant change was found with recall cards and cross-checking; 90% compliance was achieved with two-person

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verification for infusion pumps, reducing errors; error rates were cut by over 56% with multiple improvements; and no significant impact was shown with "Do not interrupt" vests.

Conclusion: The evidence supporting interventions aimed at reducing medication administration errors (MAEs) in hospital settings is limited. However, significant improvements in MAE rates have been observed with ward system change interventions. These findings should be approached with caution, as many studies did not employ optimal study designs or data collection methods, and were subject to potential bias.

Keywords: Ward System Changes; Medication Administration Errors; Intervention; Systematic Review

1. Introduction

Medication administration errors (MAEs) are any deviation from the medication order specified by the prescriber on the patient's chart, specifically relating to the process of administering the medication to the patient [1]. Studies have reported administration error rates of around 10% when using observational techniques, which are considered the most effective method for assessing the prevalence of such errors [2, 3]. It is estimated that between 18.7% and 56% of all adverse events in hospitalised patients are attributable to preventable medication errors [4]. When medication errors occur, they can lead to a range of issues for patients, from minor discomfort to severe morbidity. In some cases, these errors may result in longer hospital stays or, in some instances, mortality [5].

The World Health Organization (WHO) estimated that medication errors cost approximately $42 billion annually worldwide, representing 0.7% of total global health expenditures [6]. In response to this, the WHO launched a global initiative in 2017 with the goal of reducing medication errors by 50% within five years [7]. The administration of medications is a multifaceted process that includes counting, calculating, measuring, and mixing, all while ensuring that the correct medicine is given to the right patient, in the right dose, at the right time, via the right route, and for the right reason [8]. Each step in this process carries potential for error. The complexity is further increased by factors such as polypharmacy, the severity of patient conditions, interruptions, electronic technologies, facility design, time constraints, and the myriad of policies and procedures governing medication administration [9].

Various interventions have been designed to reduce medication errors. These include professional interventions such as nurse training and education, the use of safety vests, and double-checking medications. Organisational interventions encompass the computerization of hospital medical systems, including automated delivery systems and barcode-assisted medication administration systems [10]. Ward system changes are a subcategory of the professional interventions that include modifying medications delivery system to reduce MAEs. The aim of this review was to assess the efficacy of nursing staff based ward system change interventions to reduce MAEs in in-patient settings.

2. Methods

This review was conducted adhering to the Preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines [11]. An electronic database search was performed in four online databases; PubMed, Scopus, Embase, and Cochrane library. The search was performed using various keywords related to the topic of this review, namely; “Nurses”, “Nursing staff”, “Healthcare providers”, “Nursing interventions”, “Educational programs”, “Training”, “Protocols”, “Checklists”, “Technology-based interventions”, “Medication administration errors”, “Drug administration errors”, “Medication safety”.

Various Boolean operators were used to connect these keywords. Additionally, Mesh-terms and other database specific filters were used to identify relevant records. The search was confined to English language records only. Moreover, commentaries, editorials, letters, conference proceedings were excluded. After identifying relevant records, they went through the title and abstract screening, following that the preliminary included records were retrieved and assessed for eligibility. We included randomised and non-randomised clinical trials and other interventional studies that assessed the impact of utilising ward based system changes in reducing the rate of MAEs. studies utilising educational and technology based interventions were excluded as well as simulations and observational studies. Furthermore, studies with incomplete reported data regarding MAEs were excluded from this review.

After identification of the included studies, a data extraction sheets was prepared to extract information related to; study country, design, aim and objectives, duration, type of departments in which the interventions were conducted, medical staff included in the studies, outcome measures and management tools, ward system change interventions applied, and their impact in terms of reducing MAEs.

3. Results and discussion

A total of 655 records were identified through the electronic search. Of them 46 records remained after the title and abstract screening phase. These full texts of these 46 records were assessed for eligibility to be included in the review and after the assessment nine studies were included in this review, figure 1 demonstrates the study selection process. Five out of the nine studies were from the United states of America. Moreover, four of them had a pre and post interventional study design following quality improvement methodology, and two of them were cluster randomised controlled trials. The duration varied among the included studies ranging from 2-47 months. The number of participating institutions also varied, with the majority including a single institution, table 1 shows characteristics of the included studies.

