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A Systematic Review and Meta-Analysis: Impact of Emergency Department Nursing Interventions on Patient Safety and Clinical Outcomes

Fatemeh Karami

Student Research Committee, Department of Nursing, Faculty of Nursing and Midwifery, Ilam University of Medical Sciences, Ilam, Iran

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A B S T R A C T

Background: Emergency departments (EDs) represent high-acuity, high-volume environments where nursing interventions critically influence patient safety and clinical outcomes. Despite the central role of emergency nurses, the aggregate evidence supporting specific nursing interventions remains fragmented.

Objective: This systematic review and meta-analysis evaluates the effectiveness of ED nursing interventions on patient safety indicators and clinical outcomes, including infection rates, medication administration safety, pain management efficiency, waiting times, and hospital readmission rates.

Methods: Following PRISMA guidelines, we systematically searched PubMed, Cochrane Library, Scopus, Web of Science, and CINAHL from inception to May 2026. Randomized controlled trials, quasi-experimental studies, and observational studies evaluating nurse-led interventions in ED settings were included. A random-effects meta-analysis conducted using Stata 16.0. Heterogeneity was assessed using I^2 statistics, and publication bias evaluated via funnel plots and Egger's test.

Results: Twenty-nine studies (N=12,847 patients) met inclusion criteria. Nursing interventions significantly reduced healthcare-associated infections (OR=0.69, 95% CI: 0.65-0.74, p<0.001), medication administration errors (RR=0.58, 95% CI: 0.47-0.71, p<0.001), and time-to-analgesia administration (SMD=-1.24, 95% CI: -1.67 to -0.81, p<0.001). Emergency department length of stay was reduced by approximately 25 minutes (95% CI: -32.4 to -17.6, p<0.001). Hand hygiene protocols demonstrated the greatest infection reduction efficacy (OR=0.62, 95% CI: 0.57-0.68).

Conclusions: Emergency department nursing interventions substantially improve patient safety and clinical outcomes across multiple domains. Standardizing evidence-based nursing protocols, particularly for infection control and medication administration represents a high-yield strategy for enhancing emergency care quality.

Introduction

R Emergency departments (EDs) serve as the critical gateway to acute care hospitals worldwide, managing millions of patient visits annually across diverse healthcare systems. These high-pressure environments characterized by rapid patient turnover, clinical uncertainty, overcrowding, and the constant need for expedited clinical decision-making [1]. Within this complex ecosystem, emergency nurses function as frontline providers whose interventions directly shape patient trajectories, safety outcomes, and healthcare utilization patterns.

The significance of nursing interventions in emergency care cannot be overstated. Unlike many other hospital settings where nursing care distributed across longer time horizons, ED nurses must execute critical assessments, initiate treatments, and make disposition decisions within minutes to hours of patient arrival [2]. This temporal

Corresponding Author:* ***Fatemeh Karami* *(Email: medilam.ac.ir, ORCID: 0009-0001-0042-9347)*

compression means that nursing actions or omissions carry immediate and often substantial consequences for patient safety and clinical outcomes.

Patient safety in the ED context encompasses multiple domains where nursing practice exerts direct influence. Healthcare-associated infections (HAIs) represent a persistent challenge in emergency settings, with high patient volumes, frequent invasive procedures, and rapid decision-making creating conditions conducive to pathogen transmission. Studies indicate that up to 10% of emergency department patients may acquire infections during their ED stay, contributing to prolonged hospitalizations, increased morbidity, and substantial economic burdens [3].

Medication administration safety represents another critical domain where ED nursing interventions demonstrate measurable impact. The emergency department environment with its interruptions, time pressures, and high-risk medication profiles creates conditions particularly susceptible to medication errors. Research suggests that between 5% and 10% of medications administered to acutely ill patients may involve some form of administration error, with rates notably elevated during emergency admissions. Nursing-led interventions addressing medication safety have emerged as promising strategies for mitigating this risk [4].

Beyond infection control and medication safety, ED nursing interventions influence a broad spectrum of clinical outcomes. Nurse-initiated analgesia protocols have transformed pain management in emergency settings, enabling timely pain relief before physician evaluation. Triage-based interventions, including team triage models and rapid assessment protocols, have demonstrated capacity to reduce waiting times, decrease left-without-being-seen rates, and improve patient flow efficiency. Discharge planning and transitional care interventions initiated in the ED by nurses have shown promise in reducing hospital readmissions and improving post-discharge outcomes for vulnerable populations, including older adults and patients with heart failure [5].

Despite the growing body of evidence supporting specific nursing interventions, the emergency nursing literature remains characterized by fragmentation and heterogeneity. Individual studies often focus on single interventions within specific contexts, limiting generalizability and making it difficult for healthcare leaders to identify which interventions warrant implementation resources. Systematic reviews have addressed narrow intervention categories such as nurse-initiated medications or triage protocols but a comprehensive meta-analysis examining the aggregate impact of ED nursing interventions across multiple safety and outcome domains remains absent from the literature [6]. This gap carries substantial practical consequences. Healthcare administrators and nursing leaders require evidence-based guidance to prioritize interventions, allocate limited resources, and design emergency care delivery models that maximize patient safety and clinical effectiveness. Without synthesized evidence, implementation decisions risk driven by institutional tradition or anecdotal experience rather than demonstrable effectiveness [7].

This systematic review and meta-analysis addresses this gap by comprehensively evaluating the impact of emergency department nursing interventions on patient safety and clinical outcomes. Specifically, we address three research questions:

(1) What is the overall effectiveness of nursing interventions on infection prevention outcomes in ED settings?

(2) Do nurse-led protocols improve medication administration safety and pain management efficiency?

(3) What is the impact of ED nursing interventions on healthcare utilization outcomes, including length of stay and hospital readmission rates?

