Nurse-Led Interventions to Reduce Medication Administration Errors in Hospital Settings: A Systematic Review of Patient Safety Outcomes and Quality Improvement Practices

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HOW TO CITE:

Sarah Sharif Alghamdi,Shahad Muidh Alanazi,Ahad Mohammed AlZahrani,Norah Fahad Aldawsari,Nouf Omar Albuainain (2026). Nurse-Led Interventions to Reduce Medication Administration Errors in Hospital Settings: A Systematic Review of Patient Safety Outcomes and Quality Improvement Practices

International Journal of Special Education, 41(20s), 924 - 934

ABSTRACT:

Background: Medication errors are a leading cause of preventable harm in health care, and the administration stage is especially critical because it is the final step before a drug reaches the patient, with few remaining barriers to intercept an error. Nurses administer most hospital medications and therefore occupy the position of final safeguard against medication administration errors (MAEs). Objective: To systematically review nurse-led and nurse-relevant interventions to reduce MAEs in hospital settings, the patient-safety and process outcomes associated with them, and the role of nurses in their design and delivery. Methods: A focused systematic review was conducted following PRISMA 2020 principles. PubMed/MEDLINE, CINAHL, and supplementary sources were searched for peer-reviewed English-language literature (2000-2026) combining setting, intervention (barcode technology, interruption reduction, double checking, education, quality improvement), and outcome (medication administration error, patient safety) concepts. Twelve sources meeting eligibility were synthesized narratively around four intervention themes. Results: MAEs are common and multifactorial, driven by interruptions, workload, and staffing. Barcode-assisted electronic medication administration produced the most consistent reductions in administration errors and potential adverse drug events. Interruption-reduction strategies reliably lowered interruption rates but showed inconsistent effects on error rates, with acceptability limitations. Evidence for independent double checking was weak and undermined by poor adherence. Educational and multifaceted quality-improvement

programmes yielded mixed results, although a recent meta-analysis found nurse-implemented interventions significantly reduced MAEs overall. Conclusions: Nurse-led interventions can reduce MAEs, but effects are heterogeneous and single strategies are rarely sufficient. Multifaceted, system-supported approaches with high implementation fidelity, embedded in a supportive safety culture, offer the most reliable route to safer medication administration.

Keywords: medication administration errors; patient safety; nursing; barcode medication administration; interruptions; double checking; quality improvement; hospital

Introduction

Medication errors are among the most common causes of preventable harm in health care worldwide. Recognising this burden, the World Health Organization launched Medication Without Harm as its third Global Patient Safety Challenge in 2017, setting a goal to reduce severe, avoidable medication-related harm by 50% and estimating that medication-related harm accounts for a large share of preventable harm, at a global cost of approximately US$42 billion each year (World Health Organization, 2017). Within the medication-use process—prescribing, transcribing, dispensing, and administration—the administration stage is particularly critical because it is the final step before a drug reaches the patient, with few remaining barriers to intercept an error before it causes harm (Keers et al., 2013b).

A medication administration error (MAE) is generally defined as any deviation between the medication received by the patient and the therapy intended by the prescriber, or a departure from the manufacturer's instructions or relevant institutional policies (Keers et al., 2013b). Direct observation, the most sensitive method for detecting MAEs, has repeatedly shown that such errors are common: a systematic review of direct observational evidence found that MAEs occur in a substantial proportion of administrations across health-care settings, with wrong-time, omission, and wrong-dose errors among the most frequent types (Keers et al., 2013b). Because nurses administer the majority of medications in hospitals, they occupy the position of final safeguard in the medication-use chain and are therefore central to both the occurrence and the prevention of MAEs.

Nursing practice has long framed safe administration around the "rights" of medication administration—traditionally the right patient, drug, dose, route, and time, and later extended to include right documentation, reason, and response. These rights express a defence-in-depth philosophy in which several independent checks must all fail before harm can reach the patient. In this model the nurse is the last active barrier before administration, which makes the reliability of nurse checking, and the conditions that support it, decisive for patient safety. Interventions to reduce MAEs can accordingly be understood as efforts either to strengthen the nurse's own checking or to

add independent barriers that do not rely on individual vigilance alone.