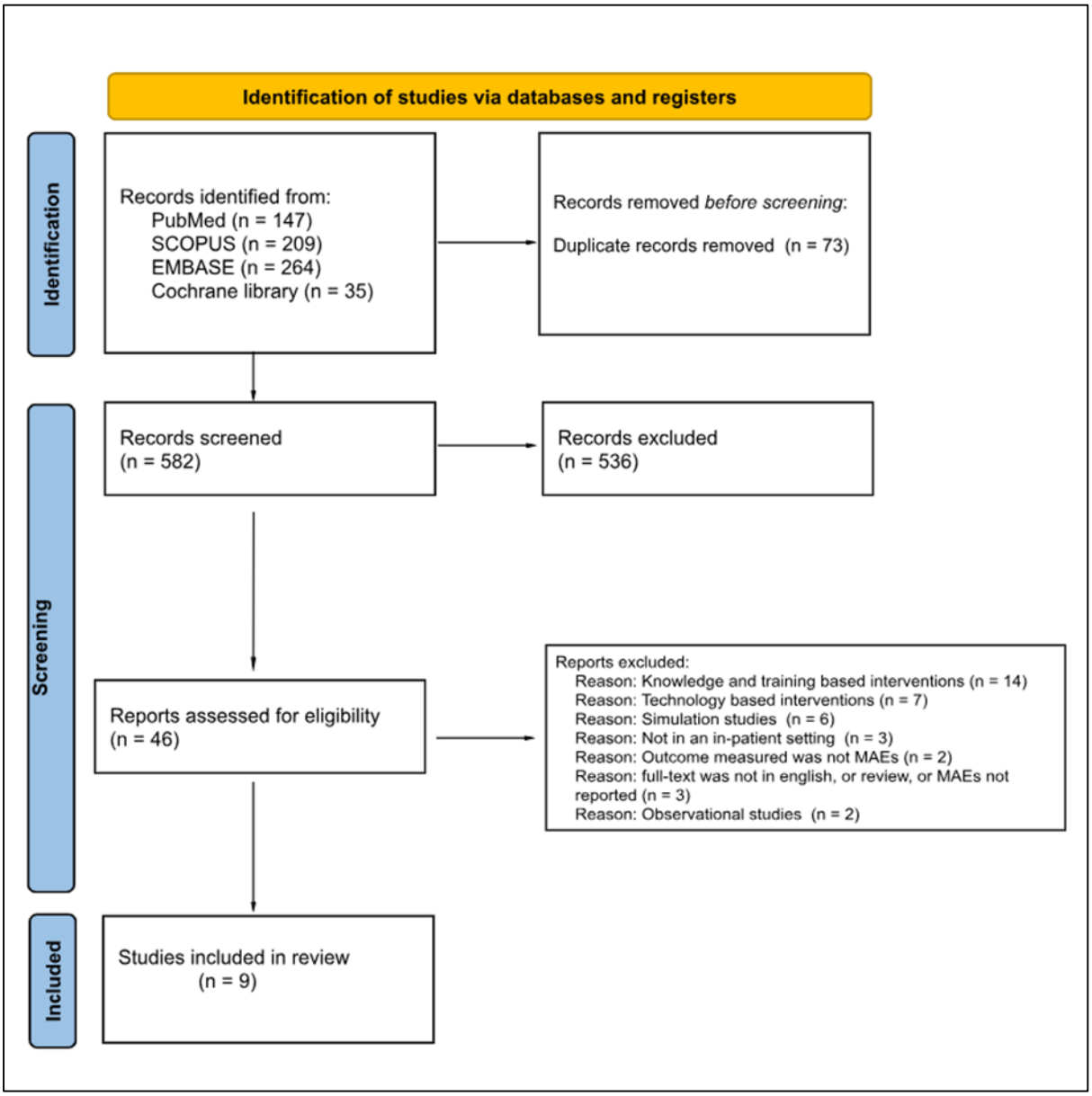

Figure 1 PRISMA flowchart of the study selection process

Table 1 Characteristics of the included studies. MAEs: medication administration errors, RCT: randomised controlled trial