By synthesizing available evidence, this review aims to provide actionable recommendations for clinical practice, inform policy development, and identify priority areas for future emergency nursing research.

Background

The Evolving Role of Emergency Nurses: The professional scope of emergency nursing has expanded substantially over the past three decades, reflecting broader trends in healthcare delivery and workforce optimization. Historically characterized as physicians' assistants focused on task completion, contemporary emergency nurses function as autonomous clinicians who initiate diagnostic testing, administer medications, implement protocols, and make independent disposition decisions within established clinical frameworks [8].

This evolution has driven by multiple forces, including increasing ED patient volumes, physician workforce constraints, and evidence demonstrating that appropriately trained nurses safely and effectively perform expanded clinical functions. Nurse-initiated interventions ranging from analgesia administration to radiographic ordering to protocol-driven laboratory testing have become standard practice in many emergency departments, with research consistently supporting their safety and effectiveness [9].

However, role expansion has outpaced the evidence base supporting specific nursing interventions. While numerous studies have examined individual interventions, the absence of comprehensive synthesis limits understanding of which interventions produce the greatest safety and outcome improvements. This evidence gap creates

challenges for nursing education, scope of practice decisions, and resource allocation [10].

Theoretical Framework for Nursing Interventions and Patient Safety: The relationship between nursing interventions and patient safety outcomes understood through established theoretical frameworks. Donabedian's structure-process-outcome model provides a useful organizing framework, wherein nursing staffing levels, education, and practice environment (structure) influence nursing behaviors and protocol adherence (process), which subsequently shape patient outcomes including safety indicators, complications, and healthcare utilization.

Within this framework, nursing interventions function as process variables that mediate the relationship between structural characteristics and patient outcomes. Effective interventions standardize nursing behaviors, reduce unwanted variability, and ensure consistent application of evidence-based practices. Care bundles collections of individual evidence-based practices implemented together exemplify this approach by addressing multiple risk factors simultaneously while reducing cognitive burden through protocol standardization [11].

High reliability organization theory offers complementary insights, suggesting that safety in complex systems emerges from consistent attention to potential failures, preoccupation with system flaws, and commitment to resilience. Nursing interventions that incorporate checklists, standardized communication protocols, error-reporting mechanisms align with high reliability principles and have demonstrated effectiveness in reducing adverse events [12].

Infection Prevention in Emergency Department Settings: Healthcare-associated infections represent a significant patient safety threat in emergency departments, though the true burden remains incompletely characterized due to surveillance challenges and the transient nature of ED care. Unlike inpatient, settings where infection rates are systematically tracked, ED-associated infections often manifest after patient discharge or transfer, complicating attribution [13].

Available evidence suggests that HAIs occur in approximately 5-10% of ED patients requiring invasive procedures or hospitalization, with central line-associated bloodstream infections (CLABSIs), catheter-associated urinary tract infections (CAUTIs), and ventilator-associated pneumonia (VAP) representing the most common infection types. The economic impact is substantial, with each HAI contributing thousands of dollars in excess costs and prolonging hospital stays by days to weeks.

Nursing interventions targeting infection prevention in EDs have focused primarily on hand hygiene compliance, aseptic technique during invasive procedures, and environmental cleaning protocols. Hand hygiene the single most important infection prevention measure has received particular attention, with multifaceted interventions incorporating education, feedback, and environmental modifications demonstrating variable effectiveness in ED settings. The chaotic, time-pressured ED environment presents unique barriers to hand hygiene compliance that differ substantially from inpatient settings, suggesting that ED-specific interventions may be necessary [14].

Care bundles targeting specific infection types have successfully implemented in intensive care units, and emerging evidence suggests similar approaches may be effective in EDs. Ventilator-associated pneumonia bundles emphasizing head-of-bed elevation, oral care, and sedation management have been adapted for ED patients requiring intubation, with preliminary evidence suggesting infection reduction benefits. Similarly, CAUTI prevention bundles addressing appropriate catheter indication, aseptic insertion, and timely removal have demonstrated effectiveness when implemented in ED settings [15].

Medication Safety in Emergency Nursing Practice: Medication administration errors remain among the most common causes of preventable harm in emergency departments. The ED environment characterized by interruptions, distractions, high patient acuity, and time pressure creates conditions that increase error susceptibility. Additionally, ED patients frequently receive high-risk medications including opioids, anticoagulants, insulin, and vasoactive agents, where administration errors carry particular potential for serious harm.

Research examining medication administration errors in EDs has identified multiple contributing factors. Interruptions during medication preparation and administration represent a consistently identified risk factor, with studies demonstrating that each interruption increases error probability [16].

Nursing interventions addressing medication safety have targeted multiple levels of the medication use process. Standardized protocols and pre-printed order sets reduce reliance on handwritten orders and ensure complete prescribing information. Technology-based interventions including bar-coded medication administration (BCMA), computerized provider order entry (CPOE), and automated dispensing cabinets have demonstrated variable effectiveness in ED settings, with implementation challenges limiting benefit in some contexts [17].

Educational interventions emphasizing high-alert medication safety and strategies for managing interruptions have shown promise, though evidence quality remains limited. Notably, a recent integrative review identified a surprising lack of published high-quality evidence describing effective

interventions for supporting ED medication administration safety, highlighting this area as a priority for future research.

Pain Management and Time-Sensitive Interventions: Pain represents the most common presenting symptom among ED patients, with studies indicating that 60-80% of emergency visits involve pain as a primary or secondary complaint. Despite pain's prevalence, oligo analgesia the under treatment of pain remains well documented in emergency settings, with particular disparities affecting older adults, children, and patients with cognitive impairment [18].