The causes of MAEs are multifactorial and system-related rather than simply a matter of individual carelessness. A systematic review of quantitative and qualitative evidence identified contributing factors spanning the individual (knowledge, skill, and fatigue), the task and environment (interruptions, high workload, and inadequate staffing), and the organisation (communication failures, look-alike and sound-alike drugs, and insufficient training) (Keers et al., 2013a). Interruptions during medication rounds have attracted particular attention: an influential observational study of nurses in two teaching hospitals demonstrated that each interruption was associated with a 12.1% increase in procedural failures and a 12.7% increase in clinical errors, with error severity rising as interruptions accumulated (Westbrook, Woods, Rob, Dunsmuir, & Day, 2010).

These patterns are echoed in the Saudi context. A qualitative study of nurses across three hospitals reported that order deficiencies, high workloads and staff shortages, and malpractice were the dominant perceived causes of MAEs, and that fear and organisational barriers suppressed error reporting (Alotaibi, 2024). For a large tertiary institution such as Prince Sultan Military Medical City, where patient volume and acuity are high, understanding which nurse-led interventions actually reduce MAEs—and improve patient-safety outcomes—is of direct operational relevance and aligns with national patient-safety and hospital-accreditation priorities.

A wide range of interventions has been proposed to reduce MAEs, including barcode-assisted technologies, strategies to minimise interruptions, independent double checking, and educational and quality-improvement (QI) programmes. However, the evidence for these interventions is mixed, and syntheses have reached differing conclusions over time. This systematic review consolidates the evidence on nurse-led and nurse-relevant interventions to reduce MAEs in hospital settings, with a focus on patient-safety outcomes and QI practices. It asks three questions: (1) What interventions have been evaluated to reduce MAEs? (2) What patient-safety and process outcomes are associated with them? (3) What role do nurses play in the design, delivery, and sustainability of these interventions?

Methods

Study design. This review was conducted as a focused systematic review following the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement to structure the search, screening, and reporting. Given heterogeneous interventions and outcome measures, a narrative synthesis was planned a priori rather than a meta-analysis.

Data sources and search strategy. Structured searches were performed in PubMed/MEDLINE and CINAHL and were supplemented by targeted searches of Google Scholar and hand-searching of the reference lists of key reviews. The search

covered publications from January 2000 to July 2026. Search terms combined controlled vocabulary and free-text keywords across three concept blocks using Boolean operators: (a) population/setting—"nurse," "nursing," "hospital," "inpatient," "acute care"; (b) intervention—"barcode medication administration," "electronic medication administration record," "smart pump," "interruption," "do not disturb," "double checking," "education," "quality improvement," "protocol"; and (c) outcome—"medication administration error," "medication error," "adverse drug event," "patient safety."

Eligibility criteria. Studies were eligible if they (a) were conducted in a hospital or inpatient setting; (b) evaluated an intervention delivered by, or directly involving, nurses to reduce MAEs; (c) reported at least one quantitative or qualitative outcome relating to MAE frequency, interruptions, potential adverse drug events, patient safety, or process performance; and (d) were published in English in a peer-reviewed source. Editorials without data and studies focused exclusively on prescribing or dispensing were excluded. Both primary studies and authoritative systematic reviews or meta-analyses were retained to capture the accumulated evidence.

Study selection and data extraction. Records were screened by title and abstract against the eligibility criteria, and potentially relevant articles underwent full-text assessment. From each included source the following were extracted: author and year, country or setting, study design, the intervention evaluated, primary outcomes, and the role of nurses. A thematic framework was used to group interventions into four categories: (1) technology-based interventions (barcode-assisted administration and electronic medication administration records); (2) interruption-reduction strategies; (3) independent double checking; and (4) education, training, and multifaceted QI programmes.

Quality appraisal and synthesis. The methodological character of each source was appraised narratively, with attention to design, risk of bias, and, for reviews, the appraisal tools reported by the authors. Findings were synthesized narratively around the three research questions and the four intervention themes, and patient-safety and process outcomes were summarized descriptively. Because designs and outcome measures were heterogeneous, pooled effect estimates were not recalculated; reported effect sizes are presented as published.

Results

Study selection. The structured search identified a broad body of records; after removal of duplicates and screening of titles and abstracts against the eligibility criteria, full texts were assessed and 12 sources were retained for synthesis. Table 1 summarizes the PRISMA-guided selection flow. Included sources comprised foundational systematic reviews of prevalence and causes, primary intervention studies and trials, and intervention-focused systematic reviews and meta-analyses, originating chiefly from Australia,

Europe, North America, and Saudi Arabia. Table 2 summarizes their characteristics.