Study	Country	Design	Study duration	Number of participating institutions	Depart-ment	Definition of MAEs
Bullock 2006 [12]	USA	Pre-post interventional	2 months	one	Medical	The text does not provide a specific, detailed definition, however it included errors due to Improper Dose and Drug Concentration
Kliger 2009 [13]	USA	Quasi-experimental	18 months	seven	medical/ surgical	MAEs were defined and classified into several categories based on deviations from the prescribed medication regimen. These categories included:Unauthorised Drug, Wrong Dose, Wrong Form Wrong Route, Wrong Technique, Extra Dose, Omission, Wrong Time, and Drug Not Available.
Mcclead 2014 [14]	USA	Quasi-experimental	47 months	one	Medical /surgical	No specific definition but included errors related to the "five rights" of medication administration (right patient, right drug, right dose, right route, and right time), as well as errors in the use of infusion pumps, bar-code scanning
Yoder 2015 [15]	USA	Pre-post interventional	10 months	one	medical	Were defined based on reported errors in the hospital event reports and included: Failures to press the start button on infusion pumps. Wrong drug or dose compared with what was ordered. Wrong time for administration. Medication reconciliation failures.
Zhou 2015 [16]	China	Pre-post interventional	42 months	one	Medical /surgical	were defined as any deviation from the physician's order, hospital policies, or standard practices during the medication administration process. This included: wrong dose, medication, time, route, omissions, and unauthorised drugs.
Johnson 2016 [17]	Australia	Cluster RCT	2.4 months	two	Medical /surgical	were defined as: Omissions: Regular medications that were not administered within 1 hour of the scheduled time. Documentation Issues.
Subramanyam 2016 [18]	USA	Pre-post interventional	6 months	one	surgical	An error occurred when an infusion pump was used for a patient, and an error in

						programming was identified and rectified.
Alomari 2020 [19]	Australia	Pre-post interventional	36 months	one	medical	were defined as any deviation from the physician's order, hospital policies, or standard practices during the medication administration process. This included: wrong dose, medication, time, route, and omissions
Berdot 2021 [20]	France	Cluster RCT	5 months	four	Medical /surgical	defined as an ordered medication dose (administered or not) or an unordered dose administered to a patient

In some studies MAEs were not directly defined, however in general most of the studies referred to MAEs as any deviations from the prescribed medication protocol, including; wrong dose, medication, time, route, omissions, and unauthorised drugs. Five of the studies were conducted in both medical and surgical units in the hospitals, three were in medical departments and one in a surgical; department. Four of the studies included paediatric patients only, and three included adults only. Most of the studies were primarily focused on nursing staff, and included some of the others in the interventions, however three studies exclusively included nursing staff only.

Bullock et al study included Paediatric Intensive Care Unit (PICU) nurses and other staff aiming to determine whether the development and implementation of a standardised IV infusion concentration list reduces the variability of IV infusion concentrations used in the PICU and decreases the number of medication errors. The study measured two main outcomes, variation in IV Infusion concentrations which was evaluated by examining the percentage of IV infusions that deviated from standardised concentrations, both before and after the intervention. Data were gathered through direct observation and reports from nurses. It also assessed medication errors Involving Incorrect Dose and Concentration, and this outcome was assessed by comparing the percentage of medication errors related to incorrect dosing and concentrations before and after the intervention. These errors were tracked using the Medication Event Reporting System [12].

The intervention involved several key components. First, a standardised IV infusion concentration list was developed and implemented. This list included 27 commonly used IV medications, along with their typical dose ranges and standard syringe concentrations. The list was made easily accessible by placing it in patient bedside charts, on the hospital's forms portal, and on pocket-sized laminated cards for staff in the PICU. Second, intensive education and training were provided to the staff, along with personalised coaching and mentoring to ensure proper adherence to the new standards. Additionally, a guideline was created to clarify expectations and actions in cases where physician orders did not align with the standard IV infusion concentrations. The implementation of the interventions had a significant impact. The variability in IV infusion concentrations was reduced, with the percentage of infusions not using standardised concentrations dropping from 26% before the intervention to 13% afterward. There was also a notable decrease in medication errors related to improper dosing, with the rate falling from 52% pre-intervention to 25% post-intervention. Additionally, medication errors related to improper concentration were completely eliminated, decreasing from 23% before the intervention to 0% afterward [12].