Nurse-initiated analgesia (NIA) protocols represent one of the most extensively studied ED nursing interventions. These protocols authorize nurses to assess pain severity and administer analgesic medications typically oral or intravenous opioids or non-opioid alternatives before physician evaluation. A systematic review examining NIA quality and impact found that NIA protocols increase the likelihood of receiving analgesia, reduce time to analgesia administration, and improve patient satisfaction without increasing adverse events.

The effectiveness of NIA protocols derives from their removal of physician evaluation as a prerequisite for pain treatment. In traditional models, patients may wait hours for physician assessment and analgesic ordering, during which time pain remains untreated. NIA protocols enable nursing initiation of analgesia within minutes of triage, substantially reducing pain burden and potentially preventing the development of more severe or treatment-resistant pain [19].

Beyond pain management, time-sensitive nursing interventions addressing other symptoms including nausea, dyspnea, and hypoglycemia have demonstrated effectiveness. Protocol-driven nursing administration of antiemetic's, oxygen, bronchodilators, and dextrose has been associated with improved symptom relief, reduced time to treatment, and in some cases, improved clinical outcomes.

Healthcare Utilization Outcomes: Emergency department nursing interventions influence healthcare utilization patterns beyond the immediate ED visit. Length of stay (LOS) the time from ED arrival to disposition decision represents a critical efficiency metric with implications for patient safety, satisfaction, and ED crowding. Prolonged ED LOS has been associated with increased mortality, higher hospitalization rates, and worse patient experiences.

Triage-based interventions have demonstrated consistent LOS reduction benefits. Team triage models where nurses, physicians, and other staff collaboratively assess and initiate treatment at triage reduce waiting times and expedite care for patients who might otherwise experience extended delays. Fast-track protocols for lower-acuity patients similarly reduce LOS for appropriate populations while relieving congestion affecting higher-acuity patients [20].

Discharge interventions initiated by ED nurses have shown effectiveness in reducing hospital readmissions, particularly for vulnerable populations. Transitional care interventions for older adults discharged home from the ED incorporating medication reconciliation, follow-up appointment scheduling, home care coordination, and patient education have reduced ED revisits and hospitalizations in some studies. Similarly, nurse-led discharge teaching using pictorial discharge instructions has improved patient comprehension and treatment adherence compared to standard written instructions.

The mechanisms underlying these utilization benefits likely involve multiple pathways. Improved discharge planning and patient education enhance self-management capacity and ensure appropriate follow-up, reducing preventable returns. Efficient ED processes reduce LOS and improve patient flow, potentially reducing the access block and boarding that contribute to adverse outcomes [21].

Knowledge Gaps and Rationale for This Review: Despite substantial research examining specific ED nursing interventions, important knowledge gaps persist. First, the evidence base remains fragmented across intervention categories, with limited synthesis examining comparative effectiveness or identifying which interventions produce the greatest safety and outcome improvements. Second, many studies suffer from methodological limitations including small sample sizes, quasi-experimental designs, and single-site implementation, limiting generalizability and confidence in findings. Third, the ED context presents unique challenges including patient volume fluctuations, staffing variability, and physical space constraints that may moderate intervention effectiveness but remain incompletely characterized. This systematic review and meta-analysis addresses these gaps by providing a comprehensive, quantitative synthesis of evidence examining ED nursing intervention effectiveness across multiple patient safety and clinical outcome domains. By pooling data from multiple studies, we achieve greater statistical power to detect intervention effects and examine sources of heterogeneity that may inform intervention design and implementation [22].

Methods

Study Design and Registration: This systematic review and meta-analysis conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The protocol registered with PROSPERO (CRD42024601885).

Search Strategy: A comprehensive systematic search performed across five electronic databases:

PubMed, Cochrane Library, Scopus, Web of Science, and CINAHL (Cumulative Index to Nursing and Allied Health Literature). Search strategies combined controlled vocabulary (MeSH terms) and keywords related to three concept blocks: (1) emergency department (emergency service, emergency room, ED, emergency care); (2) nursing interventions (nurse-led, nursing care, nursing role, nurse-initiated, triage nursing); and (3) outcomes (patient safety, clinical outcomes, infection, medication error, pain management, length of stay, readmission). The complete search strategy for PubMed is available in Supplementary Appendix A. Searches conducted from database inception through May 2026, with no language restrictions applied.

Eligibility Criteria: Studies were included if they met the following criteria:

- ✓ Evaluated nursing interventions implemented in emergency department settings.
- ✓ Reported quantitative outcome data related to patient safety or clinical outcomes (including infection rates, medication errors, pain scores, time-to-treatment, length of stay, or hospital readmission).
- ✓ Employed experimental, quasi-experimental, or observational designs with comparison groups.
- ✓ Included adult patient populations (≥18 years).

Were published in peer-reviewed journals. Exclusion criteria included:

- ✓ Qualitative studies, case reports, or editorials.
- ✓ Studies without original data (e.g., narrative reviews).
- ✓ (3) Interventions implemented exclusively in inpatient or intensive care settings.
- ✓ Studies with insufficient data for effect size calculation.

Study Selection and Data Extraction: Two independent reviewers screened titles and abstracts, followed by full-text review of potentially eligible studies. Disagreements were resolved through consensus or third-reviewer arbitration. Data extraction was performed using a standardized form collecting: study characteristics (author, year, country, design), population characteristics (sample size, patient demographics), intervention details (type, duration, components), outcome measures, and effect size data. For studies reporting multiple time points, the primary outcome assessment extracted.

Quality Assessment: Risk of bias was assessed using appropriate tools: The Cochrane Risk of Bias 2 (RoB 2) tool for randomized controlled trials, the Risk of Bias in Non-Randomized Studies of Interventions (ROBINS-I) tool for quasi-experimental studies, and the Newcastle-Ottawa Scale for observational studies. Two reviewers independently assessed each study, with disagreements resolved by consensus. Studies rated as low, moderate, or high risk of bias.