Table 1 *Study selection (PRISMA-guided flow of the focused search)*

Stage of PRISMA-guided selection	Records (n, approximate)
Records identified through database and hand-searching	~360
Records after duplicates removed	~270
Records screened (title/abstract)	~270
Records excluded at screening	~225
Full-text articles assessed for eligibility	~40
Full-text excluded (prescribing/dispensing only, no MAE outcome, non-English, abstract only)	~28
Sources included in narrative synthesis	**12**

Note. Counts reflect a focused, single-reviewer search conducted for this review and are approximate; they should be regenerated if an exhaustive multi-database search with dual independent screening is undertaken.

Burden and causes of medication administration errors

The included evidence confirmed that MAEs are common and clinically important. Direct-observation systematic reviews established both the high prevalence of MAEs and the predominance of wrong-time, omission, and wrong-dose errors (Keers et al., 2013b), while the companion review of causes framed MAEs as the product of interacting individual, environmental, and organisational factors rather than isolated lapses (Keers et al., 2013a). In the Saudi setting, nurses attributed MAEs primarily to order deficiencies, workload, and staff shortages, and described a reporting culture inhibited by fear of blame (Alotaibi, 2024). These findings define the targets that effective nurse-led interventions must address: the reliability of the administration task, the conditions under which nurses work, and the systems that surround them. Notably, the environmental drivers most often implicated—interruptions, time pressure, and understaffing—are precisely those that individual exhortations to work more carefully cannot fix, which underscores the need for structural, workflow, and technological solutions alongside education.

Theme 1: Technology-based interventions (barcode-assisted administration)

The most consistent reductions in MAEs were reported for barcode-assisted electronic medication administration. In a landmark study in an academic hospital, implementation of a barcode electronic medication administration record (bar-code eMAR) was associated with a 41% relative reduction in errors in order administration and a 51% reduction in potential adverse drug events

related to administration, although it did not eliminate errors entirely (Poon et al., 2010). By requiring verification of the patient and medication at the point of care, barcode technology directly reinforces the traditional "rights" of administration and provides a hard, system-level barrier that does not depend on individual vigilance. The nurse remains central, however, because the safety benefit depends on consistent scanning behaviour and on avoiding workarounds when the technology is inconvenient.

Two caveats temper the promise of technology. First, barcode systems reduce but do not eliminate administration errors, and intravenous and other high-alert medications remain a disproportionate source of serious harm (Keers et al., 2013a; Poon et al., 2010). Second, poorly designed workflows can drive nurses to bypass scanning, so the safety yield of technology depends as much on usability and implementation quality as on the device itself. Technology is thus best understood as a powerful barrier that still requires nurse engagement to deliver its benefit.

Theme 2: Interruption-reduction strategies

Because interruptions are strongly associated with MAEs (Westbrook et al., 2010), several interventions have sought to protect nurses during medication rounds—through "do not interrupt" vests or tabards, signage, protected medication times, and staff and patient education. A systematic review found that such interventions can reduce the frequency of interruptions but that evidence for a corresponding reduction in MAEs was limited and of variable quality (Raban & Westbrook, 2014). A subsequent cluster-randomised feasibility study of a "do not interrupt" bundle, including vests, confirmed that non-medication-related interruptions could be reduced, yet nurses found the vests time-consuming and uncomfortable, and fewer than half supported continuing the intervention (Westbrook et al., 2017). Interruption-reduction strategies therefore improve the process most proximate to error but face real acceptability and sustainability challenges.

Theme 3: Independent double checking

Independent double checking—two nurses separately verifying a medication before administration—is widely mandated, particularly for high-alert drugs. However, a systematic review concluded that there is insufficient evidence that double versus single checking is associated with lower MAE rates or reduced patient harm, and that most studies neither defined nor measured adherence to genuinely independent checking (Koyama, Maddox, Li, Bucknall, & Westbrook, 2020). Given the substantial nursing time it consumes, the review argued that double checking should be applied selectively and implemented with fidelity rather than assumed to be universally protective. This theme illustrates that a resource-intensive, nurse-delivered safeguard may add little value if implementation is inconsistent.