Kliger et al study aimed to improve the reliability of medication administration in hospitals by developing nurse leadership and process improvement skills. The goal was to enhance the accuracy of medication administration through the implementation of specific safety processes and interventions. The study measured two main outcomes: medication administration accuracy and adherence to safety processes. Medication accuracy was assessed by comparing administered doses to prescribed ones, with errors categorised into types such as unauthorised drug, wrong dose, and omission. Adherence to safety processes involved compliance with six key practices, including verifying medication with the administration record, maintaining labelling, checking patient IDs, explaining the drug to the patient, charting immediately, and minimising distractions. Both outcomes were essential for evaluating improvements in medication safety and process reliability [13].

The study implemented six safety processes, including verifying medication with records, checking patient IDs, and minimising distractions. Leadership training and small-scale tests of change using PDSA cycles were conducted, along with intersession work and support from senior consultants to reduce medication administration errors. The study saw an increase in medication administration accuracy, improving from 85% at baseline to 92% at 6 months and 96% at 18 months. "Wrong technique" errors dropped significantly, while "wrong-time" errors increased proportionally. Adherence to protecting against distractions and interruptions rose from 60% to 84% over 18 months [13].

Mcclead et al study aimed to reduce harmful adverse drug events (ADEs) across a hospital system through the implementation of a quality improvement collaborative. This collaborative, known as the Adverse Drug Event Quality Collaborative (ADEQC), sought to develop and apply targeted interventions to minimise medication errors, particularly in critical care units, and later expanded to include all inpatient units, outpatient clinics, and urgent care centres. The outcome measures were (ADEs per 1000 Dispensed Doses, administration errors, Compliance with the ADE Prevention Bundle. measured using: Monthly chart audits, surveys, direct review for electronic medical records (EMRs) [14].

The study introduced independent double-checks for high-risk medications, smart infusion pumps with alerts, monthly safety audits, and Bar-Coded Medication Administration (BCMA). ADE huddles were also conducted after harmful events to review errors and identify improvements. The interventions led to a 52% reduction in Adverse Drug Events (ADEs), with the rate dropping from 0.17 to 0.04 per 1,000 doses. Additionally, the proportion of administration errors decreased from 55% to 38% of total ADEs, while prescribing errors increased from 32% to 52% [14].

Yoder et al study aimed to implement and evaluate a protocol designed to create a "Safe Zone" for medication preparation and administration. The protocol aimed to reduce medication administration errors by minimising distractions and interruptions during these critical tasks, modelled after the airline industry's "sterile cockpit" practice. The study measured outcomes using four tools: distractions and interruptions were assessed with a Medication Administration Distraction Observation Sheet, medication administration errors were tracked through hospital event reports, patient satisfaction was gauged using surveys, and adherence to the Safe Zone Protocol was evaluated via self-reports from nurses and student nurses [15].

The study implemented several interventions: designated quiet areas were created for medication preparation to minimise interruptions, staff received education and training, and participants wore vests or sashes labelled “Medication Rounds in Progress: Do Not Disturb” during medication administration. These Safe Zone interventions had mixed results. Although participants became more aware of distractions and interruptions, the rate of medication administration errors actually increased, rising from 1.74 to 2.88 errors per 1,000 patient days [15].

Zhou et al study objective was to reduce MAEs in inpatient nursing care through a series of interventions, including quality improvement tools, organisational measures, information technology measures, process optimization, and intensified human resource management and educational measures. The study sought to evaluate the impact of these interventions on the occurrence and types of MAEs, particularly focusing on high-alert medications, in the hospital. The primary outcome measured was the reduction in MAEs, assessed through direct observation and incident reporting systems [16].

The study implemented educational programs, standardised protocols, and technology like Electronic Medication Administration Records (eMAR) and Bar-Code Medication Administration (BCMA) systems. It also created "quiet zones" to minimise distractions, improved communication with structured handovers and team meetings, and conducted regular audits and feedback.as a result, the occurrence rate of MAEs made by nursing staff decreased by 56.4%, from 0.303% (109 out of 35,920 doses) to 0.132% (64 out of 48,397 doses) [16].