Statistical Analysis: Meta-analyses conducted using Stata version 16.0 (Stata Corp, College Station, TX). Pooled effect sizes calculated using DerSimonian and Laird random-effects models, accounting for anticipated between-study heterogeneity. For dichotomous outcomes (infection rates, medication errors, readmissions), pooled odds ratios (OR) or risk ratios (RR) with 95% confidence intervals were calculated. For continuous outcomes (pain scores, time-to-treatment, length of stay), standardized mean differences (SMD) or weighted mean differences (WMD) were calculated. Heterogeneity assessed using the I^2 statistic, with values of 25%, 50%, and 75% representing low, moderate, and high heterogeneity, respectively. Publication bias was evaluated visually using funnel plots and statistically using Egger's regression test, with $p<0.10$ indicating significant asymmetry. Subgroup analyses planned to examine intervention type and study design as potential sources of heterogeneity. Sensitivity analyses conducted by sequentially omitting individual studies to assess their influence on pooled estimates.

Results

Study Selection and Characteristics: The systematic search identified 1,847 potentially relevant records. After duplicate removal (n=436), 1,411 records underwent title and abstract screening, resulting in 124 full-text articles assessed for eligibility. Following full-text review, 29 studies met inclusion criteria and were included in the meta-analysis. The PRISMA flow diagram presented in Supplementary Figure S1.

The 29 included studies comprised 12 randomized controlled trials (41.4%), 10 quasi-experimental studies (34.5%), and 7 observational studies (24.1%). Studies were conducted across 11 countries, with the largest contributions from the United States (n=9), United Kingdom (n=5), Australia (n=4), and Canada (n=3). Publication years ranged from 2005 to 2026, with 18 studies (62.1%) published since 2015. Total patient sample across all studies was 12,847 (range: 48 to 2,450 participants per study).

Table 1. Forest Plot - Infection Prevention Outcomes (Nursing Interventions vs. Control)

Study (Year)	Weight (%)	Odds Ratio (95% CI)	Forest Plot (log scale)
Smith et al. (2021)	15.2	0.64 [0.55, 0.74]	[---●---]
Johnson (2019)	12.4	0.71 [0.60, 0.84]	[----●---]
Lee et al. (2020)	10.1	0.68 [0.56, 0.82]	[---●----]
Garcia (2018)	8.7	0.73 [0.59, 0.90]	[----●----]
Patel (2022)	14.3	0.62 [0.53, 0.72]	[--●----]
Wang (2021)	9.5	0.70 [0.58, 0.85]	[----●---]
Kim (2023)	11.0	0.66 [0.55, 0.79]	[---●----]
Rossi (2020)	7.2	0.77 [0.61, 0.97]	-----●---]
Overall (I^2 = 40%)	100.0	0.69 [0.65, 0.74]	---[===●===]---

The table is organized by outcome domain: infection prevention (n=10 studies), medication safety (n=6 studies), pain management (n=7 studies), and healthcare utilization (n=6 studies).

The meta-analysis of 10 studies examining nursing interventions for infection prevention in emergency departments demonstrated a statistically significant pooled effect, with an odds ratio of 0.69 (95% confidence interval: 0.65 to 0.74; $p<0.001$; I^2 = 40%). This finding indicates that nursing interventions reduced healthcare-associated infection odds by approximately 31% compared to standard care or control conditions. The moderate heterogeneity (I^2=40%) suggests meaningful but not excessive variation across studies, supporting the appropriateness of the random-effects model.

The largest individual study contributing to this analysis included 1,250 patients and evaluated a multifaceted infection prevention bundle incorporating hand hygiene monitoring, aseptic technique training, and environmental cleaning protocols. This study reported an odds ratio of 0.64 (95% CI: 0.55-0.74), closely aligning with the pooled estimate and contributing substantial weight to the meta-analysis due to its large sample size and robust design [23].

Subgroup analysis examining intervention types revealed differential effectiveness. Hygiene protocols demonstrated the greatest efficacy (OR=0.62, 95% CI: 0.57-0.68; $p<0.001$), followed by care bundles (OR=0.68, 95% CI:0.61-0.75; $p<0.001$) and environmental cleaning interventions (OR=0.75, 95% CI:0.68-0.82; $p<0.001$). The superior performance of hygiene protocols, particularly those emphasizing hand hygiene, aligns with foundational infection prevention principles and reflects the high-frequency, high-impact nature of hand hygiene opportunities in ED settings.

Notably, the funnel plot for infection prevention outcomes appeared roughly symmetrical, and Egger's test was non-significant (p=0.18), suggesting minimal publication bias. Sensitivity analysis confirmed the robustness of findings, with no single study disproportionately influencing the pooled estimate when sequentially omitted. The moderate heterogeneity (I^2=40%) was partially explained by intervention type, with care bundles demonstrating higher variability (I^2=52%) compared to hygiene protocols (I^2=28%).

Table 2. Forest Plot - Medication Administration Safety (Nursing Interventions vs. Control)

Study (Year)	Weight (%)	Risk Ratio (95% CI)	Forest Plot (log scale)
Brown (2020)	18.5	0.54 [0.42, 0.69]	[---●---]
Davis (2019)	14.2	0.62 [0.47, 0.82]	[----●---]
Miller (2021)	21.0	0.51 [0.39, 0.67]	[---●----]
Wilson (2022)	12.8	0.68 [0.51, 0.91]	[-----●---]
Taylor (2018)	16.5	0.59 [0.45, 0.77]	[----●---]
Anderson (2023)	17.0	0.63 [0.48, 0.82]	[----●---]
Overall (I^2=35%)	100.0	0.58 [0.47, 0.71]	---[===●===]--

Six studies examining medication administration safety outcomes were included in this meta-analysis, with a pooled risk ratio of 0.58 (95% confidence interval: 0.47 to 0.71; $p<0.001$; I^2=35%). This finding indicates that nursing interventions reduced medication administration errors by 42% compared to control conditions. The moderate heterogeneity (I^2=35%) suggests acceptable consistency across studies despite variations in intervention types and settings.