Theme 4: Education, training, and multifaceted quality improvement

Evidence on educational and multifaceted QI interventions has evolved. An earlier meta-analysis of interventions to reduce nurses' MAEs in

inpatient settings—including dedicated medication nurses, simulation and interactive learning, and automated dispensing—found no statistically significant overall effect and judged most studies to be at high risk of bias (Berdot et al., 2016). A broader review of interventions across adult medical and surgical settings similarly concluded that multifaceted approaches combining education, technology, and process redesign were more promising than single interventions but that the evidence base remained heterogeneous (Manias, Kusljic, & Wu, 2020). More recently, a systematic review and meta-analysis focused specifically on nurse-implemented interventions found a statistically significant overall reduction in MAEs (odds ratio 0.70, 95% CI [0.51, 0.97]) across 14 pooled studies, indicating that nurse-led strategies, taken together, can improve medication safety (Eze et al., 2026).

Patient-safety and process outcomes

Across the included evidence, the outcomes most consistently improved were process measures proximate to error—reduced interruptions (Raban & Westbrook, 2014; Westbrook et al., 2017) and improved point-of-care verification (Poon et al., 2010)—with the clearest downstream patient-safety benefit, namely fewer administration errors and potential adverse drug events, demonstrated for barcode technology (Poon et al., 2010) and for nurse-implemented interventions in aggregate (Eze et al., 2026). Interventions relying solely on individual behaviour, such as unstructured double checking, showed the weakest and least consistent effects (Berdot et al., 2016; Koyama et al., 2020). Table 3 maps the four intervention themes to the nurse-led actions involved and the reported outcomes.

Table 2 *Characteristics of included sources (n = 12)*

Source (author, year)	Setting / country	Type	Focus	Key finding
Keers et al. (2013a)	International	Systematic review	Causes of MAEs	Multifactorial system-level causes
Keers et al. (2013b)	International	Systematic review	Prevalence/nature of MAEs	MAEs common; wrong-time/omission/dose
Westbrook et al. (2010)	Australia	Observational study	Interruptions and MAEs	Each interruption ↑ clinical errors 12.7%
Poon et al. (2010)	USA	Before-after study	Barcode eMAR	Administration errors ↓41%; PADEs ↓51%
Raban & Westbrook (2014)	International	Systematic review	Interruption-reduction	↓ interruptions; limited error evidence
Berdot et al. (2016)	International	SR & meta-analysis	Nurse MAE interventions	No significant overall effect; high bias

Source (author, year)	Setting / country	Type	Focus	Key finding
Westbrook et al. (2017)	Australia	Cluster RCT (feasibility)	"Do not interrupt" vest bundle	↓ interruptions; low acceptability
Koyama et al. (2020)	International	Systematic review	Double checking	Insufficient evidence; adherence poor
Manias et al. (2020)	International	Systematic review	MAE interventions (adult wards)	Multifaceted > single interventions
Alotaibi (2024)	Saudi Arabia	Qualitative study	Causes/reporting barriers	Workload, staffing, blame culture
Eze et al. (2026)	International	SR & meta-analysis	Nurse-implemented interventions	Significant ↓ MAEs (OR 0.70)
WHO (2017)	Global	Policy/challenge	Medication safety	50% harm-reduction goal

Note. MAE = medication administration error; eMAR = electronic medication administration record; PADE = potential adverse drug event; SR = systematic review; RCT = randomised controlled trial; OR = odds ratio.

Table 3 *Intervention themes, nurse-led actions, and reported outcomes*

Theme	Representative strategy	Nurse-led action	Reported outcome
Technology	Barcode eMAR; point-of-care scanning	Scan patient and drug; avoid workarounds	Administration errors and PADEs reduced
Interruption reduction	"Do not interrupt" vests; protected medication time	Divert interruptions; protect the round	Interruptions reduced; error effect mixed
Double checking	Independent two-nurse verification of high-alert drugs	Perform genuinely independent checks	Weak evidence; depends on adherence
Education / QI	Training, simulation, multifaceted bundles	Participate in and sustain QI programmes	Mixed; nurse-led bundles ↓ MAEs overall

Note. eMAR = electronic medication administration record; PADE = potential adverse drug event; QI = quality improvement.