Johnson et al study aimed to evaluate the effectiveness of the "Recall and Check" intervention, which included nurse-initiated recall cards and cross-checking medication charts during handover, in reducing MAEs. The study measured omissions without documentation and the total omissions rate using audits of medication records. The study implemented several interventions: Nurse-initiated recall cards were used to notify patients if their medications were missed during their absence from the ward. Cross-checking of medication charts was required during nursing handovers to ensure accuracy. Additionally, education was provided on these interventions. The impact of the interventions showed no significant changes: Omission rates without documentation and overall omission rates did not differ significantly between the intervention and control groups, even after adjusting for patient age [17].

Subramanyam et al study aimed to improve the safety and accuracy of infusion pump programming in anaesthesia for radiologic imaging by implementing a 2-person verification process. The measures used included the proportion of two-person verification of infusion pump programming, assessed through standardised questionnaires and visual aids, and

tracking medication errors related to infusion pump medications, focusing on errors identified and corrected before administration. The interventions included education, visual aids such as stickers and reminder visuals, updates to the EMR for accurate documentation of two-person verification of infusion pump programming, and the integration of the two-person verification process into routine procedural timeouts. The interventions successfully achieved their goals: 2-person verification compliance increased from 0% to 90%, with this high level of compliance maintained throughout the study. Additionally, medication errors related to infusion pump programming were significantly reduced, with only four errors detected and corrected before affecting patients, demonstrating a marked improvement [18].

Alomari et al study aimed to improve medication administration practices and reduce medication administration errors in a specialised paediatric ward through a series of targeted interventions. The study measured several key outcomes to evaluate its impact. The primary focus was on reducing medication administration error rates, with data collected through the Incident Management System (IIMS) and calculated per 1,000 admissions and prescribed medications. Secondary outcomes included improvements in medication administration practices, assessed via audits of medication rounds. Additionally, staff safety awareness was gauged using the Safety Attitudes Questionnaire (SAQ) [19].

The study implemented several key interventions to improve medication administration. Mobile medication administration trolleys with computers were introduced to provide more space for medication preparation. Parental involvement was integrated into medication admission forms. Medication administration times were adjusted to two hours earlier, from 8 pm to 6 pm. Additionally, the medication policy was updated to include new sections focusing on family and patient engagement in the process. As a result, the study observed a significant decrease in medication administration error rates, with a reduction of over 56% from 2014 to 2016 per 1,000 patient admissions [19].

Berdot et al study aimed to evaluate the impact of a 'Do not interrupt' vest on medication administration errors and interruptions in the medication process. The primary outcome was the rate of medication administration errors, excluding wrong-time errors. These errors were identified by comparing medication prescriptions with observed data. The interventions included providing nurses in the experimental group with blue reflective safety vests labelled "Do not interrupt, I am preparing medication" and placing an informational poster at the unit entrances to explain the purpose of the vests. During the pre-intervention period, the administration error rates were 4.94% for the experimental group and 6.44% for the control group. In the intervention period, the rates were 7.09% for the experimental group and 6.23% for the control group. The difference in error rates between the experimental and control groups during the intervention period was not statistically significant ($p = 0.355$), indicating that the intervention vest did not impact medication administration error or interruption rates [20].

The diversity of outcome definitions used in studies reviewed has been identified as a factor affecting reported measures and complicating result comparisons. Additionally, the variability in the types of medication administration errors (MAEs) studied and whether error severity was assessed further contributes to this uncertainty. Direct observation is regarded as the most effective method for identifying medication administration errors (MAEs) because it captures a broader spectrum and greater number of errors compared to chart reviews and self-reports [21, 22]. This method is also less affected by the duration of observation or observer intervention [23].

The attitudes and experiences of front-line staff play a crucial role in the successful implementation of interventions, and these factors need to be evaluated more thoroughly [24]. While RCTs are generally preferred for evaluating interventions, they may not always be feasible for specific patient safety research questions or for assessing interventions implemented hospital-wide simultaneously [25]. It is now advised to identify potential barriers to change before planning an intervention. Tailoring interventions to these specific barriers is believed to be more effective than using a one-size-fits-all approach [26]. The complexity of the medication administration process necessitates employing a diverse array of quality improvement tools and methodologies to design effective interventions, while also considering local factors [27].

4. Conclusion

The evidence supporting interventions aimed at reducing medication administration errors (MAEs) in hospital settings is limited. However, significant improvements in MAE rates have been observed with ward system change interventions. These findings should be approached with caution, as many studies did not employ optimal study designs or data collection methods, and were subject to potential bias.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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