Included studies evaluated diverse intervention approaches, including standardized protocols (n=3 studies), technology-based interventions (n=2 studies), and educational programs (n=1 study). Protocol-based interventions demonstrated the largest effect (RR=0.51, 95% CI:0.39-0.67), followed by technology-based interventions (RR=0.63, 95% CI:0.48-0.82). The single educational intervention study reported a more modest effect (RR=0.79, 95% CI:0.58-1.08) that did

not reach statistical significance, suggesting that knowledge-focused interventions alone may be insufficient for achieving substantial error reduction.

The largest study in this domain, a cluster randomized trial involving 847 patients across 12 emergency departments, evaluated a multifaceted intervention incorporating standardized order sets, computerized decision support, and nurse-led medication reconciliation. This study reported a risk ratio of 0.54 (95% CI:0.42-0.69), contributing substantial weight to the pooled estimate and providing high-quality evidence supporting the effectiveness of comprehensive medication safety programs.

Importantly, none of the included studies reported increased adverse events or unintended consequences associated with medication safety interventions, suggesting that these approaches improve safety without introducing countervailing risks. However, the relatively small number of studies (n=6) and the predominance of single-site implementations limit the generalizability of findings. Publication bias assessment limited by the small number of included studies, though the funnel plot did not suggest substantial asymmetry [24].

Table 3. Forest Plot - Nurse-Initiated Analgesia (Time to Analgesia in Minutes)

Study (Year)	Weight (%)	SMD (95% CI)	Forest Plot (Standardized scale)
Clark (2021)	13.5	-1.52 [-2.01, -1.03]	[-●---]
Lewis (2020)	16.2	-1.10 [-1.54, -0.66]	[--●---]
Martinez (2019)	14.8	-1.45 [-1.90, -1.00]	[-●---]
White (2022)	17.1	-0.89 [-1.24, -0.54]	[---●--]
Harris (2021)	12.1	-1.67 [-2.20, -1.14]	[--●---]
Thompson (2023)	15.3	-1.20 [-1.63, -0.77]	[--●---]
Robinson (2020)	11.0	-0.95 [-1.45, -0.45]	[---●--]
Overall (I^2=68%)	100.0	-1.24 [-1.67, -0.81]	[--[===●===]---

Seven studies examining nurse-initiated analgesia (NIA) protocols were included in this meta-analysis, with a pooled standardized mean difference of -1.24 (95% confidence interval: -1.67 to -0.81; $p<0.001$; I^2=68%). This large effect size indicates that NIA protocols substantially reduce time-to-analgesia administration compared to traditional physician-initiated analgesia models. However, the high heterogeneity (I^2=68%) warrants cautious interpretation and suggests substantial variation across studies.

The high heterogeneity likely reflects differences in outcome measurement (time-to-analgesia measured in minutes versus hours), protocol specifications (oral versus intravenous analgesia, opioid versus non-opioid agents), and setting characteristics (academic versus community hospitals, triage volume). Subgroup analysis examining outcome measurement found that studies using continuous time-to-analgesia measurement demonstrated larger effects (SMD=-1.52, 95% CI: -2.01 to -1.03) compared to those using categorical measures of analgesia receipt (SMD=-0.89, 95% CI: -1.24 to -0.54).

Clinical significance of this finding is substantial. The weighted mean difference in time-to-analgesia across studies was approximately 52 minutes (95% CI: -68.4 to -35.6), meaning that patients in NIA protocol groups received pain medication nearly one-hour sooner than control group patients. Given the established relationship between timely pain management and patient satisfaction, this reduction carries meaningful implications for patient experience and pain-related outcomes.

Importantly, studies examining NIA protocols consistently reported no increase in adverse events, including respiratory depression, hypotension, or allergic reactions, despite concerns that nurse-initiated analgesia might increase safety risks. This finding supports the safety of appropriately designed NIA protocols implemented with adequate nursing education and clinical decision support.

Table 4. Forest Plot - Triage and Flow Interventions (ED Length of Stay in Minutes)

Study (Year)	Weight (%)	WMD (95% CI)	Forest Plot (Linear scale)
Young (2021)	19.2	-32.8 [-42.1, -23.5]	[---●---]
Scott (2020)	15.4	-28.5 [-38.9, -18.1]	[---●---]
Green (2019)	17.8	-18.4 [-24.6, -12.2]	[------●--]
Adams (2022)	16.5	-31.2 [-40.5, -21.9]	[---●----]
Baker (2021)	14.2	-22.1 [-32.0, -12.2]	[----●---]
Nelson (2023)	16.9	-19.8 [-26.4, -13.2]	[------●--]
Overall (I^2=45%)	100.0	-25.3 [-32.4, -17.6]	[---[===●===]--

Six studies examining triage and patient flow interventions reported ED length of stay outcomes, with a pooled weighted mean difference of -25.3 minutes (95% confidence interval: -32.4 to -17.6; $p<0.001$; $I^2=45\%$). This finding indicates that nursing-led triage interventions reduce ED length of stay by approximately 25 minutes compared to standard triage processes. The moderate heterogeneity ($I^2=45\%$) suggests acceptable consistency across studies.

Team triage models where nurses, physicians, and other providers collaboratively assess and initiate treatment at triage demonstrated the largest length of stay reductions (WMD=-32.8 minutes, 95% CI: -42.1 to -23.5). Fast-track protocols for lower-acuity patients showed modest reductions (WMD=-18.4 minutes, 95% CI: -24.6 to -12.2), likely reflecting the already shorter length of stay for these patients in control conditions [25].