Discussion

Summary of evidence. This review synthesized 12 sources to characterize nurse-led and nurse-relevant interventions to reduce MAEs and their patient-safety outcomes. Three messages emerged. First, MAEs are common, clinically important, and driven by interacting individual, environmental, and organisational factors, so interventions must address the task, the working conditions, and the system together (Keers et al., 2013a, 2013b;

Alotaibi, 2024). Second, the interventions with the clearest patient-safety benefit are those that build a hard, system-level barrier into the administration task—most notably barcode-assisted administration, which reduced administration errors and potential adverse drug events (Poon et al., 2010). Third, interventions that depend chiefly on individual behaviour, such as unstructured double checking, show weak or inconsistent effects (Berdot et al., 2016; Koyama et al., 2020).

Interpretation and the central role of nurses. A cross-cutting finding is that nurses are simultaneously the last line of defence and the agents through whom every intervention succeeds or fails. Barcode technology protects patients only when nurses scan reliably; interruption-reduction bundles work only when nurses and colleagues accept and sustain them (Westbrook et al., 2017); double checking adds value only when performed as a genuinely independent check (Koyama et al., 2020). The evolution of the meta-analytic evidence is instructive: an earlier pooled analysis found no significant effect of nurse MAE interventions (Berdot et al., 2016), whereas a more recent, nurse-focused meta-analysis found a significant overall reduction (Eze et al., 2026). This shift likely reflects both improved study quality and a move toward multifaceted, better-implemented interventions. The practical lesson is that investment should favour interventions that either remove reliance on human vigilance or actively support nurses in exercising it, and that implementation fidelity deserves as much attention as the choice of intervention itself.

Implications for practice. For a tertiary centre such as Prince Sultan Military Medical City, the evidence supports a layered, nurse-centred medication-safety programme: (1) implement or optimise barcode eMAR at the point of care and actively monitor for workarounds; (2) protect the medication round through realistic, nurse-endorsed interruption-reduction measures rather than mandates alone; (3) reserve independent double checking for genuinely high-alert medications and audit its fidelity; (4) combine targeted education and simulation with process redesign in multifaceted QI bundles; and (5) strengthen a non-punitive error-reporting culture, given that fear of blame suppresses the reporting on which learning depends (Alotaibi, 2024). Adequate staffing and workload management underpin all of these, because time pressure is a recurrent driver of error.

Comparison with prior work. The findings are consistent with the foundational MAE literature (Keers et al., 2013a, 2013b) and with reviews favouring multifaceted over single interventions (Manias et al., 2020). The contrast between the null result of Berdot et al. (2016) and the positive pooled effect reported by Eze et al. (2026) highlights that conclusions in this field are sensitive to the interventions studied, the rigour of implementation, and the growing maturity of the evidence base.

Strengths and limitations. Strengths include a structured, PRISMA-guided search, exclusive use of verifiable peer-reviewed sources, and a synthesis organised around nurse-led interventions and patient-safety outcomes. Limitations warrant

caution. This was a focused review conducted through curated database searching rather than an exhaustive, dual-independent-reviewer screen, so relevant studies may have been missed and selection bias cannot be excluded. Included primary studies were often single-centre before-after or feasibility designs vulnerable to confounding, and heterogeneity of interventions and outcomes precluded new pooled estimates. The English-language restriction introduces possible language bias, and publication bias may favour interventions with positive results.

Future research. Priorities include rigorous multi-centre cluster-randomised trials of multifaceted, nurse-led bundles with patient-harm endpoints; implementation-science studies examining scanning fidelity, vest acceptability, and double-check adherence; and regional evaluations in Saudi and Gulf hospitals, including at institutions such as Prince Sultan Military Medical City, to establish which combinations of interventions are both effective and sustainable in local practice.

Conclusion

Medication administration is the final barrier between a prescribing decision and the patient, and nurses are the professionals who hold that barrier in place. The evidence synthesized here indicates that nurse-led interventions can reduce medication administration errors, but their effects are heterogeneous and no single strategy is sufficient on its own. The most reliable patient-safety gains come from hard, system-level defences such as barcode-assisted administration and from multifaceted, well-implemented, nurse-led quality-improvement programmes, whereas measures that depend solely on individual vigilance are least dependable. Embedding these interventions within a supportive, non-punitive safety culture with adequate staffing offers the most credible route to safer medication administration—an approach directly applicable to large tertiary institutions such as Prince Sultan Military Medical City and consistent with global medication-safety goals.

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