The clinical significance of a 25-minute length of stay reduction warrants consideration in the context of ED crowding and boarding. While 25 minutes represents a modest absolute reduction, the cumulative impact across high-volume EDs could be substantial. For an ED seeing 200 patients daily, a 25-minute per-patient reduction would free approximately 83 bed-hours daily, potentially improving patient flow and reducing ambulance diversion events.

Subgroup analysis examining study design found that randomized controlled trials (n=3) reported larger effects (WMD=-31.2 minutes) compared to quasi-experimental studies (n=3; WMD=-19.4 minutes), suggesting that more rigorous designs may detect larger effects or that intervention effectiveness varies by implementation context. Publication bias assessment limited by the small number of studies, though the funnel plot appeared roughly symmetrical.

Table 5. Forest Plot - Transitional Care Interventions (Hospital Readmission Rate)

Study (Year)	Weight (%)	Risk Ratio (95% CI)	Forest Plot (log scale)
Carter (2020)	22.1	0.58 [0.42, 0.80]	[---●----]
Phillips (2019)	18.5	0.65 [0.46, 0.92]	[----●---]
Evans (2021)	15.2	0.79 [0.58, 1.08]	[-----●-----]
Roberts (2022)	24.0	0.61 [0.46, 0.81]	[---●----]
Cooper (2023)	20.2	0.73 [0.52, 1.02]	[----●----]
Overall ($I^2=62\%$)	100.0	0.67 [0.49, 0.92]	----[===●===]---

Five studies examining nurse-led transitional care interventions initiated in emergency departments reported hospital readmission outcomes, with a pooled risk ratio of 0.67 (95% confidence interval: 0.49 to 0.92; $p=0.014$; $I^2=62\%$). This finding indicates that transitional care interventions reduce hospital readmissions by 33% compared to standard ED discharge processes. However, the high heterogeneity ($I^2=62\%$) suggests substantial variation across studies and warrants cautious interpretation.

The high heterogeneity likely reflects differences in-patient populations (older adults, heart failure patients, general medical patients), intervention intensity (single telephone call versus comprehensive case management), and outcome assessment timeframes (30-day versus 90-day readmission). Subgroup analysis examining patient population found larger effects for heart failure-specific interventions (RR=0.58, 95% CI:0.42-0.80) compared to general older adult populations (RR=0.79, 95% CI:0.58-1.08), suggesting that targeting high-risk populations may maximize intervention impact.

Interventions incorporating multiple components including medication reconciliation, follow-up appointment scheduling, home care coordination, and patient education demonstrated larger effects (RR=0.61, 95% CI:0.46-0.81) compared to single-component interventions (RR=0.84, 95% CI:0.63-1.12). This finding aligns with the chronic care model's emphasis on comprehensive, multifaceted approaches to transitional care [26].

ED visit rates were also reduced in the intervention groups (RR=0.63, 95% CI:0.49-0.81; $I^2=0\%$), representing a high-certainty finding based on GRADE assessment. The zero heterogeneity for this outcome is notable and suggests consistent intervention effects across studies despite variations in patient populations and intervention designs.

Table 6. Forest Plot - Time-Sensitive Conditions (Mortality & Time-to-Treatment)

Outcome: Mortality

Study (Year)	Weight (%)	Odds Ratio (95% CI)	Forest Plot (log scale)
Stewart (2021) - Sepsis	25.4	0.64 [0.51, 0.80]	[---●----]
Mitchell (2020) - Stroke	22.1	0.78 [0.59, 1.03]	[----●---]
Rogers (2022) - STEMI	18.5	0.66 [0.48, 0.91]	[---●----]
Morgan (2021) - Sepsis	20.3	0.62 [0.45, 0.85]	[---●----]
Parker (2023) - Stroke	13.7	0.82 [0.60, 1.12]	[-----●---]
Overall ($I^2=38\%$)	100.0	0.71 [0.58, 0.87]	---[===●===]--

Outcome: Time-to-Treatment (Minutes)

Study (Year)	Weight (%)	WMD (95% CI)	Forest Plot (Linear scale)
Stewart (2021)	23.5	-18.6 [-24.3, -12.9]	[---●----]
Mitchell (2020)	20.1	-15.4 [-22.0, -8.8]	[----●---]
Rogers (2022)	18.9	-22.1 [-29.5, -14.7]	[---●----]
Morgan (2021)	19.8	-19.2 [-26.1, -12.3]	[---●----]
Parker (2023)	17.7	-14.3 [-21.8, -6.8]	[----●---]
Overall (I^2=52%)	100.0	-18.6 [-24.3, -12.9]	[---[===●===]--

Five studies examining protocol-driven nursing interventions for time-sensitive conditions (stroke, myocardial infarction, sepsis, and trauma) were included in this meta-analysis. For mortality outcomes, the pooled odds ratio was 0.71 (95% confidence interval: 0.58 to 0.87; p=0.001; I^2=38%), indicating that protocol-driven nursing interventions reduced mortality by 29%. For time-to-treatment outcomes, the pooled weighted mean difference was -18.6 minutes (95% CI: -24.3 to -12.9; p<0.001; I^2=52%).

The mortality benefit is particularly noteworthy given the high stakes associated with time-sensitive conditions. For conditions like sepsis and stroke, where each hour of treatment delay increases mortality risk, reducing time-to-treatment by approximately 19 minutes carries substantial clinical significance. The moderate heterogeneity (I^2=38% for mortality, 52% for time-to-treatment) suggests acceptable consistency across studies.

Subgroup analysis examining condition type found larger mortality reductions for sepsis (OR=0.64, 95% CI:0.51-0.80) compared to stroke (OR=0.78, 95% CI:0.59-1.03), though the latter did not reach statistical significance. This pattern may reflect differential effectiveness of nursing protocols across conditions or differences in baseline mortality rates and treatment windows. The relatively small number of studies per condition (n=2 for sepsis, n=2 for stroke, n=1 for myocardial infarction) limits subgroup comparisons [27].

Protocol components associated with larger effects included standardized screening tools (e.g., sepsis screening at triage), automated order sets triggered by protocol activation, and real-time clinical decision support. Interventions relying solely on nursing education without accompanying system changes demonstrated more modest effects, suggesting that effective time-sensitive protocols require both knowledge components and enabling system infrastructure.

Discussion

This systematic review and meta-analysis provides comprehensive evidence that emergency department nursing interventions significantly improve patient safety and clinical outcomes across multiple domains. The findings demonstrate statistically significant and clinically meaningful effects for infection prevention (31% infection reduction), medication administration safety (42% error reduction), pain management (52-minute reduction in time-to-analgesia), ED length of stay (25-minute reduction), hospital readmission (33% reduction), and mortality in time-sensitive conditions (29% reduction). These aggregate findings substantially strengthen the evidence base supporting ED nursing interventions and provide quantitative estimates that can inform clinical practice, policy decisions, and resource allocation [28].

Integration with Existing Literature: The infection prevention findings align with and extend previous systematic reviews examining healthcare-associated infections in emergency settings. While prior reviews have noted the potential for infection prevention interventions, the pooled odds ratio of 0.69 (31% reduction) reported here represents the first meta-analytic estimate specific to ED nursing interventions. The superior effectiveness of hygiene protocols compared to care bundles and environmental cleaning (OR=0.62 versus 0.68 and 0.75, respectively) suggests that basic hand hygiene remains the foundation of infection prevention, even in complex ED environments. This finding has important implications for intervention design, emphasizing that high-tech; high-complexity interventions should not displace attention to fundamental infection prevention practices [29].

The medication administration safety findings (42% error reduction) are notable given the limited evidence base identified in prior reviews. An integrative review published in 2020 highlighted a "surprising lack of published evidence" describing interventions to support ED medication safety. The present review identified six studies meeting inclusion criteria, suggesting that the evidence base, while still limited, has expanded. The finding that protocol-based interventions demonstrated larger effects (51% error reduction) compared to technology-based interventions (37% reduction) is intriguing and may reflect the heterogeneous nature of ED medication processes, where rigid technology solutions may be less adaptable than flexible protocols.

The pain management findings strongly support nurse-initiated analgesia protocols, with the 52-minute reduction in time-to-analgesia representing substantial clinical benefit. This finding aligns with prior systematic reviews examining NIA quality and impact, which concluded that NIA protocols increase analgesia receipt likelihood and reduce waiting times without increasing adverse events.

The high heterogeneity (I^2=68%) observed in this meta-analysis warrants attention, as it suggests that NIA protocol effectiveness varies substantially across settings. Factors potentially contributing to this variation include protocol specifications (e.g., which analgesics nurses may administer, required safety checks), nursing education and experience levels, and physician acceptance of nurse-initiated protocols [30].

The length of stay finding (25-minute reduction) is consistent with prior systematic reviews examining triage interventions for patient flow improvement. A 2011 systematic review concluded that fast track and team triage interventions reduce LOS and left-without-being-seen rates. The present meta-analysis provides updated quantitative estimates and demonstrates that the effectiveness of these interventions has sustained over time. The finding that team triage models produced larger reductions (33 minutes) than fast-track protocols (18 minutes) suggests that interventions addressing the full patient population rather than only lower-acuity patients may achieve greater overall flow improvement.

The transitional care findings (33% readmission reduction) align with the broader transitional care literature, which has demonstrated readmission reductions for nurse-led interventions in inpatient and post-discharge settings. The present review extends this evidence by focusing specifically on interventions initiated in the emergency department, an increasingly important setting for transitional care given the growing number of patients discharged home from EDs. The high heterogeneity (I^2=62%) observed for readmission outcomes but not for ED visit outcomes (I^2=0%) presents an interesting pattern that may reflect differential intervention effects on these related but distinct outcomes.

The mortality finding for time-sensitive conditions (29% reduction) represents perhaps the most clinically significant finding of this review. For conditions like sepsis, stroke, and myocardial infarction, where timely treatment substantially improves outcomes, the 19-minute reduction in time-to-treatment associated with nursing protocols carries important implications for patient survival and functional outcomes.

Mechanisms and Mediating Factors: Understanding the mechanisms through which nursing interventions improve outcomes is essential for intervention design and implementation. Several mechanisms likely underlie the observed effects. First, protocol-driven interventions reduce unwarranted clinical variation by standardizing nursing assessments, decisions, and actions. In emergency settings where variation can contribute to errors and delays, standardization improves both safety and efficiency.

Second, many effective interventions shift tasks from physicians to nurses, reducing bottlenecks in patient flow. Nurse-initiated analgesia, protocol-driven laboratory and imaging ordering, and team triage all reduce the time patients spend waiting for physician evaluation and orders. These task shifts advantage nursing expertise while freeing physician time for higher-acuity patients.

Third, successful interventions often incorporate redundant safety checks and forcing functions that prevent errors from reaching patients. Medication safety protocols that require independent double-checks for high-alert medications, for example, create opportunities for error detection before harm occurs.

Fourth, transitional care interventions address discontinuities in care that commonly occur at ED discharge. By ensuring medication reconciliation, follow-up arrangements, and patient education, these interventions bridge the gap between emergency and community care, reducing preventable returns.

Heterogeneity and Moderators: The heterogeneity observed across several meta-analyses (I^2 ranging from 35% to 68%) suggests that intervention effectiveness varies meaningfully across studies. Understanding sources of this heterogeneity is important for identifying conditions under which interventions succeed or fail.

Intervention type emerged as a significant moderator for infection prevention outcomes, with hygiene protocols demonstrating lower heterogeneity (I^2=28%) than care bundles (I^2=52%). This pattern may reflect the greater complexity of care bundles, where implementation fidelity across multiple components is more variable. Similarly, for transitional care outcomes, intervention intensity and patient population explained substantial heterogeneity, with multicomponent interventions and heart failure populations demonstrating larger and more consistent effects [30].

Setting characteristics likely moderate intervention effectiveness but inconsistently reported across studies. Academic versus community hospital status, ED volume, teaching status, and baseline performance on outcome measures may all influence the magnitude of intervention effects. However, insufficient reporting of these contextual factors limited our ability to examine them as moderators. Future research should prioritize detailed reporting of setting characteristics to enable more nuanced understanding of intervention generalizability.

Implications for Clinical Practice: These findings carry several implications for clinical practice. First, healthcare organizations should prioritize implementation of evidence-based nursing protocols for infection prevention, particularly hand hygiene programs with performance monitoring and feedback. The 31% infection reduction observed in

this meta-analysis translates to substantial patient harm avoidance given baseline HAI rates in ED settings.

Second, medication safety addressed through protocol-based interventions rather than reliance on education alone. The finding that protocol-based interventions substantially outperformed educational interventions (51% versus 21% error reduction) suggests that system changes, not just knowledge transfer, are essential for achieving medication safety improvement.

Third, nurse-initiated analgesia protocols should be standard practice in emergency departments. The substantial reduction in time-to-analgesia (52 minutes) without increased adverse events supports widespread adoption of NIA protocols, addressing the well-documented problem of oligo analgesia in emergency settings.

Fourth, transitional care interventions initiated in the ED implemented for high-risk populations, particularly older adults and patients with chronic conditions like heart failure. The finding that ED visit rates were reduced with high certainty (I^2=0%) suggests that these interventions produce consistent benefits across settings.

Fifth, protocol-driven nursing interventions for time-sensitive conditions implemented as core components of emergency care for stroke, sepsis, and myocardial infarction. The mortality reduction associated with these protocols (29%) represents a clinically significant benefit that few other interventions in emergency medicine can match.

Limitations: Several limitations of this review warrant consideration. First, the quality of included studies varied; with only 12 of 29 studies (41%), using randomized controlled designs. The predominance of quasi-experimental and observational studies introduces potential confounding and limits causal inference. Second, publication bias may have influenced findings, as studies with null or negative results may be less likely to publish. While funnel plot and Egger's test results did not suggest substantial bias for most outcomes, these tests have limited power with small numbers of studies.

Third, heterogeneity across studies in intervention definitions, outcome measurement, and patient populations complicates synthesis and limits the precision of pooled estimates. While we used random-effects models to account for heterogeneity, the high I^2 values for some outcomes (particularly pain management and transitional care) indicate substantial unexplained variation. Fourth, most included studies were conducted in high-income countries (United States, United Kingdom, Australia, Canada), limiting generalizability to low- and middle-income settings where ED resources and nursing roles may differ substantially.

Fifth, few studies examined potential unintended consequences or adverse effects of nursing interventions. While available data did not suggest increased harms, the possibility of unmeasured adverse effects not excluded. Sixth, the relatively small number of studies for some outcome domains (e.g., medication safety, n=6; transitional care, n=5) limits statistical power and precision of estimates.

Conclusion

This systematic review and meta-analysis provides robust evidence that emergency department nursing interventions significantly improve patient safety and clinical outcomes across multiple domains. The aggregate findings demonstrate that nursing interventions reduce healthcare-associated infections by 31%, medication administration errors by 42%, time-to-analgesia by 52 minutes, ED length of stay by 25 minutes, hospital readmissions by 33%, and mortality in time-sensitive conditions by 29%. These effect sizes are clinically meaningful and, in many cases, comparable to or exceeding those of other quality improvement interventions in emergency medicine.

The evidence supports several specific recommendations for clinical practice and healthcare policy. First, hand hygiene protocols with performance monitoring and feedback prioritized as foundational infection prevention interventions. Second, protocol-based medication safety interventions incorporating standardized order sets and independent double-checks should be implemented to reduce administration errors. Third, nurse-initiated analgesia protocols should become standard practice to address oligo analgesia and improve pain management timeliness. Fourth, team triage models adopted to reduce ED length of stay and improve patient flow. Fifth, transitional care interventions initiated in the ED should target high-risk populations to reduce hospital readmissions. Sixth, protocol-driven nursing interventions for time-sensitive conditions should be core components of emergency stroke, sepsis, and myocardial infarction care.

Future research should address several knowledge gaps. First, randomized controlled trials of ED nursing interventions needed to strengthen causal inference and reduce confounding. Second, studies examining intervention effectiveness across diverse settings including community hospitals, rural EDs, and low- and middle-income countries would improve generalizability. Third, research examining the comparative effectiveness of different intervention components would inform optimization of intervention design. Fourth, implementation science studies examining barriers and facilitators to intervention adoption would support successful translation of evidence into practice. Fifth, cost-effectiveness analyses examining the economic impact of nursing interventions would inform resource allocation decisions.

In conclusion, emergency department nursing interventions represent a high-yield strategy for improving patient safety and clinical outcomes. Healthcare organizations, policymakers, and nursing leaders should prioritize implementation of evidence-based nursing protocols, recognizing that emergency nurses are essential agents of patient safety whose interventions save lives, prevent harm, and improve the quality of emergency care.

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Conflicts of interest
The authors declare that they have no competing interests.

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